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Final Technical Report

Market Mechanisms, Efficiency, Processing and Public Health Risks in Peri-Urban Dairy Product Markets: Synthesis of Findings from Ghana and Tanzania

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Structure of the Report

After an initial Background Chapter (1), this report is comprised of three main chapters, each dealing with one of the major research components of the project. Chapter Two addresses Market Mechanisms and Efficiency, and contains the results of the economic and structural analysis of the markets. Chapter Three deals with the Milk Borne Public Health Risks, and focuses on the results of laboratory testing of milk and dairy product samples, but also uses some of the economic results in its analysis. Chapter Four addresses Processing of Traditional Dairy Products, with focus on the traditional fresh cheese *wagashi* in Ghana.

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Executive Summary

Inefficient milk market mechanisms constrain the development of market-oriented smallholder dairying, which has been shown to be a promising avenue for alleviating rural poverty. This report is aimed at improving the welfare of smallholder dairy producers, small-scale processors and market agents and consumers by strategically identifying efficient and viable market mechanisms and processes which deliver safe, consumer-preferred dairy products at low cost, and which provide higher and more reliable returns to resource-poor smallholder dairy producers. This was done through the quantification of actual public health risks and economic performance in indigenous dairy product markets, and identification of relationships with those and market agent practices and government policies. Indigenous dairy markets have not previously been examined in this manner. The technology developed and promoted worked towards the project goal by improving dairy product quality for consumers, and increasing opportunities for livelihoods for small-scale market agents. It addresses the DFID-LPP purpose of “Energy-efficient and socio-economically acceptable handling, processing and distribution technologies identified and promoted.”

Activities and outputs

The project investigated three major areas of indigenous milk and dairy markets in the target countries (Ghana and Tanzania): a) marketing, profits and economic efficiency, b) threats to public health from milk products, and c) processing of indigenous milk products.

Marketing and efficiency

In both countries, several hundred milk/dairy market agents were surveyed in key urban areas and their peri-urban milk sheds. In Ghana this included the Accra and Kumasi areas, while in Tanzania this comprised Dar es Salaam, including a wide area of the coast, and Mwanza. In both countries, the survey respondents represented a wide variety of milk market agents including small local vendors, wholesalers or milk assemblers, milk hawkers, retailers with fixed premises, commercial cheese makers, local indigenous cheese (*wagashi*) makers (Ghana), cooperatives, and dairy farmers themselves. In both countries, the large majority of these were women, and about ¾ were either proprietors or family members of proprietors. Many were very small-scale operators, handling less than 30 litres of milk per day. Raw milk is the primary product sold in most areas, although in some parts of Tanzania (Mwanza) fermented milk is important, and *wagashi* is important for some communities in Ghana. The markets studied displayed a wide variety of interactions between market agents and market channels. In the simplest example, milk producers sold raw milk directly to consumers, with no other intermediaries. At the other extreme, three intermediaries could play a role between farmer and consumer, including rural assembler, larger urban assembler, and small fixed retailer or hawker. This was particularly true when market chains were long, bringing milk from distant areas. The market agents were studied for profitability, market margins, policy-related constraints, and handling/hygiene practices. Quality control measures were very rarely used, although in Mwanza there was significant use of lactometers. Milk preservation was found mainly in Tanzania, with refrigeration used by many

retailers, and boiling employed by some other market agents. A key finding was the recognition that proper metal milk containers were rarely used, with plastic buckets and jerry cans being preferred, except among retailers in some cases.

Returns were highest to farmers who sold their milk directly to consumers. For those who had no such opportunities, returns were split by about half with intermediaries. As the number of intermediaries increased, the price received by farmers generally declined; although in Ghana this effect was very small. In many cases, the market margins were shared among intermediaries. An important result was that there was no systematic difference in profitability between large and small market agents. Instead, unit returns differed according to volume handled, and the value added in terms of labour. For example, large wholesalers showed low unit profits, while retailers exhibited the highest unit profits in both countries, reflecting the market service and provision of refrigeration or premises at the retail level. Assemblers who travelled longer distances to collect milk also showed higher returns. Statistical analysis comparing volume of milk with profitability showed very little effect, suggesting that there are few economies of scale in milk marketing. This finding points towards strong continued viability of small markets agents, and the consequent creation of employment opportunities in both rural and urban areas. In both countries, the policy environment was conducive, in that small milk agents were not required to be licensed, and experience few regulatory constraints. However, another key finding, although expected, was the universal lack of any formal training in milk handling, except for some cooperatives. This often resulted, as shown below, in low quality milk.

Public health

Uniquely in such milk market studies, the project also gathered information on the quality of milk, using milk samples taken from the respondents interviewed above. Samples were taken in both dry and wet seasons, to capture seasonal variability in quality. The samples were tested for bacterial counts, both coliform and total counts, for anti-microbial drug-residue such as anti-biotics, for adulteration, and for the zoonitic diseases *Brucella abortus* and *M. bovis* (the latter in Tanzania only). Haemorhagic *E.Coli* strain O157:H7 was also assessed.

Overall, milk quality was often found to be quite low. Adulteration with water was found to have occurred in some 20% to 60% of samples in Tanzania (highest in Mwanza), and some 30% to 45% of samples in Ghana, varying particularly by season and site of sampling. Adulteration was highest during the dry season, when milk supply was lowest, prices were highest and the economic incentives to add volume also highest. Bacterial counts were similarly high. In Tanzania, some 67% had un-acceptable levels of coliform counts in Mwanza, compared to about 50% in Dar es Salaam. These figures are closely related to the high rate of adulteration in Mwanza seen above, since coliform counts reflect both adulteration and poor hygiene. Total bacterial counts, reflective mainly of time since milking, were also poor, with over 60% showing unacceptably high levels, and did not significantly differ between the urban areas. In Ghana, bacterial counts were somewhat lower, with only some 25% of milk with unacceptable levels of either coliforms or total counts, although this differed by season. This likely reflects the lack of intermediaries in most milk market pathways in Ghana, where the majority were producer-sellers. The key finding from these milk quality tests was that small milk market agents, often targeted by the public as being the greatest threat to public health, did not show significantly worse milk quality than other market agents. Indeed, in some cases such as wholesalers in Ghana, the worst milk quality was found among larger market agents. Again the issue of lack of training in hygiene became evident, as coliform counts were seen to generally increase as one moved down the chain to retailers, and milk was repeatedly handled. The use of inappropriate plastic containers was also found to contribute to low milk quality.

Antimicrobial drug residues were found in a significant number of samples, some 35-40% of samples in Tanzania, and also 35% of samples in Ghana. These residues are likely to arise mainly at the farm level from farmer use of antimicrobials to treat cattle, but may also occur as result of the addition by market agents as milk preservative. It should be noted that such residues are not degraded by milk pasteurisation, so will continue to exist even in processed milk. Although the long term health consequences of human consumption of these residues are not clear, because these residues cannot be removed, they may pose a long-term public health threat, and one which policy-makers are scarcely aware of nor equipped to deal with.

Antibodies for Brucella were found in some 15% to 35% of samples in both countries, depending on which test procedures were used. This suggests potential health threats from milk consumption unless milk is boiled, in which case the pathogens are destroyed.

The common practice by consumers of boiling milk before consumption shields them from most of these health hazards. However, the observed lack of training, coupled with the lack of policy support in terms of regulation, is clearly contributing to low milk quality. Training modules were developed and implemented to address the milk quality issues.

Processing of indigenous dairy products

In Ghana, considerable attention was given to the processing of a traditional fresh cheese product, know locally as *wagashi*. It is produced as a cottage industry product, made in homes by individual processors, nearly all women. It is generally made when there is surplus milk for which no market is available. An extract from the plant *Calatropis procera*, which grows naturally in the area, is universally used as a coagulant for *wagashi* production. Initial investigation found shelf life constraints to the cheese, which had to be reboiled and dried daily if it could not be sold, with consequent costs in terms of firewood/fuel and possible nutrient losses. The *wagashi* makers were found to handle less than 15 lt of milk per day, and had no formal training – the technique was learned from family members. Another constraint was found to be a lack of clear knowledge on the amount of coagulant to use, which varied widely between different cheese makers. Inefficient use would further exacerbate the problem of increasing scarcity of *Calatropis* in some areas. Experiments were thus conducted to identify the optimum quantity used, and relative proportions of stem and leaf. These trials showed that 20grams of *C. procera* stem or 30grams of leaves are sufficient to coagulate two litres of milk.

These quantities were then converted into typical local measures. Several means of increasing shelf-life were explored. Trials were conducted on the use of *Xylopia aethiopica,* a local plant thought to have anti-microbial properties. However, no preservative effect on the *wagashi* was observed. Brining trials found that soaking in brine concentrations over 10% overnight led to significant reduction in bacterial growth. After conducting consumer organoleptic tests, a 10% brine level was selected as effective and acceptable to consumers.

These refined techniques, designed to be easily adopted by the cheese makers and to be acceptable to consumers, were then incorporated into a training module and dissemination leaflet. Basic economic analysis showed that reasonable returns were available to these household cheese makers, and that improved shelf life would reduce their costs and increase their market opportunities.

Overall findings

This research project, one of the first to systematically address economic and public heath issues in indigenous dairy markets in Africa, has found that important opportunities for livelihoods continue to be created in such markets. Further, the small market agents that are often regarded as posing public health threats were not found to offer significantly lower quality products than other larger market agents, some of whom work within the regulated environment. Lack of training was found to be a systematic contributing factor to both low quality milk, and to variability in economic returns. The training materials and modules developed by the project address these problems. Policy recommendations from the project are aimed at bridging the gap between the regulated and unregulated dairy markets, and so reducing public health risks, through targeted training of market agents coupled with licensing where appropriate.

Chapter 1. Background to the Study

1.1 Importance of the Dairy Industry and Constraints to its Development

The importance of market-oriented smallholder dairying for income generation has been well documented (Okantah et al., 1995, Haile 1995, van Schaik, 1995, Staal et al., 1997; MOAC/SUA/ILRI, 1998;). Market-oriented smallholder dairying has higher returns than many traditional agricultural activities and thus offers important income opportunities for resource-poor producer households and for rural and urban poor through their participation in processing and marketing. Importantly, the keeping of cattle for milk production and sale has been demonstrated to be adoptable by even the most resource-poor households (Nicholson et al., 1998). The contribution of the dairy industry to the Tanzania economy is also well documented. The available data indicate that, the dairy industry contributes 30% of the livestock GDP, beef (40%) and other livestock (30%). The livestock production as a whole contributes 18% of the national GDP and 30% of agricultural GDP. The population of livestock in Tanzania in 2002 is estimated at 17.7 million cattle, 11.7 million goats, 3.5 million sheep, 435,000 pigs and 29 million poultry (FAO Statistics 2002). The number of cross-bred dairy cows is estimated at 450,000. Ghana on the other hand, represents an economy, in which livestock play a smaller role. Agriculture contributes about 36% to national GDP. Of this livestock accounts for 19% agricultural GDP or just 7% of national GDP. This is due to the importance of cash crops such as cacao in Ghana. The population of livestock in Ghana is estimated at 1.43 million cattle, 3.4 million goats, 2.97 million sheep and 22 million sheep (FAO Statistics 2002)

1.1.1. Opportunities for dairy development

The potential for considerable growth in demand constitutes an important element to income-generation prospects in dairy. The potential demand stems from the persistently notable gap between the supply of dairy products and the human population increases in urban areas. Population growth, urbanisation, and income growth greatly influence the demand for milk. Studies (MOAC/SUA/ILRI, 1998; Staal and Mullins 1996) have shown that, urban consumers consume more dairy products than rural consumers in the same income group. Tanzania has an estimated population of 34.4 million people, increasing at a rate of 2.1%, out of which the urban population was estimated to be 15%, growing at a rate of about 5% (World Bank, 2001), while Ghana has a population of 19.7 million growing at 1.8% annually. Rural-urban migration has disproportionately increased the population in urban areas such as Kumasi and Accra. A substantial growth in domestic dairy demand can be expected as cities grow. The incomes in both the rural and urban areas are also expected to grow. The available reports show that, the average income growth rate in Tanzania was 4.0 percent between 1995 and 1999. Per capita income grew from $210 in 1997 to $270 in 2001. Ghana's economy grew similarly but per capita income dropped from $390 to $290 over the same period partly as a result of relatively high population growth. Since dairy products have a high income-elasticity of demand. As income grows, demand for milk/dairy products can be expected to grow. It is thus critical that domestic markets develop the mechanisms necessary to efficiently supply larger quantities of milk with greater levels of safety.

1.1.2. Critical constraints

While the growing demand represents new market opportunities for smallholder producers, there are some serious constraints, which limit the farmers from taking the advantage of these opportunities. Dairy marketing and processing problems constitute the major constraints to capturing the available opportunities to dairying. Marketing problems must be addressed if dairying is to realise its full potential to provide food and stimulate broad based agricultural and economic development (Brokken, 1990). The most important critical constraints include restricted smallholder access to markets due to market inefficiency and unreliability caused by the small quantities of milk they market and consumer reluctance to pay for the costs of industrial processing. Collection and transportation of such small quantities of milk using expensive equipment is generally non-economic. Direct sales to neighbours is an important outlet for this kind of milk. This outlet is however restricted to a locality and may be unavailable in milk-surplus areas. For sustainable dairying the dairy products must be sold to deficit areas (usually urban areas). This requires bulking, longer market chains and more intermediaries (small traders, dairy co-operatives, or dairy processors and retailers). Market channels serving smallholders are thus often complex and are associated with high transaction costs (Staal et al., 1997).

1.1.3. Formal and informal markets

Development of an effective milk-processing sector is important for sustainable development of the dairy industry. Milk is one of the most perishable food products. Unless refrigerated, raw milk can only be kept for a few hours before bacterial action takes hold, changing not only its taste but also reducing its usefulness. As temperature increase this process accelerates. The timing of milk collection, delivery and processing are therefore crucial. Consumer reluctance to pay for pasteurisation causes formal milk processing systems to play a small role in SSA and other developing countries. In Kenya, Uganda, and Tanzania for example, pasteurised milk accounts for an estimated 20%, 10%, and 2% of marketed milk respectively (MAAIF/NARO/ILRI, 1996; MOAC/SUA/ILRI, 1998; MOA/KARI/ILRI, 1998). Consumer cost-consciousness and preferences thus ensures that most milk passes through raw milk markets, which generally operate informally, or is processed traditionally and at low cost. Smallholder producers consequently rely mainly on informal markets for raw or traditional products, and on a variety of small traders/vendors. These markets exhibit great variability in efficiency, reliability and transactions costs to producers, and in quality delivered. Research in East Africa has shown wide local differences in producer prices, market margins, and regularity of payment (MAAIF/NARO/ILRI, 1996; Staal et al 1997; MOAC/SUA/ILRI, 1998). In Tanzania, related work by Sumberg (1996) showed similar price variation spatially, and highlighted some of the difficulties confronted by markets in Dar es Salaam and Mwanza including fluctuations in milk supply, unmet demand and concerns over milk quality. Efforts to increase marketing and supply of milk in both urban areas from traditional extensively kept zebu cattle are being facilitated by an NGO - the Austro Project Association. Women play a crucial role in the production and marketing of milk from these herds (Austro-project Association, 1997).

Since formal processing channels have failed consistently in many parts of Africa, attention must be given to improving these existing and important market mechanisms. Due to systematic inattention, however, ways of improving the efficiency of informal market mechanisms are generally unknown. Policies typically discourage informal marketing, forcing marketers to operate on a small scale, reducing efficiency and increasing unreliability. Partly as a result, in both Tanzania and Ghana, raw bulk milk prices in urban areas are substantially higher than global norms, at over $0.6/l in Dar es Salaam (MOAC/SUA/ILRI, 1998), and over $0.8/l in Kumasi (observed during recent consultation). At the same time, only some tens of kilometres distant, farm-gate prices were about half. In comparison to areas where markets are better developed, such as Kenya, these margins point to opportunities for improvement in milk market mechanisms (MOA/KARI/ILRI, 1998).

Further, there are justifiable public health concerns regarding milk-borne diseases and hygiene in raw milk and traditional products. Greater concerns are associated with milk from extensive production systems due to higher risk of milk-borne zoonotic disease transmission. Though some preliminary studies (e.g., Msanga et al., 1986; Daborn *et al*., 1997; Swai, 1997) have reported prevalence's of up to 15% for bovine tuberculosis and brucellosis in some areas in Tanzania, little accurate information is available regarding these risks in most dairy producing areas. The risks from bacterial contamination have been reported to originate at farm level (Mathias, 1998) and increases with milk bulking and number of agents handling milk before it reaches the consumer (Ombui et al., 1994) and there are also justifiable public health concerns over chemical contamination mainly from antimicrobial (antibiotic and antibacterial) residues and drugs used in disease vector control practices. Informed policy-making regarding informal milk markets cannot occur without quantitative information on these milk-borne public health hazards.

Poor infrastructure, in particular poor communication including transport, limit the distance that fresh produce destined for markets can go, and low-cost technologies to prolong the shelf life of dairy products are necessary. Research in West Africa on *Wara* (soft, wet unripened cheese) identified hygiene and use of local coagulants (*Calotropis procera* or Sodom's Apple) as aspects of dairy processing requiring further research (Awor and Nakai, 1986). Other species with rennet type properties (e.g., *Prososis africana*) as well as the disinfecting characteristics of plants such as *Moringa olifera*, *Xylopia aethiopica* and *Monodora myris* and other appropriate species identified by indigenous technical knowledge require investigation to determine what impact they can make in prolonging shelf life of milk and reducing milk-borne public health hazards.

1.2 Problem Statement and Need for Research

Inefficient milk market mechanisms constrain the development of market-oriented smallholder dairying, which has been shown to be a promising avenue for alleviating rural poverty. Smallholder access to markets is restricted by market inefficiency and unreliability due to the small quantities of milk they market and/or poor marketing infrastucture. The small quantities ensure that the collection using expensive equipment over long distances is generally not economic and so rely on markets that are largely unorganised using inexperienced and inexpensive labour. An important outlet in such undeveloped markets is direct sales to neighbours, which are restricted to a locality and are usually unavailable in milk-surplus areas. Milk products must then be sold to deficit areas, requiring bulking, longer market chains and more intermediaries, including a combination of small traders, private/parastatal dairy processors. Market channels serving smallholders are thus complex and could vary widely even within a given peri-urban area. In such situations there is likely to be wide differences in producer prices and market margins.

Due to systematic inattention, however, ways of improving the efficiency of informal market mechanisms are generally unknown. There has been little research on ways to improve the efficiency of fresh milk marketing in developing countries in general. Development programmes and policies in the past have typically neglected or discouraged informal marketing, forcing marketers to operate on a small scale, reducing efficiency and increasing unreliability.

Although some market studies have identified general market failures (Staal 1995, MOAC/SUA/ILRI, 1998, Sumberg 1996), none have attempted to differentiate individual markets mechanisms by level of performance and safety. The methodologies for doing so are being currently refined in the DFID bilaterally funded Kenya studies being conducted by the Smallholder Dairy Project. Comparative analysis across Tanzania, Kenya and Ghana was considered to be an important output leading to specific and widely-applicable recommendations for the development of viable dairy markets serving resource-poor producers and alleviation of public health risks without impeding the efficient marketing of milk.

1.3 Study Areas and Populations

In Tanzania, the study was conducted among dairy product producer-sellers and market agents in and around the cities of Dar es Salaam (abbreviated “Dar”) and Mwanza; while in Ghana, respondents of similar cadres were drawn from urban and peri-urban areas of Kumasi and Accra.

Figure 1 and Figure 2 show the survey areas in both Ghana and Tanzania. The sites were chosen to be able to relate findings to variation in dairy product supply, market access and consumer demand. Both countries have low annual dairy product consumption per capita of only 28 and 5 kg LME for Tanzanian and Ghana, respectively, compared to the average of 55 kg LM E for sub-Saharan Africa; 120 kg LME recommended by FAO and over 200 kg LME in Western Europe. Local milk supply in Ghana is very low, considering that the per capita annual consumption of 5 kg LME includes a large proportion of imported dairy products. Milk and dairy products are not traditionally consumed in large parts of southern Ghana, where cattle keeping is not widespread due to disease constraints, contributing to these low levels of average consumption. Consumption levels are higher in northern Ghana, where cattle keeping is a traditional practice.

A substantial proportion of marketed milk supply in Tanzania is derived from exotic or crossbred (with *Bos taurus*) dairy cattle, unlike in Ghana where nearly all marketed milk supply originates from zebu cattle mainly kept by Fulani herdsmen. Dar es Salaam and Accra are large cities with population sizes of over two million and potentially higher demand and market opportunity for dairy products compared to Mwanza and Kumasi that have lower populations of about one million persons each. Consumption of traditional cheese and other processed dairy products is common in Ghana and much of West Africa, whereas fresh and fermented liquid milk consumption dominates in Tanzania and East Africa in general.

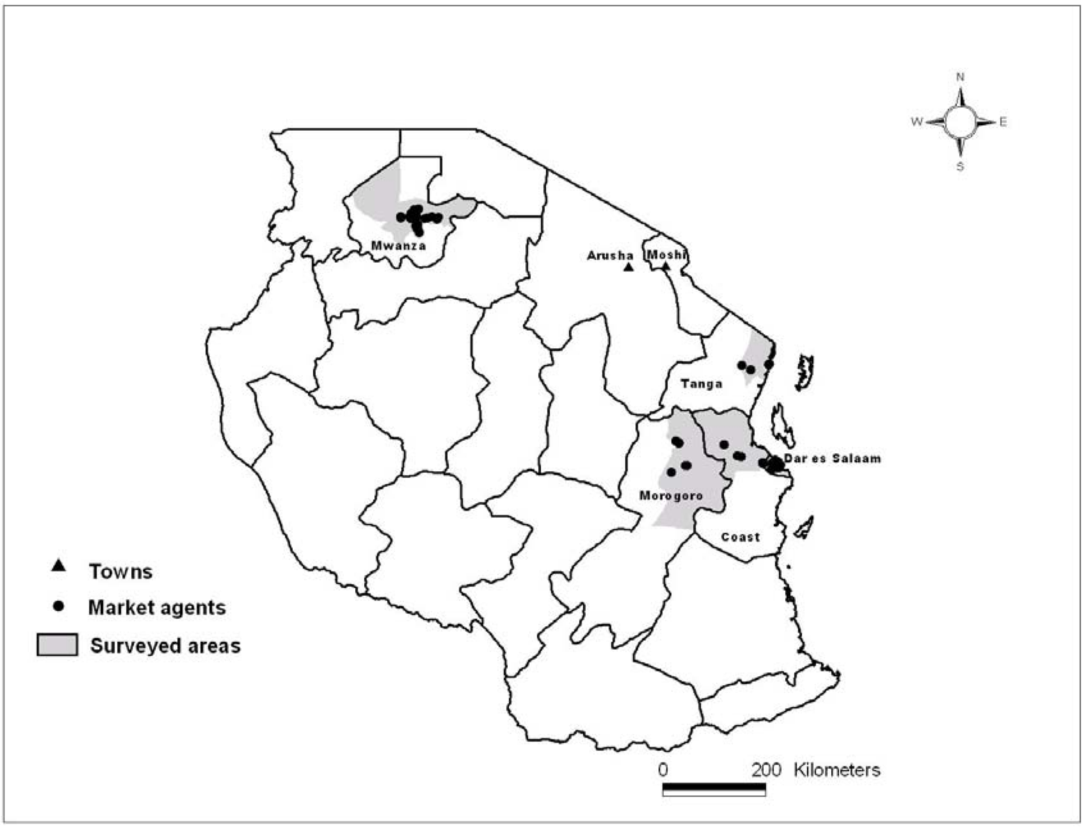


Figure 1: Map of study sites in Tanzania

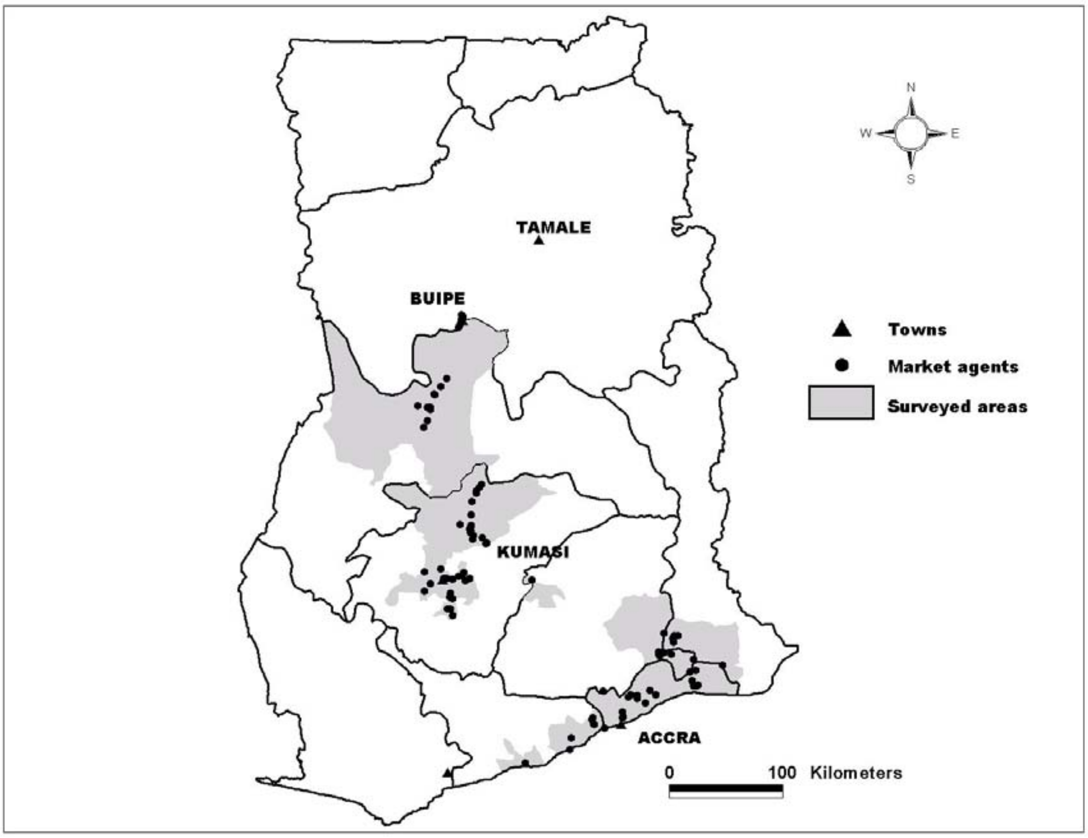


Figure 2: Map of study sites in Ghana

1.4 Project Purpose

In the project log-frame, the purpose was defined as: "Energy-efficient and socio-economically acceptable handling, processing and distribution technologies identified and promoted." This did not change during the course of the project. Inefficient milk market mechanisms constrain the development of market-oriented smallholder dairying, which has been shown to be a promising avenue for alleviating rural poverty. This project aimed at improving the welfare of smallholder dairy producers, small-scale processors and market agents and consumers by strategically identifying efficient and viable market mechanisms and processes which deliver safe, consumer-preferred dairy products at low cost, and which provide higher and more reliable returns to resource-poor smallholder dairy producers. This was done through the quantification of actual public health risks and economic performance in indigenous dairy product markets, and identification of relationships with those and market agent practices and government policies. This is new knowledge, in that indigenous dairy markets have not previously been examined in this manner. The technologies and knowledge developed contribute towards the project goal of improving dairy product quality for consumers, and increasing opportunities for livelihoods for small-scale market agents. Regionally, these technologies and strategies will offer possibilities for direct adoption or adaptation in other similar production and market systems.

Chapter 2. Dairy Product Market Mechanisms and Efficiency

This section addresses market mechanisms and efficiency, and contains the results of the economic and structural analysis of the markets.

2.1 Research Activities

2.1.1. Approach

The research focus was on markets for raw milk and indigenous products under the following objectives:

- Identify and study the marketing channels for indigenous and raw milk products.
- Determine the ways in which marketing activities (procurement and sale) are conducted.
- Determine the costs and benefits involved in the milk business.
- Identify factors that affect profits in milk marketing.
- Identify problems affecting the different market participants.
- Suggest policy remedies to improve the milk marketing system.

The approach combined Participatory Rural Appraisal (PRA) methods with structured interviews. The PRA's were used to identify market channels and contractual arrangements, and market agents' perceptions of primary constraints. The targeted market agents included a wide variety of intermediaries, including small scale milk product traders, wholesalers, assemblers of milk from rural areas, retailers, group collection centres, processors and sellers of traditional products, and milk producers/farmers themselves. The information from the PRA's and previous analyses (e.g., Mdoe 1993; Mdoe et al., 2000) were used to develop sample frames and structured questionnaires of the next phase. Every attempt was made to obtain information from representative actors in the market. The details of these activities are described below.

The approaches to marketing analysis fall under two main categories namely the industrial organisational approach (Bain, 1959) and the historical, institutional and descriptive approach (McCalla and Schmitz, 1979). Whereas the industrial organisational approach emphasises the structure and conduct of the firms in the marketing system as the determinants of the marketing performance, the historical, institutional and descriptive approaches involve the examination of trends in output, prices and institutional factors in the marketing system.

The available literature shows that researchers have usually employed one or a combination of the above approaches in studying different marketing systems. Mdoe (1993) used two sets of indicators i.e. effective and efficiency indicators in assessing the performance of the marketing system for dairy products in Hai district in Tanzania and nearby areas. The effective indicators included the level and stability in volume of marketed dairy products, level and stability of producer and consumer prices and timeliness of effecting payments to producers, while efficiency indicators included the marketing costs and market margins. A similar approach was earlier used by McCalla and Schmitz (1979) who used the level and stability of producer and consumer prices in comparing performance of the Canadian and U.S. grain marketing systems over time.

For this study, the Structure-Conduct-Performance (SCP) approach, in combination with GIS, was used to analyse the milk market. The major proponents of the SCP model are Brain (1968), Shaffer (1983), Marion (1986) and Reid (1987). The basic tenet of this approach is that, given certain conditions, the structure of an industry or market determines the conduct of its participants (sellers and buyers), which in turn influence its performance (Scarborough and Kydd, 1992, Jabbal et al, 1997). Market structure is the environment in which the market agents operate; while market conduct refers to the patterns of commercial behaviour (Pomeroy, *et al*., 1995). Market performance refers to the impact of structure and conduct as measured in terms of variables such as prices, costs and volume of output (Bressler *et al.*, 1970 quoted by Pomeroy, *et al.*, 1995).

Thus, the economic analysis for this research focuses on structure, conduct and performance analysis as a general approach. Important topics within the SCP analysis are to assess variation in risk due to seasonality, unreliable contractual arrangements, and access to capital, and identifying the effects either via either price or non-price factors of government policies. Within this framework various tools: descriptive statistics, budgets, geo-referenced information system (GIS) based tools, correlation and regression were applied to determine the nature of structure, conduct and performance factors within alternative market channels. Descriptive statistics are used to quantify various variables in terms of averages, distribution and percentages, while budgets are used to assess the market performance factors in various market channels. GIS-based tools are used to better quantify the spatial factors influencing marketing behaviour and performance. Regression tools are used to identify critical factors influencing milk market performance. Details on how these tools are applied are presented below under respective components of the SCP model.

2.1.2. Data collection

Participatory rural appraisal (PRA) exercises were conducted at each study site at the beginning of the research to identify the nature of dairy products consumption and marketing channels, including documenting marketing points and processing techniques. The PRA was designed to focus on three groups: consumers, producers and marketing agents (including processors of *wagashi*, traditional soft cheese, in the case of Ghana). Consumers were asked to describe seasonal patterns of consumption, prices, preferences, main market sources and reasons for their use, constraints to availability, and un-met demand. Producers were asked to describe the seasonality and level of milk marketed milk production, their main outlets, with associated information on products, prices transaction costs, reliability, contractual arrangements, and main constraints. Market agents and processors were asked to describe the seasonality of dairy product procurement and sales, prices, main sources and buyers, transaction costs, marketing techniques, sources of variation in milk quality, handling techniques and equipment and main constraints. The primary objective of the PRA was to describe in detail all the main dairy marketing channels and associated processing and handling techniques. The results of the PRA were used to design the main market study, using a structured questionnaire.

The PRA was followed by a more formal survey using a standardized questionnaire during two contrasting seasons representing periods of high and low milk production, and thus variation in milk market volumes and prices, associated with the dry and wet seasons experienced in both countries. The questionnaire sought information on the background of the agent, their milk procurement activities, milk handling before sale, milk sales as well as all costs and revenues. Questions on milk hygiene and milk quality were also asked in the questionnaire. Simultaneously, milk and milk products samples were collected from the survey respondents for use in the public health assessment. GPS units were used to geo-reference all points where the interviews were held.

A stratified random sampling procedure was used, targeting all the market agents identified in the PRAs, described above. Given the difficulty in locating for enumeration the small milk traders and processors, they were sampled by geographical sampling methods and based on prior knowledge gathered through the PRA results.

In Tanzania, the study was conducted in the areas within and around Dar es Salaam (including outlying areas of Chalinze, Kibaha, Tanga and Morogoro) and Mwanza. In Ghana, the study was conducted in two broad zones, the areas comprising the two main cities of Kumasi and Accra. These sites, which include villages, towns and cities, were chosen to represent variation in consumer concentration, market access and dairy production intensity within each zone.

The sampling of market agents varied by their location and type. All bulking centres (large cooperative societies and assemblers and wholesalers) were sampled. Smaller scale market agents producer-sellers, vendors, retailers) were identified through local informants and sampled at in a selected area (or along a route in the case of Mwanza) up to 30. For areas/routes with more than 30 milk traders, selection was made to cover all major urban/retail sites in the area. In Greater Dar, marker agents were sampled in 8 areas (including Tanga and Morogoro), 5 in Mwanza, 5 in Accra and 7 in Kumasi.

The distribution and number of respondents is shown in Table 1. In Ghana, 229 respondents were interviewed, 94 in the Accra zone and 135 in the Kumasi zone. Of this total, 106 were males (46%) and 123 were females (54%). In Tanzania, 439 respondents were interviewed in the Dar es Salaam area, and 319 in and around Mwanza, for a total of 758. In Tanzania, males formed a larger proportion of the respondents with 556 (73%), compared to 202 females (27%).

Table 1. Number of sampled market agents, and proportions of female, in each survey location.

Market agents	Dar- es-Salaam	Mwanza	Accra	Kumasi	Total
Coops/ collection centres	7	0	1	0	8
Producer-sellers	116	116	49	82	363
Wagashi processors	NA	NA	7	16	23
Wholesalers/ assemblers	17	0	22	5	44
Vendors/ Mobile traders[a]	77	185	0	8	270
Retailers	222	18	15	24	279
Total	**439**	**319**	**94**	**135**	**987**
% Female	36	14	44	54	33

[a]Includes hawkers

2.1.3. Analysis of market structure

Structure of an industry or market is defined as characteristics of the organisation of the market that seem to exercise strategic influence on the nature of competition and pricing within the market (Bain, 1968). The characteristics most stressed (Jabbar et al, 1997; Koch, 1980) are:

- Marketing channels;
- Market concentration;
- Product differentiation;
- Degree of vertical integration;
- Ratio of fixed to total costs; and
- Conditions for entry.

These elements measure the extent of deviation from a perfectly competitive market. The milk shed market structures in the four main study sites were assessed in terms of marketing channels, buyers' concentration, product differentiation and entry barriers. These aspects have an influence on the nature of competition, buying practices and pricing behaviour of the market agents.

2.1.3.1 Marketing channels

Milk marketing systems consist of different marketing chains and channels. Marketing channels are alternative routes of product flows from producers to consumers (Kohls and Uhl, 1990). Thus milk-marketing channels are different passages or outlets through which milk is distributed to consumers. In the milk marketing system milk products flow from the producer to the consumer. On the way to the consumer, the products change ownership from time to time among the milk-marketing participants. In each case marketing costs are incurred. The more hands it involves the higher the costs are likely to be. This would imply that in analysing marketing costs and margins an attention has to be focused on the nature and types of marketing channels involved.

2.1.3.2 Market concentration

Concentration accounts for a large part in determining market behaviour, as it tends to affect interdependences among market agents and bargaining power to influence prices and transactions. Non-competitive behaviour such as collusion is normally a result of high market concentration. High levels of market concentration are often found in food processing, wholesaling and retailing. Concentration ratios (ratio of buyers and market share ratio) are employed in examining the market concentration. The estimation of market shares is based on the amount of milk procured from producers by different categories of market agents. This is given as follows:

$$(1) \quad MS_i = \frac{V_i}{\sum V_i}$$

Where MS_i is market share of agent *i*; V_i is amount of milk procured by agent *i*; and $\sum V_i$ is the total amount of milk handled.

2.1.3.3 Product differentiation

A product is differentiated if there exists significant basis for distinguishing the product of one seller from those of another. Food market agents generally operate under conditions that are neither competitive nor completely monopolistic. The marketing strategies are designed to gain them some special advantages over rivals. Sellers differentiate their products in order to increase their appeal to buyers, to reduce the substitutability for their products and increase the latitude in pricing. Typical product differentiation factors include products typology, product handling and preservation and advertisement. Successful competitors through product differentiation eliminate their rivals or discourage market agents' entry. The focus of this research with respect to product differentiation is on product types, handling and preservation.

2.1.3.4 Entry conditions

Barriers to new market agents' entry exist in food markets and may encourage imperfections in the market. Conventional barriers to market entry usually revolve around institutional, technological and financial factors. Where any of these exists; it deters potential entrants thus impeding competition and market efficiency. Existing agents usually enjoy a cost advantage over potential competitors through command over financial resources, access to raw materials, technical know how, or the existence of economies of scale. In this study legal and institutional factors, capital requirements, scale economies, infrastructure, location and distance were assessed to determine the level of market barriers in the informal milk markets of the selected sites in Ghana and Tanzania.

Legal and institutional factors with regard to milk quality and business establishment may retard or promote entrance of new market agents. A qualitative description of the legal and institutional factors is presented to reflect their potential effects on informal milk market performance.

Capital requirements serve as an entry barrier because only those who can afford such a monetary outlay can enter the market (Pomeroy et. al., 1995). In this study capital costs and operating capital are computed and compared for different marketing agents to reflect market entry conditions.

Scale economies are a useful parameter for explaining market entry conditions and market concentration. Scale economies are said to exist when the average marketing costs are inversely related to the volume of products handled. These scale economies encourage the growth of large and specialised market intermediaries.

The state of roads influences the farmer's ability and willingness to participate in marketing milk. As opposed to good roads and short distances, poor roads and long distances entail high transport costs, unreliable markets and prices. Remote areas face spatial problems in marketing their milk. Types of roads distances and location factors are assessed using descriptive statistics to assess the magnitude and importance of these factors for various market agents.

2.1.4 Analysis of market conduct

There are no agreed upon procedures for analysing the elements of market conduct. Previous research (Bain, 1968; Smith, 1981; Ishak, 1988; Pomoroy, 1989) give some guidelines to illustrate conduct assessment. Conduct refers to the behaviour and action programmes by market agents given the structure within which they operate. The salient features of conduct can be grouped into two:
Buying and selling behaviour: Source of products; no-price competition; selling/procurement modes; market channels; moral hazards; and terms of payment.

Buying behaviour: Price formation; collusion; price setting; price differentiation; price movement; and location effects on prices.

Descriptive assessment is used to study the milk market conduct factors. Buying and selling practices as well as pricing strategies used by different intermediaries are analysed to determine the nature and implication of the market conduct on informal milk market performance.

2.1.5 Analysis of market performance

Economists have had great difficulty in defining an aggregate norm for evaluating the performance of marketing systems (Mdoe, 1993). There are several approaches used in marketing system studies. Normally a combination of approaches is used to evaluate different aspects of marketing systems. No single criterion of performance seems to exist (Mdoe, 1993). A single measure seems to be inadequate in assessing the overall performance of a marketing system especially when the marketing participants have some choice of operating in different channels and where the structure of the channels varies (Patnaik, 1985).

Market performance is largely the outcome of market structure and conduct, but all are affected by policy and other factors. Basic performance variables include prices, costs and volume of outputs (Bessler and King, 1970). These variables are the building blocks for market margins and net returns. By analysing the level of market margins, net returns and their cost components, it is possible to evaluate the impact of structure and conduct characteristics on market performance (Bain, 1968). Estimates of market margins and net returns provide indications of the nature of market agents' competitiveness.

Selling and purchase prices, market margins, marketing costs and net returns are assessed to examine the market performance in the milk sheds using trading budgets. Factors affecting milk marketing performance are also assessed. Regression is used to determine the nature, direction and magnitude of the factors influencing the performance.

2.1.5.1 Sale and purchase prices

The magnitude of relative spatial and temporal price variation is an important market performance factor. This carries the implication that the pricing system in the market does or does not perform its functions effectively. To assess this, one has to establish how the two prices closely move together. In efficient markets, change in prices in one location or level of marketing system should be followed by an adjustment in another location or level of the marketing system to ensure the market margins are fairly close to marketing costs. Correlation analysis and t-test are used to determine whether the estimates of prices, marketing and profit margins are move together while t-test determines whether the estimates are different across seasons or market levels.

2.1.5.2 Market margins

Market margins are calculated as the difference between buying prices and selling prices for intermediaries. High market margins may imply above average returns, differences in marketing costs, or implicit selling or buying prices that are either higher or lower than competitive market prices, respectively.

(3) $$M = \sum (PS_{ij} - PB_{ij}) / n$$

Where *M* = Marketing margin; *PS*= Sale price; *PB* = Buy price; and *n* = Number of market agents.

2.1.5.3 Marketing costs

Marketing costs involve fixed costs and variable costs. Fixed Costs were calculated as annual equivalent value for fixed assets (CRC) using:

(4) $$A = Z[\frac{(1+i)^{ni}}{(1+i)^{n-i}}]$$

where: A = Capital Recovery Cost of item; Z = Replacement cost of the item = Initial cost – Salvage value (includes zeros); i = Real rate of return on capital invested elsewhere; n = Useful life of the item (Excludes zeros).

Variable costs were calculated on annual basis while the total cost was calculated as follows:

(5) $$TC = TFC + TI + SC + LC + C + MPC$$

Where: TC = Total cost; TFC= Total fixed costs; TIT =Total intermediate costs; SC= Statutory costs; LC= Labor costs; CF = Contingency fees; MPC = Milk purchase cost.

2.1.5.4 Net returns

Net returns are generated from trading budgets. Net returns are calculated by subtracting fixed and variable costs from gross returns. The trading budgets were constructed using the calculated revenues, fixed costs; intermediate costs statutory fees, labor costs and contingency fees as follows.

Total revenues and net returns for various market agents were computed as follows:

(6) $$TR = MVxP$$

(7) $$PM = TR - TC$$

Where: TR= Total revenue; MV = Volume of milk sold; P = Selling price; PM= Profit margin
Analysis of net returns aims to assess the profitability of marketing businesses while market margins signify the capacity of intermediaries to cover the cost of providing marketing services.

2.1.6 Factors influencing milk market performance

This is analysis to determine the nature, direction and magnitude of the factors influencing the market performance, measured particularly in profit margins. These determinants include spatial factors, non-spatial factors and seasonality factors. Spatial factors include those related to location of the market agents' collection and supply points, and the infrastructure and transport services connecting them. Some cost variables such as inputs and wages may also vary spatially. Non-spatial factors include those that vary with individual market agents, such as management skills, level of education and training. Seasonality affects both supply and demand of milk and dairy products, and thus influences quantities and prices faced by the market agents. Typically, the buying price, sales price and profit margin per litre of milk are modelled as an independent variable using a linear function form equation:

(12) $PM^* = aX + u$

Where PM* is selling price, buying price or profit margin realized by a market agent from milk marketing business; X is a set of variables influencing the selling price, buying price or marketing profits, u = error.

However, rather than using the method above, another approach was employed. The stochastic frontier analysis, described below, goes beyond comparison of absolute values of profit. It further allows a comparison between market agents of their relative ability to achieve hypothetical profit maximums, and thus the degree of efficiency of maximizing profit.

2.1.6.1 Stochastic frontier analysis of profitability

A milk market agent's efficiency in profitability may be looked at as his/her ability to achieve maximum possible profits given the specific set of prices and technology s/he faces. While there are other methods that are used to estimate efficiency, the use of a normalized profit frontier model is more attractive in cases where the aim is to generate individual profit efficiencies for a cross-section of firms which face differing prices and factor endowments and thus have different practices that could be termed as most efficient (Ali and Flin, 1995). The normalized profit model is an adaptation of the stochastic production frontier model, which was first proposed by Aigner *et al* (1977) and Meeusen and van den Broeck (1977). The adaptation simply involves expressing the dependent variable as normalized profits and including prices and levels of fixed factors (in addition to levels of variable inputs) as possible determinants of profitability. In this case the form of stochastic frontier model proposed by Battese and Coelli (1995) was used to evaluate factors that influence profitability and efficiency among the various sets of market agents in both Tanzania and Ghana. The normalized profits model was specified as:

(8) $Ln\pi = \beta X_k - u + v$

Where: $Ln\pi$ is the natural log of the normalized profits; β is a vector of unknown parameters; X_k is a k x 1 matrix of explanatory variables; v is a measure of the usual idiosyncratic effects and is independent and normally distributed with mean=0 and variance=σ^2_v; u is the inefficiency term which is a non-negative, random variable with mean=m_i and variance=σ^2_u; $m_i=z_i\delta$, where: z_i is a vector of variables which may influence the efficiency. Estimation of the parameters β and z_i is done using the maximum likelihood technique. The variance parameters are estimated as $\sigma 2 = \sigma^2_v + \sigma^2_u$ and $\gamma = \sigma^2_u / (\sigma^2_v + \sigma^2_u)$. Normalized profits (N_PROFIT) were computed using the formula:

$$(9) \quad \pi = \frac{R - VC}{N\,\mathrm{Pr}}$$

Where: R is the total revenue per annum (annualised revenue), VC represents variable costs per annum and NPr is the normalizing price. The annualised revenue (R) was computed as:

$$(10) \quad R = N\,\mathrm{Pr} \times Q_{adj} \times 365$$

Where normalized prices (NPr) is multiplied by the adjusted quantity of milk (Q_{adj}) and 365 days.

Adjusting the quantity of milk (Q_{adj}) was necessitated by the observation that quantities recorded as "purchased" and "sold" differed. The difference in the two quantities was perhaps because "quantity sold" was recorded as previous day sale and "quantity purchased" as the quantity purchased at the day of the interview. Although the variable "quantity of milk left over" was available, it could not be used to explain the difference because it was recorded for the previous day. The adjusted quantity was calculated as the mean of the quantities purchased and sold.

The normalizing price is agent specific and was computed using the formula:

$$(11) \quad N\,\mathrm{Pr} = \frac{\sum_{i=1}^{i=n} Q_i P_i}{\sum_{i=1}^{i=n} Q_i}$$

Where: Q_i is quantity sold to consumer type i while P_i is the selling price to consumer type i in US$ per litre of milk. The normalizing price was also the weighted sale price.

Variable costs (VC) were calculated as the annual sum of the cost of milk purchase, transport, labour, intermediate costs processing costs e.g. inoculants, sugar, food colouring, flavouring etc. vehicle expenses, water cost, stationary, fuel and electricity, sanitation, repairs and maintenance.

The factors included as determinants of profitability in model (8) included natural logarithms of normalized input prices (wage rates and transport cost per litre of milk), natural logarithms of factor inputs (capital recovery cost of capital stock, numbers of family and also hired workers), and dummies of shift factors (type of milk cans used-metallic or otherwise, and whether or not there is piped water in the business premises). The determinants of inefficiency included dummies on trader type (processor, vendor/hawker or wholesaler), location of the business (urban, peri-urban or municipal location) GIS distances from the premises to the capital city on tarmac, murram and earth roads, type of source for the milk traded (own milk, other traders, or processors) and the specific characteristics of the milk market agent (age, years of experience, gender, source of funds to start the business, and quantity of milk handled per day). The stochastic frontier model was estimated using the FRONTIER 4.1 computer package developed by Battese and Coelli (1995).

2.2 Outputs

2.2.1 Structure of the milk marketing system

Traditional milk markets are observed to be characterised by an enormous variety of market intermediaries, playing slightly different but often overlapping roles, which often are distinguished by scale of operation, and buyer/seller clients they serve. They exhibit different degrees of vertical integration, with some serving the same functions that two or more other intermediaries may be simultaneously performing. Fresh milk is sold through almost any combination of market types and seller types. A significant proportion of the milk collected is sold at the farm gate (referred to as *kraals* in Ghana) directly to individual consumers, milk vendors, assemblers, wholesalers or processors. The main types of milk market agents found in the two countries are presented in Table 2.

Table 2: Main types of market agents in milk product markets

Type of seller	Description
Producer-seller	Producers who also sell their milk. In Ghana, herdsmen or their wives who sell their own milk at the farm/kraal or in the village, rural town or road- side. These are differentiated from processor-sellers, who sell home manufactured soft cheese, and are included among processors below.
Processors	These procure milk to process into other products like yoghurt, ice cream, soft cheese (*wagashi*) and hard cheese. In Ghana, these include home processors of *wagashi*, generally wives of stockmen/producers.
Private Wholesalers/ Assemblers	Wholesalers buy milk in bulk from producers or from rural assemblers and sell it to retailers. Assemblers sell generally to other wholesalers. In Tanzania, some wholesalers operate milk collection/cooling centres, while in Ghana no chilling is generally used. They therefore play the role of bulkers in the marketing system.
Collection centres/ dairy cooperatives	Dairy co-operatives facilitate milk collection and marketing, which activity is located around collection centres. Most dairy co-operatives have cooling facilities and collect milk from their members and vendors. They resell the milk to wholesale processors, vendors and household consumers.
Hawker/ Vendors	In this study vendors are referred to as the traders who collect milk from producers and/or milk collectors and sell directly to consumers and other market agents. In Ghana, they may also be the wives of stockmen/producers. Vendors play an important role in collecting milk and delivering it to other market participants, consumers and/or retail outlets such as milk bars, kiosks and hotels. Vendors normally trade on fresh milk unless there is unsold milk, which can be fermented and sold as *mtindi* (soured milk) in the following day in the case of Tanzania. Vendors have more or less permanent customers and may some times deliver milk on credit, while hawkers refer to those vendors that hawk milk to whatever customers they may find, often using small volume selling units such as a cup. In Tanzania, hawkers may sell *mtindi,* particularly during the dry season when hot weather creates demand for this beverage.
Retailers	Retailers present milk to the consumer in the smallest desirable quantity, and in a convenient form and location. In Ghana these are largely open-air roadside sellers, while in Tanzania (Dar only), they comprise mainly specialized milk bars selling a variety of milk products to consumers and particularly consumers away from home.
Fura seller (Ghana only)	These are individual food-drink sellers mainly in urban centres of Ghana. They buy milk from the kraal, assembly market or from the sedentary wholesalers and retail it with combined with balls of cooked cereal, the *fura*, as a snack or meal.

Source: Field Surveys

2.2.1.1 Milk marketing channels in Tanzania

The most important participants identified in Tanzania are dairy co-operatives, private wholesalers, vendors, hawkers and retailers (Figure 3). These traders play the role of middlemen, who play a more important role in the Dar es Salaam milkshed than in Mwanza. Other intermediaries such as cooperatives and wholesalers were not found in the Mwanza milk shed during the study.

Dairy farmer co-operatives operate in Tanga and Coast regions. Most dairy co-operatives have cooling facilities and collect milk from their members and vendors. They resell the milk to wholesale processors, vendors and household consumers.

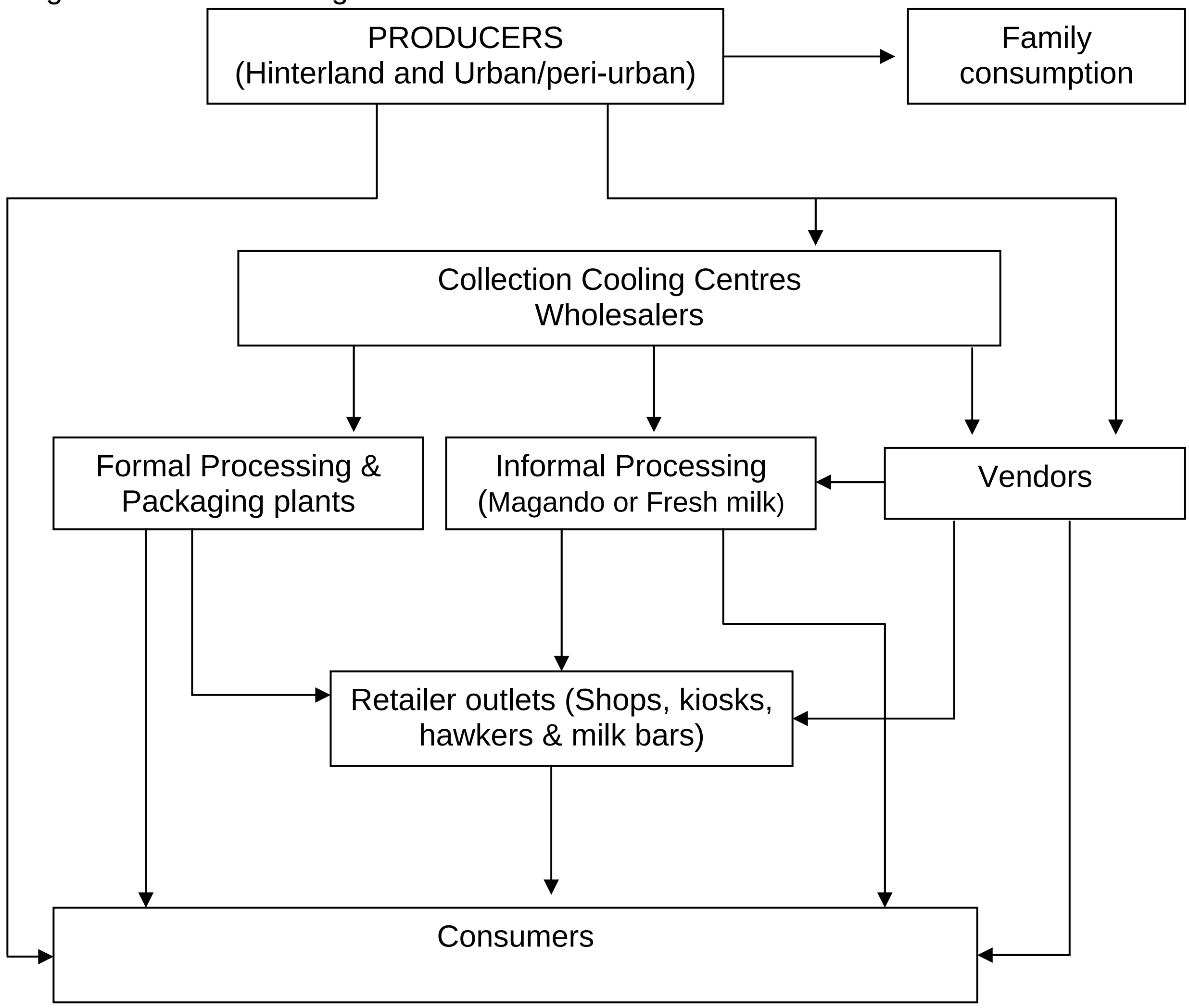
Private wholesalers collect or buy milk in bulk and sell it to retailers. Most wholesalers operate milk collection/cooling centres. Almost all the wholesalers are involved in processing, wholesale and retail business.

Those who collect milk from producers and milk collection and sell directly to consumers and other market agents are referred to as vendors in Tanzania. They play an important role in collecting milk and delivering it to other market participants. In some areas, vendors collect milk from hinterland producers and deliver it to consumers and/or retail outlets such as milk bars, kiosks and hotels. Vendors normally trade in fresh milk unless there is unsold milk, which is often fermented and sold as *mtindi*. Vendors have more or less permanent customers and may some times deliver milk on credit. The major means of transport is bicycles. Carrier equipments for the milk are normally plastic and aluminium containers.

Hawkers are involved in selling small quantities of milk (fresh, *mtindi*) to consumers in the street). Hawkers in Dar es Salaam sell fresh and packaged milk while hawkers in Mwanza largely trade on *mtindi* and fresh boiled milk. These hawkers sell *mtindi* in recycled plastic containers (formally containing cooking fat) of 250 ml each. The amount of *mtindi* traded by the hawkers daily varies with season. They sell 15-18 units per hawker daily during wet season and 25-30 units per hawker daily in the dry season when demand for *mtindi* is high, mainly due to the hot weather. When the weather is hot, *mtindi* is taken as a beverage.

The group of traders retailing milk directly to consumers are known as retailers. These include those selling milk only such as milk bars, and others who also sell other foods such as kiosks, shops, restaurants and hotels. The major route of milk and milk products retailed in Dar es Salaam is specialized milk bars selling a number of milk products to consumers and particularly consumers away from home. While there are known to be more than 100 milk bars in Dar es Salaam city, milk bars in Mwanza were virtually non-existent during the surveys. A number of the milk bars in Dar es Salaam are owned by wholesalers.

Figure 3: Milk marketing channels in Tanzania



In both Dar Salaam and Mwanza milksheds, selling directly to consumers is the oldest of all channels in the milk marketing system. This channel involves milk selling by producers to household consumers at the farm gate or at the local market in the producing areas. The farmers themselves and their relatives in their homesteads may consume part of the milk produced. The popularity of the direct sales channel is however apparently dwindling, owing to the increasing number of households keeping dairy cattle in the producing areas and the growing number of alternative market channels and intermediaries.

Currently most of the producers dispose of their milk through intermediaries. Different types of traders are involved in collection of milk from the hinterlands and peri-urban areas of Dar es Salaam and Mwanza milksheds and deliver the milk directly or indirectly to consumers in the cities. However, there are fewer market channels in Mwanza than in Dar es Salaam as cooperatives and milk wholesalers are virtually non-existent.

The overall picture that one gets from the description of milk market channels in Tanzania is that the milk marketing system is characterised by a multitude of milk market channels and relatively long market chains, which tend to increase in complexity in larger urban areas where demand may be more differentiated.

2.2.1.2 Milk marketing channels in Ghana

The marketing channels in Ghana are illustrated in Figure 4. In Ghana, milk is often taken to other sale points when customers do not buy all the milk at the farm-gate. House delivery of milk is done mainly to local processors (referring to makers of traditional *wagashi* cheese, who operate from their own residences), milk assemblers or consumers who have a supply contract with the milk seller. Some business people are becoming interested in the establishment of milk bars, as are found in Tanzania. Two such bars are being operated in the Accra area where consumers sit to drink fresh milk. Stockmen deliver fresh milk daily to these bars.

Producers and a cadre of individual market agents (hawkers) often carry milk from house to house or from street to street to retail in small quantities to consumers. *Wagashi* processors who for one reason or the other are not able to process all their fresh milk may engage the services of milk hawkers, usually their own children.

Some consumers prefer fresh milk mixed with millet or maize meal called *fura* and *lekr*i respectively. Sellers of *fura* who hawk milk and *fura* will carry fresh milk along with them to use in preparing the *fura* for people to drink. A few *fura* and *lekri* sellers are sedentary with recognized sale points particularly in the cities of Kumasi, Accra and Tema. Consumers usually determine how much fresh milk they want added to the *fura* or *lekri* and are charged a price accordingly. The quantity of milk sold through this channel is small since people require small quantities to accompany the cereal (usually between 0.1 litres and 0.5 litres).

In areas where there is high demand for fresh milk and where cattle kraals are located further away from the town centre, many consumers are reluctant to spend time, energy and transport cost just to buy one bottle of milk. Under such situations, stockmen[1] and their wives may decide to transport milk to their customers in the town or city centre. For those stockmen who do not have established customers or who cannot hawk their milk, a place is chosen usually in the centre of town where milk sellers assemble to sell their milk. Such assembly markets have developed in Kumasi, Kintampo, Nima and Ashiaman. However, when milk sellers fail to sell all their milk by afternoon, they are compelled to hawk their leftover-milk.

[1] Stockmen are generally Fulani cattle keepers, who are hired to manage cattle usually owned by others.

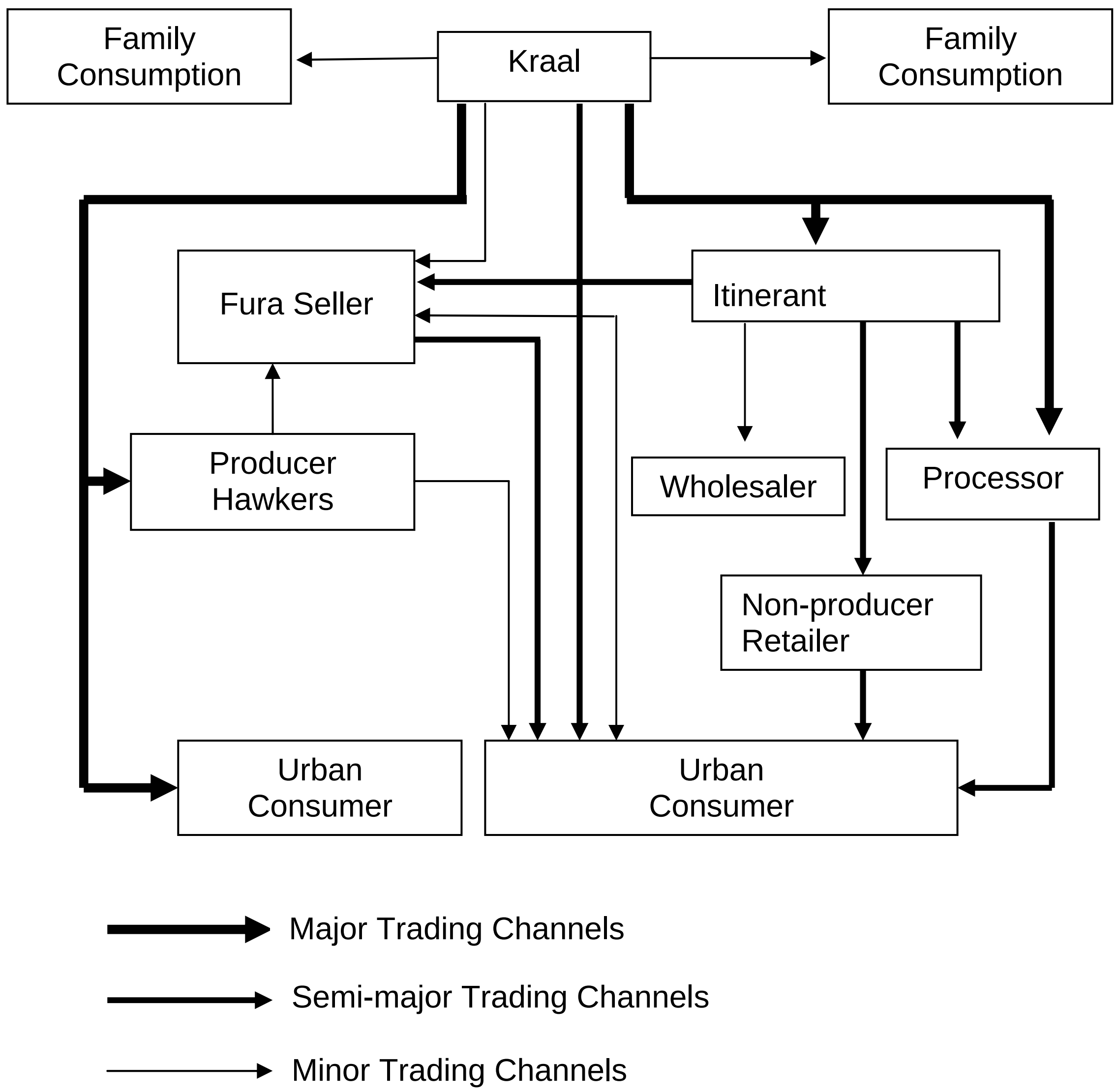


Figure 4: Milk marketing channels in Ghana

2.2.2 Conduct in milk marketing

2.2.2.1 Milk Procurement

The amount of milk collected varied according to the number of cows being milked, the breed of the cows being milked, the location of production and the season when milk is collected. Milk collection was higher in the wet season when more feed/forage was more available than in the dry season. The average amounts procured were also generally higher in Tanzania than Ghana irrespective of season, which is associated with higher levels of consumption. The mean daily collections per producer (farmer, herdsman or stockman) for the various sites are given in
Table 3 .

Table 3. Quantity of milk procured daily in litres from producers

Country/site	Dry Season			Wet Season		
Litres/day/producer	Mean	Min	Max	Mean	Min	Max
Tanzania						
Dar es Salaam(n=142)	24	0	300	54	2	1,150
Mwanza (n=118)	5	0	30	12	0	105
Ghana						
Accra (n=94)	20	3	60	24	3	100
Kumasi (n=158)	10	0	54	12	1	52

In Ghana, the quantity of milk collected in the wet season (March – November) is usually higher than the collection in the dry season (December – February), but only moderately so. Mean daily collections are lower in the Kumasi zone, varying from 10 litres in the dry season to 12 litres in the wet season. In the Accra area daily collections are quite high, averaging 24 litres and 20 litres respectively for the wet and dry seasons as shown in .

In Tanzania, the seasonal differences between the quantities of milk collected per producer are larger than that seen in Ghana. Mean daily collections during the wet season are 24 litres and 5 litres in Dar es Salaam and Mwanza respectively – rising to 54 litres and 12 litres respectively. Per farm collections in the Dar area are much higher than those seen in Mwanza, most likely due to increased intensification and use of higher yielding cross-bred cattle.

The quantities of milk handled by the different type of market agents varies considerably (Table 4), with those performing bulking or processing roles handling the most milk. In Ghana, milk assemblers and *wagashi* processors are the most important in the procurement activity. The assembler and processor travel furthest and procure the greatest quantity of milk. Processors and assemblers procure daily on the average 109 litres and 82 litres respectively in the Accra zone and 47 litres and 82 litres respectively in the Kumasi zone. Milk retailers including vendors and *fura* sellers procure small quantities of between seven and ten litres (7-10 litres) of milk daily for sale in the urban areas of the Kumasi zone. Retailers in Accra procure larger quantities (on average about 82 litres daily) than their counterparts in Accra.

As shown in (Table 4), cooperatives and collection centres play the largest role in procurement in Dar es Salaam, with monthly averages totalling 23,205 litres or 774 litres daily. Wholesalers and assemblers also procure significant amounts (733 litres daily). The contrast with Mwanza is stark, where only producers, retailers and vendors conduct procurement from producers. This difference is closely linked to the much larger and more complex market in Dar es Salaam.

Table 4. Volumes of milk procured monthly by marketing agent and site (Litres)

Market agents	Dar es Salaam			Mwanza			Accra			Kumasi		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Coop/Collection centres	23,205	7,950	43,815	NA	NA	NA	2,760	2,760	2,760	NA	NA	NA
Producers-sellers	1,133	0	34,500	252	0	3,150	659	75	3,000	344	0	1,800
Processors	NA	NA	NA	NA	NA	NA	3,281	180	12,000	1,398	94	7,500
Wholesalers/ assemblers	21,995	540	60,300	NA	NA	NA	2,465	150	12,000	2,447	300	9,600
Retailers	1,839	0	27,720	887	0	3,600	2,578	300	30,150	216	20	945
Vendors/Mobile traders	1,564	0	4,920	711	0	13,500	NA	NA	NA	233	60	837
Others	980	450	3,000	NA	NA	NA	300	300	300	615	120	1,500

2.2.2.2 Market Concentration

The average volume of milk handled (estimated quantities procured *and* sold) by different market agents is presented in Table 5. The volume of milk handled varies between milk market agents and by site. In Tanzania, the dairy business is more developed in Dar es Salaam with significantly larger volumes of dairy products being traded in Dar es Salaam than in Mwanza. The same pattern is observed in Ghana with larger volumes of dairy products traded in Accra than in Kumasi.

In Dar es Salaam, cooperatives and wholesalers were found to be handling larger volumes of milk compared to other market agents. In Mwanza, vendors who are the majority (85% of respondents) handle most of the milk (81%) while in Dar es Salaam, wholesalers and cooperatives, which form only 7% of the intermediaries, handle about 43% of the traded milk. These data verify the PRA findings, which show that most of the milk procured from farmers in the Dar es Salaam milkshed passes through wholesalers and cooperatives while in Mwanza the milk passes through vendors. The procurement of milk from producers in Dar es Salaam takes place at homesteads and milk collection centres owned by co-operatives and private wholesalers. Some other milk is delivered directly to retailers' trading premises and household consumers mainly in the urban areas. Vendors were found to play a significant role in collecting milk from farmers' homesteads both in Mwanza and Dar es Salaam. Vendors usually transported milk to the collection centres, trading premises and household consumers on bicycles or public transport and in some cases by head carrying. Transportation of milk from the collection centres, in the case of Dar es Salaam, to the urban areas is mainly done using hired or own private vehicles. From these results, it appears that there may be oligopolistic conditions in the Dar es Salaam market than in Mwanza market at procurement level as only 7% of the intermediaries are handling more than 40% of the milk procured from farmers.

In Ghana, no specific market agent type dominates the dairy products in Accra, with cooperatives, *wagashi* processors, wholesalers and retailers handling on average the same volumes of milk. In Kumasi on the other hand, wholesalers followed by *wagashi* processors, are the larger players.

Table 5: Volumes of milk handled monthly (Litres) (average quantities, procured and sold)

Market Agents	**Dar es Salaam**			**Mwanza**			**Accra**			**Kumasi**		
	Mean	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**
Coop/ Collection Centres	22,306	7,725	42,807	NA	NA	NA	2,760	1,650	3,870	NA	NA	NA
Producers-sellers	1,163	30	52,686	210	0	1,598	660	75	3,000	349	13	1,800
Processors	NA	NA	NA	NA	NA	NA	2,555	180	7,500	1,398	94	7,500
Wholesalers/ assemblers	20,181	450	60,000	NA	NA	NA	2,383	150	12,000	2,448	300	9,600
Vendors/Mobile Traders	1,601	360	4,230	723	13	7,425	NA	NA	NA	233	60	837
Retailers	1,431	54	14,404	1,014	150	4,050	2,578	300	30,150	262	20	945
Others	781	431	2,025	NA	NA	NA	300	300	300	615	120	1500

2.2.2.3 Milk Transport

Due to the perishable nature of fresh milk, the success of dairy businesses often hinges on the efficiency of transportation. Information on transportation was collected during the PRA in order to illustrate the role played by transport in dairy market access.

It was found that most Ghanaian herdsmen-producers normally sell milk at the kraal (farm-gate) or in their homes, buyers coming to make purchases in both cases. The majority (85%) of these producers therefore needed no transport from the procurement point to the sale point. Only 12% of the herdsmen transported their milk by foot to a sale point other than the kraal or home. This is a remarkable finding, suggesting that in a large majority of cases, marketing of milk is not a constraint – demand outstrips supply to the extent that buyers are willing to seek out sellers and incur the transport costs and time. Of those who did transport, the majority of market agents in Ghana (72%) also transported their milk on foot from the procurement point. The rest (28%) of the market agents used varied means of transport to convey milk from the procurement point. Twenty-one percent (21%) used public transport, 6% used bicycle, 1% used their own vehicles, and only 1% of market agents hired vehicles to transport their milk. The percentage use of modes of transport for procurement is given in .

In Tanzania, 56% and 47% of the market agents rely mostly on bicycles to procure and to deliver milk to sales points, respectively (Table 6). 30% of Tanzanian market agents used vehicles to procure milk while 30% of the sales deliveries were done on foot - usually by hawkers. Producers and vendors in Tanzania usually transport milk to selling points on bicycles or public transport and in some cases by head carrying. Transportation of milk from the collection centres to the urban areas is mainly done using hired or own private vehicles. Higher frequency of vehicle use in Tanzania is likely to be related to larger average volumes, and to much more spatial dispersion between supply and demand areas. Supply close to urban demand areas is not enough to meet demand, requiring procurement from more distant areas.

Table 6. Percentage use of different modes of transport in milk procurement and sales delivery in Ghana and Tanzania

Mode of Transport	**Ghana**		**Tanzania**	
	Procurement	Sales Delivery	Procurement	Sales Delivery
None	35.2	56.0	NA	NA
On foot	37.8	25.4	6.4	29.1
Bicycle	5.8	1.2	56.2	46.5
Public Vehicle	20.3	15.0	29.8	1.9
Own Transport	0.7	0.5	4.4	2.7
Hired transport	0.2	1.9	1.4	0.9
Draught animals/cart	NA	NA	1.8	0.5
Other	NA	NA	NA	18.4
Total	100	100	100	100

The importance of bicycles for transportation especially among small-scale traders and vendors has been highlighted in both countries. It is clear however that with increasing number and complexity in the channels used, the need for mechanised transport increases. From the simplest form in Ghana where herdsmen sell directly to buyers at the point of production and no movement is necessary to the more complex situations in Dar es Salaam where milk moves from producers through wholesalers and retailers in different places and requiring different quantities and greater reliance on vehicles.

2.2.2.4 Product Differentiation

Milk is marketed by most market agents in raw fresh form. In Ghana, herdsmen market their milk as raw fresh milk, though some process it into soft cheese (*wagashi*) when they are unable to sell the raw fresh milk. Most of the traders who procure milk from the herdsmen also sell this further in the fresh form even though a small proportion (14.4%) of them will boil milk before selling. Others (3.5%) will ferment milk before selling. Some milk is also processed into yoghurt and hard cheese. A range of milk products can therefore be found on the Ghanaian markets. These include raw fresh milk, boiled fresh milk, fermented milk, yoghurt, soft cheese, hard cheese and ghee. This relatively high degree of product differentiation in Ghana is a key difference in the Ghana and Tanzania comparison.

All cooperatives in Ghana handle raw milk, while 79%, 74%, 22%, 19% and 13% of producers, wholesalers, retailers, hawkers and processors handle raw milk respectively (Table 7). This makes raw milk the most popular product among traders in Ghana. Some of this milk is converted into wagashi – fresh and fried – marketed by 25% of the hawkers and 19% of retailers. Ghanaian retailers also sell fresh boiled milk (30%) and natural fermented milk (24%) similar to hawkers who also sell 25% and 31% of these products respectively. Cultured milk is a preserve of processors in Ghana and a few retailers with the skills. A very small proportion of the traders in Ghana market ghee, with hardly 3% of the retailers reporting its sale.

In Tanzania, while the types of milk products traded vary somewhat between trader types, products are general common for particular trader types in both the Mwanza and Dar es Salaam milksheds. Most of the milk marketed in the Dar es Salaam milk shed is either unprocessed or informally processed liquid milk. Raw fresh milk constitutes the most traded item followed by fresh boiled milk sold - warm and sold-cool. Table 7 shows the types of milk products traded by various market agents. From the table it is indicated that along the marketing chain in the Dar es Salaam milkshed, raw milk is mostly traded by cooperatives producers, wholesalers, vendors and hawkers. More than 90% of these traders cited raw milk as the major sale product.

Table 7. Proportion (%) of market agents citing various products in Ghana.

Product type	Co-ops	Producer	Processor	W/Saler	Retailer	Hawker	Other
Raw milk	100.0	79.2	12.7	73.6	22.2	18.8	0.0
Natural fermented milk	0.0	1.1	0.0	0.0	23.6	31.3	0.0
Fermented (Cultural) milk	0.0	0.0	8.5	0.0	1.4	0.0	0.0
Wagashe fresh	0.0	12.3	28.2	0.0	11.1	25.0	5.0
Wagashe fried/dried	0.0	0.3	12.7	4.6	8.3	0.0	85.0
Ghee	0.0	0.6	2.8	1.2	2.8	0.0	0.0
Boiled fresh milk	0.0	3.3	0.0	2.3	30.6	25.0	0.0
Other	0.0	3.3	35.2	18.4	0.0	0.0	10.0

Table 8. Proportion (%) of market agents citing various products in Tanzania.

Product type	Co-ops	Producer-sellerss	Wholesaler	Retailer	Hawker	Other
Raw milk	86	97	66	8	95	0
Fresh boiled (cool)	9	<1	0	27	1	38
Fresh boiled (warm)	0	<1	0	30	<1	25
Naturally fermented milk	0	1	0	19	2	19
Fermented cultured milk	0	0	24	8	<1	19
Packaged pasteurised milk	5	0	2	4	0	0
Packaged fermented milk	0	0	7	3	<1	0
Ghee	0	0	0	0	0	0
Cream	0	0	0	0	0	0
Ice cream	0	0	0	0	0	0
Youghurt	0	0	0	<1	0	0
Tea	0	0	0	<1	0	0
Other	0	<1	0	<1	0	0

At the retail level in Tanzania a mix of products is found with fresh boiled milk being the most importantly retailed commodity. About 57% of the retailers who cited various product types indicated either fresh boiled cool or warm milk as their main products they sell. Other products cited by retailers are raw milk (8%); naturally fermented milk (19%); culture-fermented milk (8%); packaged pasteurised milk (4%) and packaged fermented milk (3%) (Table 8). There was no reported sale of ghee by any market agent type.

In Mwanza, a slightly different picture is found compared to Dar es Salaam; while producers and vendors trade mainly in raw milk, hawkers and retailers do not deal with raw milk at all. Hawkers sell fresh boiled, warm and naturally fermented milk – in Dar es Salaam hawkers sell raw milk. Similar to Dar es Salaam, more than 50% of the retailers in Mwanza sell fresh milk either boiled warm or cool. Only 19% of the retailers sell naturally fermented milk and only 7% sell culture-fermented milk.

What emerges from the analysis of product differentiation is that most market agents trade in similar products although some variations exist between trader-types. The second observation is that most of the milk traded is unprocessed (raw) or informally processed. This confirms that the industry is characterised by low levels of processing in both Ghana and Tanzania, although less so in Ghana. Traditional products (*wagashi, fura and lekri*) seem to play a bigger role in Ghana especially amongst the vendors while in both countries, retailers appear to have the largest variation in products sold. Liquid milk, however, remains the most important product in both countries.

2.2.2.5 Business contracts

Most contracting intermediaries used informal unwritten contractual arrangements stipulating time of delivery, price and timing of payment to attract supplies. Formal contracts, those defined as 'lawyer assisted' were not found except for one case below in Ghana. Some instances of informal written contracts were also found. The distribution of supply contracts according to their nature and the trader involved is presented in Table 9 .In Ghana, only the government-assisted Milk Collection Centre located in Sege in the Dangbe East District conducted milk procurement under a written contract with suppliers. Where contractual arrangements between buyers and sellers exist, they have often included arrangements on the mode of payment and the time of supply.

Table 9. Number and nature of contractual arrangements with suppliers by market agent.

Market Agent	**Ghana**			**Tanzania**		
	None	**Informal unwritten**	**Informal written**	**None**	**Informal unwritten**	**Informal written**
Coops/ collection centres	1	0	0	0	11	1
Producer-sellers	145	4	0	79	3	0
Wagashi processors[a]	26	17	0	13	19	4
Wholesalers/assemblers	9	24	1	149	356	7
Vendors/Mobile traders[b]	27	7	0	6	13	0
Retailers	9	2	0	232	280	8

[a]Includes fried *wagashi* sellers
[b]Includes hawkers, and *fura*/*lekri*/*burkina* sellers

In Ghana, the study revealed that eighty percent (80%) of procurement transactions were made without any form of business contract, even informal. Out of the 272 transactions studied, 217 were made without business contracts, 54 (20%) were made under unwritten informal contracts and only one procurement transaction was made under a written informal contract. Producer herdsmen do not normally transact their sales business under any contract arrangement except in a few cases where sales of significant volumes of milk is to be made on regular basis to an assembler or processor. Unwritten informal contracts were made mainly between milk processors and/or milk assemblers and herdsmen.

In Tanzania, most of the interviewed respondents during the survey had not entered any formal contractual arrangements with their suppliers. Out of the 1,181 respondents interviewed in Tanzania, 479 (41%) indicated to not have been practising any form of contractual arrangements with their suppliers. However, a number of respondents reported the use of at least one or more informal contracts with their suppliers. About 682 respondents (58%%) indicated use of informal unwritten contracts and only 20 (2%) respondents indicated the use written but informal contracts. The informal verbal contractual arrangements were based on payment modes, price and time of delivery and time of payment. There were more informal written contracts in Tanzania compared to Ghana, which may reflect the generally more development nature of the dairy industry in Tanzania. The absence of formal contractual arrangements implies that informal milk marketing may be prone to business risks and uncertainties, particularly in Ghana. The distribution of types of contractual arrangements with suppliers by site is given in .

Table 10. Specification of contractual arrangements with suppliers by site.

Contract specification	**Ghana**		**Tanzania**	
	Freq.	%	Freq.	%
None	331	79.8	162	40.0
Quantities of daily supply	2	0.5	114	28.2
Mode of payment	23	5.5	52	12.8
Date of payment	1	0.2	15	3.7
Time of supply	26	6.3	17	4.2
Guaranteed purchase of all milk/milk product supplied	21	5.1	12	3.0
Price of milk supplied	NA	NA	8	2.0
Date of supply	NA	NA	NA	NA
Daily supply	6	1.5	NA	NA
Good quality of milk	1	0.2	NA	NA
Other	4	1.0	25	6.2
Total	415	100.0	405	100.0

While in Tanzania 60% of the traders had contracts of one form or another, only 20% of the Ghanaian traders used such contracts. The traders in Ghana who had contractual arrangements were either concerned about the time of supply (6%), mode of payment (6%) or guaranteed purchase of all milk supplied (5%). This contrasts with Tanzania where the contracts dealt mainly with fixing quantities for daily supply (28%) and mode of payment (13%).

2.2.2.6 Handling vessels

Handling vessels used in milk procurement included plastic buckets, gallons and jerry cans; milk cans/churns, aluminium bowls and calabashes. Others include glasses and clay cups. shows different handling vessels used by various market agents. The table shows that in both countries, milk is most often handled using plastic containers, which are prone to bacterial contamination. In Tanzania, 41%, 12% and 8% of the respondents who cited various handling materials used plastic buckets, plastic gallon and plastic jerry cans respectively. The remaining respondents (39%) used non-plastic vessels such as metal cans, aluminium basins and others. Glasses and clay cups (the “Other” in) were mostly used by retailers. Milk handling problems coupled with the lack of quality assurance of milk delivered to most of the retailers and household consumers, pose as potential sources of public health risks to consumers, and may contribute to low consumption of milk.

In Ghana, although herdsmen sometimes use calabashes or aluminium bowls to collect milk during milking the most commonly used vessels are the plastic buckets, plastic gallons and plastic jerry cans (). Plastic buckets are the most common in all areas visited, accounting for 58% of the total in Ghana and are used mostly by the herdsmen to keep milk before sale. The aluminium bowl is used also by most rural consumers in Ghana to purchase milk from the kraals.

Table 11. Handling vessels used by traders – proportion of responses.

Handling vessel	**Ghana**		**Tanzania**	
	Freq.	**%**	**Freq.**	**%**
Plastic bucket/basin	237	58	345	40.8
Plastic gallon	49	12	105	12.4
Jerry cans (plastic)	46	11	68	8
Milk cans/churns	2	0.5	194	22.9
Aluminium basin/bowls	45	11	63	7.45
Baskets/calabash	6	1.4	0	0
Other	26	6.3	71	8.4
Total	411	100	846	100

The plastic bucket is also used for milk that is to be transported for short distances for sale in Ghana while the plastic jerry can (21 – 40l) is used to transport milk over longer distances. Its use is restricted to the Accra zone by itinerant assemblers who handle bigger volumes of milk. Plastic jerry cans are seldom used in the Kumasi zone and it is only the few assemblers and processors in this zone that transport milk in plastic jerry cans. Milk churns and cans are used mainly by well-organized milk firms like the Ministry of Food and Agriculture dairy farm at Amrahia near Accra and the Milk Collection Centre at Sege in the Dangbe East District to transport milk. These milk firms also use a bulk tank to store milk.

The use of plastic containers is popular in both countries with the usage more entrenched in Ghana (81%) compared to Tanzania (61%). In both countries the handling vessels are important for both storage and transportation and a high degree of innovation is seen depending on cost considerations as well as what is readily available. The use of the recommended aluminium milk cans/churns is rare with Ghanaian traders with less than 1% using compared to about 23% of the traders in Tanzania. A way to encourage the use of the recommended aluminium cans/chuns in Ghana may be to draw the attention of local aluminium manufacturing companies to fabricate such cans/churns.

2.2.3 Result of margin and budget analysis

Economic analysis of the market agent enterprises is closely tied to quantities of milk handled. The average quantities of milk handled by various market agents were discussed in Section 2.2.2.1 and illustrated in Table 5. These are the quantities used in calculating revenues, costs and margins for the market agents in the analysis that follows. In Ghana, quantities sold per day varied from as low as 1 litre by a *fura* seller in the Buipe area to a high of 400 litres by an itinerant assembler and some 1005 litres by retailers in the Accra zone. In Tanzania, where the dairy industry plays much larger role and consumption is higher, wholesalers handle quantities up to 60,000 litres monthly (2,000 litres daily) while retailers handle maximum quantities of 460 litres daily during peak seasons.

Herdsmen and other small-scale milk producers will usually reserve between 1 and 5 litres (8 – 17% of milk collected) for the use by the household depending on the number of family members consuming milk and the amount of milk collected. Less milk is reserved for family consumption when the quantities collected are small. Marketing agents (traders) however sell most of the milk they procure daily. Losses suffered usually result from spillage and spoilage.

2.2.3.1 Milk prices and market margins

Price variability among market agents is one indicator of market efficiency, although transport and transactions costs will create price differences spatially. Further, output product differentiation, particularly in terms of value added, create differences in margins, which no not reflect costs. Market margins are not by themselves a measure of profitability of a marketing business. Conspicuously high market margins may imply high marketing costs and/or profits. In this example, in order to compare the margins observed among agents selling different products, all products such as *wagashi* were converted into liquid milk equivalents (LME's). Table 6 and 7 show the variation in prices received by various market agents in districts in Ghana and Tanzania. The exchange rates used in these price analyses, and in the rest of economic analysis are 1 US$ equals 800 Tanzania Shillings, and is also equal to 4050 Ghana cedis. Generally, there are significant variations in the producer and retail price of milk among districts and among the different trader groups within each zone. For all districts, the average prices received were generally higher for mobile traders and retailers suggesting either more value addition (and costs) or higher margins.

In Ghana, producers in the Kumasi zone receive higher prices for milk than producers in Accra. This is somewhat surprising, in that Accra is a larger consumer demand area, and suggests that supply is also proportionately large, most likely from the nearby Accra plains. Producers received on average $0.3 per litre in Kumasi compared to $0.17 in Accra. This is due to general milk scarcity in Kumasi, a forested area, which forces producer prices up.

Wholesalers in Kumasi receive on average $0.37 per litre against $0.29 in Accra. However, the consumers in Accra pay more as retailers there receive $ 0.46 against $0.44 per litre – likely the result of higher incomes and greater urbanisation in Accra. Those handling the smallest quantities, but offering a specialized service, milk retailers and especially the *fura* sellers receive the highest milk price in both Kumasi and Accra. Milk sellers who retail milk with *fura* or *lekri* earn higher prices than traders who retail solely fresh milk. This is because the *fura* seller sell their milk in very small sale-units (at times less the 100ml) and thus earn more per litre of fresh milk sold than other retailers who sell using larger measures like the litre cup, soda or beer bottle and also because these products have some value-added.

Wagashi and other product processors in Accra and Kumasi receive the highest prices of all market agents. This is because these processors deal in value added products such as *wagashi*, *lekri* and *fura*, which fetch higher prices. Processors in Accra receive the highest margins, apparently due to limited supply of the *wagashi*, which is generally produced only by members of the Fulani ethnic, who are a small minority in the Accra area.

Table 12. Producer prices, retail prices and market margins per litre of liquid milk equivalent by milk agent and district in Ghana.

	Accra			**Kumasi**		
	Purchase price ($)	Sale price ($)	Market Margin ($)	Purchase price ($)	Sale price ($)	Market Margin ($)
Coop/collection centre	0.17	0.22	0.05	-	-	-
Producer-seller*	NA	0.17	0.17*	NA	0.30	0.30*
*Wagashi p*rocessor	0.18	0.65	0.47	0.19	0.42	0.23
Whole seller	0.16	0.29	0.13	0.23	0.37	0.14
Retailer	0.27	0.46	0.19	0.22	0.44	0.22
Hawkers	-	-	-	0.09	0.29	0.20
Others	-	-	-	0.11	0.16	0.05

*Costs of milk production are not known, so that milk producer (herdsman in Ghana) "purchase price" is not applicable. Producer market margin should be understood in that context.

Further regional analysis in Ghana shows that average milk prices are generally lower in the rural districts like Ejura, Kintampo, North Tongu and Ewutu-Efutu than in peri-urban districts like Ejisu Juaben or urban and municipal districts like Sekyere West, Amansie-East, Kumasi, Tema and Accra municipalities. The producer price for milk is lowest in the Juapong area of the North Tongu district ($0.12/ litre) and in the Ewutu Efutu district ($0.16). Again, this is due to relative supply and demand. There are a significant number of cattle in these areas and good quantities of milk is collected, yet there is little demand for fresh milk in these areas. Apart from the stockmen and their families who consume small quantities of the milk collected, the population in the North Tongu and Ewutu-Efutu districts do not consume fresh milk. Most milk produced in the two districts is thus sold to visiting itinerant assemblers from the Tema and Accra municipalities, or is made into *wagashi* for transport and sale. The producer price for fresh milk is also low ($0.19/litre) in the Ejura-Sekyedumasi District in the Kumasi zone where milk production is also high and demand is low.

The average prices received by various market agents in Dar es Salaam as shown in Table 12 were $0.62, $0.31, $0.38, and $0.28 for retailers, mobile traders, wholesalers and co-operatives respectively. In Mwanza the prices were $0.43, and $0.26 for retailers and mobile traders respectively. On the other hand, prices received by producers also varied with districts. The prices received by milk producers varied from $0.29 to $0.23 in Tanzania. The results in the table show that generally market margins in Dar es Salaam may be slightly higher than those in Mwanza, although this is not tested statistically. For example, retailers in Dar display a margin of $0.25 vs. $0.20 in Mwanza. This may be related to higher labour costs in Dar, typical of larger urban areas. However, margins remain remarkably similar. Hawkers, with almost no input costs except labour, show the lowest market margins.

Table 13. Producer prices, retail prices and market margins per litre of liquid milk equivalent by milk agent and district in Tanzania.

	Dar es Salaam			**Mwanza**		
	Purchase price ($)	Sale price ($)	Market Margin ($)	Purchase price ($)	Sale price ($)	Market Margin ($)
Coop/collection centre	0.22	0.28	0.06	-	-	-
Producer-seller*	NA	0.29	0.29*	NA	0.23	0.23*
Whole seller	0.23	0.38	0.15	-	-	-
Retailer	0.37	0.62	0.25	0.23	0.43	0.20
Hawkers	0.22	0.31	0.09	0.18	0.26	0.08
Others	0.40	0.61	0.21	-	-	-

*Costs of milk production are not known, so that milk producer "purchase price" is not applicable. Producer "market margin" should be understood in that context.

Table 12 reveals substantial differences in the retail and producer prices among districts in Tanzania. Generally, the average producer sale price ($0.29) and average retail sale price ($0.62) are higher in Dar than in the Mwanza milk shed (i.e. $0.23 and $0.43 respectively). The difference between producer prices and retail prices is also higher in the Dar es Salaam milk shed than in the Mwanza milk shed ($0.33 and $0.20) suggesting that marketing costs are lower in the Mwanza milk.

In both regions in Tanzania, milk prices are generally higher closer to the urban centres, reflecting centres of demand and the costs associated with moving milk to those centres. Within the Dar es Salaam milk shed, producer and retail prices are higher in Dar es Salaam district than other areas such as Tanga, Coast and Morogoro. The producer prices are lowest in the Coast ($0.20) while retail prices are lowest in Tanga ($0.17). The difference between producer price and retail price is lowest in Dar es Salaam district implying lower marketing costs, possibly due to close proximity of production and consumption compared to other areas of the milk shed. Similarly producer prices in the Mwanza milk shed are highest in Mwanza urban and peri urban and lowest in distant places of Sengerema.

In Dar es Salaam, retailers display the largest market margins ($0.25), as would be expected given their higher costs, while collection centres were observed to have the lowest margins ($0.06), contributing to their lack of profitability. Hawkers in both Dar and Mwanza accept comparatively low margins ($0.09 and $0.08 respectively) due to the low capital and variable costs.

2.2.3.2 Distribution of market margins by channels

The distribution of market margins among the market participants in various sites in the two study countries is shown in Table 14. The distinction between the channels is based on the type and/or number of market intermediaries. The primary channel is that which is most prevalent in the given zone, the second is the next most important, and so on. Because they are calculated separately for each zone, the primary channel in one may not be the same in the others. In Dar es Salaam four channels are identified, while in the other zones two or three channels are described. It is seen that the involvement of more intermediaries in a chain causes the rest to give up a portion of their margins. Thus the longer the chain the smaller the proportion enjoyed by a market agent. It appears, therefore, that producers receive higher market margins in shorter milk marketing channels.

A common channel is one in which the producer sells directly to the consumers and therefore takes 100% of the consumer price. This channel type was evident in all sites and was the primary channel in the less urban Mwanza (Tanzania) and in Kumasi (Ghana), and was the second channel in Dar es Salaam. Where this channel predominates, demand is typically strong enough so that no intermediaries are required to move milk to more distant deficit areas.

Another important type of channel is that in which one intermediary is involved; either wholesaler, trader, retailer or processor. Through wholesalers, these form the primary channel in Accra, suggesting (as does the low price) that supply is significant, and so needs assembling to move to urban markets. In Accra this imposes a significant cost: the producer gets only 58% of the consumer price, with the wholesaler absorbing 42% of the price margin. Where wholesalers then sell to retailers in Accra, they give up some of their margin, while the producer retains the same price. Traders also take a large share of the margin (52%) in Dar es Salaam (fourth channel), but a smaller share in Mwanza (20%) where distances may be shorter along the channel.

Retailers in both Ghana and Tanzania usually receive the smallest portion of the margins: 3.2% in Dar, 18.8% in Accra and 10.22% in Kumasi, while producers get the biggest share – almost always bigger than 50%. As evident from the figures Tanzanian traders in Dar accept very small margins due to high competition.

It is also observed that producers in the Kumasi zone get a greater portion of the market margin than do producers in the Accra zone. This is because the producer price of milk in the Kumasi zone is quite high relative to the retail price for milk. Milk agents in the Accra zone however receive higher market margins than their counterpart in the Kumasi zone except for the processor who deals in value added products and receives 35% in Kumasi.

Table 14. Distribution of total market margins, by type of marketing channel, and by country and zone

	Primary channel		Second channel		Third channel		Fourth channel	
Dar es Salaam	$	%	$	%	$	%	$	%
Producer-seller	0.22	50.57	0.37	100	0.43	96.75	0.21	48.05
Wholesaler	0.2	46.2						
Trader							0.22	51.95
Retailer	0.01	3.23			0.01	3.25		
Consumer	0.44	100	0.37	100	0.44	100	0.43	100
Mwanza	$	%	$	%				
Producer-seller	0.31	100	0.2	79.59				
Trader			0.05	20.41				
Consumer	0.31	100	0.25	100				
Accra	$	%	$	%	$	%		
Producer-seller	0.16	57.91	0.16	46.67	0.23	100		
Wholesaler	0.12	42.09	0.12	34.52				
Retailer			0.06	18.81				
Consumer	0.27	100	0.34	100	0.23	100		
Kumasi	$	%	$	%	$	%		
Producer-seller	0.32	100	0.25	64.36	0.27	89.78		
Wagashi processor			0.14	35.64				
Retailer					0.03	10.22		
Consumer	0.32	100	0.39	100	0.3	100		

Only channels involving at least 10 agents were usually considered. The first column by channel gives the margins (difference between sale price and purchasing price), in US$. For producers, margins equal sale price.

2.2.3.3 Market agent revenues and costs.

Summarised trader budgets for Tanzania and Ghana are presented in and . These budgets show the costs, revenues and profits (losses) by marketing agent and by site.

The figures in show that in Dar es Salaam cooperatives and wholesalers have the highest total revenue per enterprise, followed by mobile traders. Producers have the lowest revenue owing to low volumes. The revenues for various market agents are closely tied to volumes of milk sold, since revenue is a function of volume of milk sold and average selling prices received by the agents.

In both sites in Ghana, *wagashi* processors collect the highest revenues, which is likely to be tied to the volume of milk equivalent in processing cheese. Wholesalers also generate significant revenues in both zones due to volume.

Monthly costs are summarised in Table 15 and Table 16 for Ghana and Tanzania respectively. Total monthly costs for various market agents were found to vary substantially, in the fixed costs as well as variable costs. Major variable cost items for milk traders include the milk cost and transport charges. The transport costs incurred by market agents are of two kinds. These include procurement transport costs, and sales transport costs.

It should be noted that traders who were also milk producers, dealing in own produced milk, made profits both as producers and market agents. To enable inclusion of only that part of profits made through milk marketing, means of prices paid out to milk producers by other traders who procured milk from them were used as estimates of milk costs for the traders dealing in own produced milk.

For the procurement of milk, marketing agents using public transport have to pay a personal transport fare to and from the procurement point. In addition the agent also pays a charge for the empty handling vessels and the procured milk to and from the procurement point respectively. A single transaction may also involve the travelling of the market agent by a combination of different means of transport. Other variable costs including intermediate sales costs, labour and vehicle repair costs were relatively low.

In Tanzania, the cooperatives and wholesalers were found to incur higher fixed and variable costs than other market agents while retailers, hawkers and vendors incurred the lowest levels of fixed costs. The high levels of fixed costs for cooperatives and wholesalers are attributed to the initial costs for purchasing cooling tanks. Co-operatives and wholesalers have large cooling facilities at their collection centres, which form a significant component of the fixed costs. Cooperatives and wholesalers were not found in Mwanza during the study, and retailers were found to have higher variable costs compared to hawkers and vendors. High heating and cooling costs amongst the retailers may be attributed to boiling and cooling practices commonly used with a dual purpose of preserving and improving quality of milk.

In Ghana costs varied similarly with volumes handled. The fixed cost incurred by all categories of traders in Ghana was very low and has an insignificant influence on the profits made.

Table 15. Revenue, costs and profits (US $) among milk traders in Ghana

Market Agents	Accra				Kumasi			
	Revenue per month	Costs per month	Profit		Revenue per month	Costs per month	Profit	
			Profit / month	Profit/ litre			Profit / month	Profits/ litre
Coop / collection center	641	539	101	0.04	NA	NA	NA	NA
Producer	97	11	86	0.15	367	5.6	362	0.27
Processor	2,187	566	1,621	0.44	654	499	155	0.02
Wholesaler	727	508	220	0.07	422	295	127	0.11
Retailer	437	294	144	0.12	197	72	124	0.08
Hawkers	NA	NA	NA	NA	38	18	20	0.12
Others					101	77	24	0.03

Table 16. Revenue, costs and profits (US $) among milk traders in Tanzania

Market Agents	Dar es Salaam				Mwanza			
	Revenue per month	Costs per month	Profit		Revenue per month	Costs per month	Profit	
			Profit / month	Profit / litre			Profit / month	Profits/ litre
Coop /collection center	5,195	5,355	-160	-0.01				
Producer	149	32	117	0.22	59	5.9	52.9	0.22
Wholesaler	3,878	3,679	199	0.02				
Retailer	436	430	5.6	0.01	318	299	19	0.03
Hawkers	470	397	72	0.05	173	173	0.7	0.001
Others	467	494	-28	-0.04				

2.2.3.4 Market agent profits

Generally, the profit results suggest that milk marketing is capable of yielding substantial income to many entrepreneurs in the study areas The profit margins for vendors and retailers, most of whom are sole-proprietors, is significantly higher than the country's per capita income (Tanzania - $270 and Ghana - $290 according to World Bank figures). Returns to working capital among market agents are higher than the interest rates offered by the local banks in the country. Generally the recorded returns to working capital for cooperatives, wholesalers and vendors are adequate to allow them to accumulate and re-invest

In Ghana, among the various groups of milk sellers, the *wagashi* processors makes the highest profit in Accra while the producer makes the highest profits in Kumasi for each litre of milk sold. *Wagashi* is more widely produced product in the Kumasi zone, where many ethnic Fulani live, resulting in a lower price compared to Accra. As noted above, producer profits are revenues less estimated cost of milk production based on mean prices paid to producers by traders. In Kumasi this is the result of milk shortages allowing producers to charge higher prices. The sale of value added products such as wagashi, lekri and burkina allows processors to make bigger profits. Retailers, who may sell other goods as well, make lower nevertheless significant profits in Ghana. Retailers in Accra make a net profit of $0.12 for a litre of milk sold and retailers in Kumasi make a net profit of $0.08 from the litre of milk (Table 15). Monthly profits in Accra are higher for processors, wholesalers and retailers, the result of bigger volumes handled as discussed in section 2.2.5.

Itinerant assemblers (wholesalers) in the Kumasi zone earn a net profit of $0.11 from every litre of milk sold and the assemblers operating in the Accra zone earn a net profit of $0.07 from the litre of milk sold. Milk assembling is most profitable when procurement is done in very remote areas and sale takes place in the urban centres where high prices prevail. Where milk assembling and resale takes place within the same district, profits are quite low. In extreme cases where assemblage and resale takes place in the same village, profits are near zero as seen in the case of the assembler in the North Tongu district where the assembler earns only $0.02 from every litre of milk sold.

The average monthly and unit profits for Tanzanian milk sellers are similarly presented in Table 16 for various market agents in both Dar es Salaam and Mwanza milksheds. Producers show the highest profits per litre of milk ($0.22) in both Dar and Mwanza. They are followed by mobile agents ($0.05), wholesalers ($0.02) and retailers ($0.01) in Dar. Mobile agents have lower unit costs while wholesalers, whose monthly profits are highest at $198.53 reap benefits of bigger scale. In general unit profits are much lower in Tanzania, where the milk market is much larger, with a greater range and number of market agents, and so where competitive forces may be stronger.

Cooperatives and collection centres recorded losses in Dar es Salaam. This is explained by the high set-up and fixed costs incurred by these traders, and may point to low sustainability in collective marketing arrangements.

Overall, reasonable profits are observed in nearly all market channels and market enterprises. Excluding processors, who are engaged in significant product transformation and value addition, profits per unit LME range from a low $0.01/0.03 in the case of Tanzanian wholesalers and retailers, to relatively high returns of over $0.10 per unit in case of several groups of Ghanaian traders. In general, profits both per unit and per enterprise were found to be higher in Ghana than in Tanzania, possibly linked to the higher level of competitiveness in the latter market. With the exception of a few cases, such as hawkers in Mwanza, reasonable profits were observed for these small scale market agents, pointing at the important role of these markets in providing non-farm rural and urban incomes and employment.

2.2.4 Results of stochastic frontier analyses

This section looks at the determinants of profitability and of efficiency in profitability among milk market agents in Ghana and Tanzania. This was estimated using the stochastic profit frontier model (see section 2.1.6.1) The model is estimated in a two step process, first by estimating the level of profitability, then by estimating the determinants of variation in that profitability from a hypothetical optimal profit level. The latter step forms an estimate of efficiency and its determinants. Efficiency was found to be an important source of variation in profitability amongst the market agents in both countries, a conclusion that is shown by the significance of the parameter gamma. A significant gamma also justifies the use of the stochastic profit frontier model in analysing the determinants of profitability among the market agents.

The are two components in the results of this analysis:
- Determinants of profitability
- Determinants of inefficiency in profitability

In Table 17 below, positive coefficients indicate a positive correlation between the determinant and profitability while in Table 18 positive coefficients indicate higher inefficiency while negative coefficients mean lower inefficiency.

2.2.4.1 Determinants of Profitability

Table 19 shows the frontier model results for the first step, the determinants of profitability among Ghanaian and Tanzanian milk market agents. The profitability was positively related to value of capital depreciation (P=1%). This suggests that investment in capital equipment such as cooling tanks and processing facilities yields higher profits in both countries.

Use of metal cans by the milk agents also enhanced profitability in Ghana (P=1%) perhaps due to reduced milk spillage and spoilage. Experience from an on-going milk handling technology project in Kenya also shows that use of metal cans by informal milk agents is associated with increased milk sales because the cans are perceived by customers as neat and attractive.

Milk agents with piped water in their premises realised higher profitability (P=5%), (in Ghana) presumably due to improved cleanliness and hygiene. Hired labour was associated with increasing profitability (Ghana: P=5% and Tanzania P=1%). This shows that the marginal product of hired labour was positive for the market agents. Surprisingly, profitability increased significantly with transport cost (P=5%) in Ghana perhaps because the higher transport costs were offset by lower milk procurement prices. All of the above results show a link between higher use of inputs with higher profitability may point to higher levels of management expertise as well.

Table 17: Frontier results of the determinants of profitability among the milk market agents in Ghana and Tanzania

Variable (Determinants)	Ghana		Tanzania	
	Coeff.	Std-error	Coeff.	Std-error
Constant	9.09***	0.52	4.69***	0.51
Ln value of depreciation of capital	0.10***	0.03	0.22***	0.06
Ln number of family labourers	0.05	0.09	0.08	0.19
Ln number of hired labourers	0.17**	0.09	0.11*	0.07
Ln normalised cost of transport/litre	0.03***	0.01	0.04	0.04
Ln normalised wages	-0.01	0.07	0.11	0.08
Type of milk cans (1=metallic, 0=other)	0.33***	0.1	0.14	0.17
Piped water (0,1)	0.14**	0.08	-0.08	0.15
Sigma-squared	1.05***	0.23	1.72***	0.1
Gamma	0.94***	0.02	0.05***	0.01
Number of observations	175		429	
Number of iterations	25		49	
Log likelihood function	-83		-703	

NB: ***, **, and * indicates significance at 1%, 5% and 10% respectively

2.2.4.2 Determinants of Inefficiency in Profitability

Table 18 and Table 19 show the results of the determinants of inefficiency among the milk agents in Ghana and Tanzania, respectively. The results show that on average milk agents in Ghana were relatively more efficient (73%) than their counterparts in Tanzania (52%) given the set of technologies and prices prevailing in each of the respective two countries. By the same token, an inspection of the distribution of efficiency among the milk market agents in the two countries shows that the distribution was more skewed towards higher efficiency in Ghana than in Tanzania (Figure 5).

Table 18. Frontier results of the determinants of inefficiency among the milk market agents in Ghana

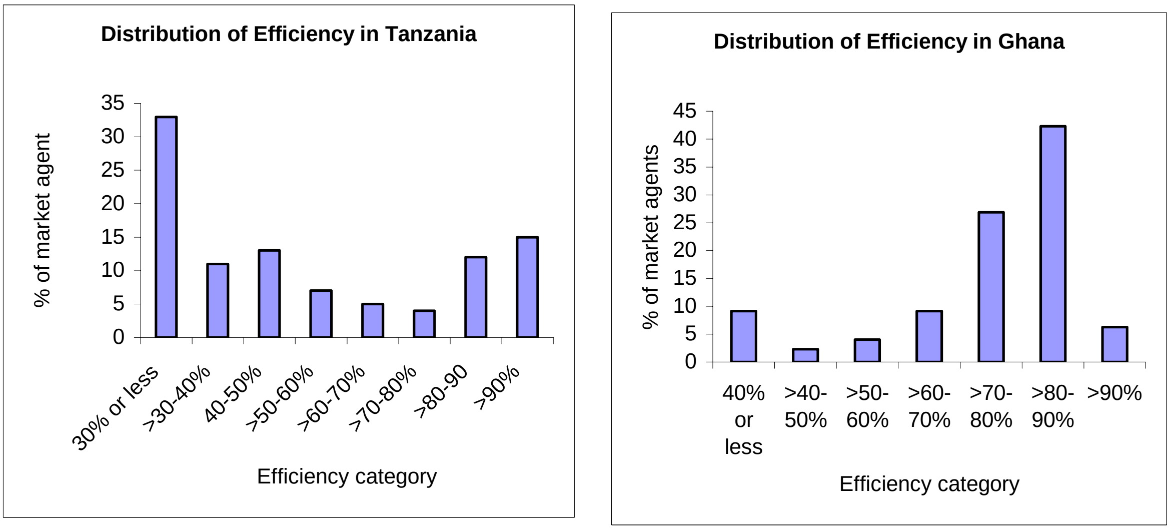
Variable category	**Variable**	**Coeff.**	**Std-error**	**t-ratio**
	Constant	-0.07	0.94	-0.07
Trader type (base of comparison=producer)	Processor (0,1)	-1.02	1.06	-0.97
	Milk retailer or a hawker (0,1)	-1.39*	1.04	-1.35
	Itinerant milk assembler (0,1)	-0.65	0.96	-0.68
	Fura seller (0,1)	-0.78	0.99	-0.79
Business location (base of comparison=rural)	Municipal location (0,1)	-0.69	0.92	-0.75
	Peri-Urban location (0,1)	-1.90**	0.91	-2.09
	Urban location (0,1)	-1.75**	0.88	-1.98
Milk source dummies (base of comparison = other farms)	Milk from processors (0,1)	-2.27**	1.2	-1.88
	Milk from other traders (0,1)	-0.33	1	-0.33
	Use of own milk (0,1)	4.33***	0.84	5.15
GIS weighted distances	Kms tarmac from source to sale areas	$0.4*10^{-7}$	$0.1*10^{-4}$	0
	Kms murram road from source to sale areas	-3.1	$0.1*10^{-3}$	-0.82
	Kms earth road from source to sale areas	$0.1*10^{-3}$	$0.1*10^{-3}$	0.9
Other agent & business characteristics	Age of trader (yrs)	-0.03*	0.03	-1.34
	Traders years of experience	-0.04	0.05	-0.85
	Gender of trader (1=Male, 0=otherwise)	-0.63	0.56	-1.12
	Personal savings used to start the business	-3.26***	0.66	-4.95
	Mean litres of milk sold per day	0.02**	0.01	2.19

Table 19. Frontier results of the determinants of inefficiency among the milk market agents in Tanzania

Variable category	Variable	Coeff.	Std. error	t-ratio
	Constant	-0.76	0.53	-1.42
Business type (base for comparison= producers)	Vender or hawker (0,1)	0.13	0.44	0.3
	Retailer (0,1)	0.36	0.42	0.86
Milk source (base for comparison= own milk)	From other farmer (0,1)	0.22	0.36	0.61
	From whole seller (0,1)	-1.15*	0.61	-1.9
	From vendors (0,1)	0.67**	0.32	2.12
Other occupations (base for comparison= retired with and without pension)	Farming (0,1)	0.24	0.37	0.67
	Employed or in other businesses (0,1)	-0.31	0.28	-1.09
	None	0.09	0.25	0.34
Other business characteristics	Used own savings to start the business (0,1)	0.95***	0.18	5.21
	Use of any milk preservation methods (0,1)	-0.33	0.25	-1.32
	Training in milk quality control and testing (0,1)	0.56	0.75	0.75
	Quantity of milk dealt with per day	0.004***	0.001	-5.85
	Distance of business premises to Dar-salaam distance/ Mwanza	0.001**	0.001	-2.44
	Procurement contract (0,1)	0.08	0.15	0.53
	Mwanza (0,1)	0.77*	0.46	1.68

***, ** and * indicates significance at 1%, 5% and 10% respectively

Figure 5: Distribution of efficiency in Tanzania and Ghana



Volumes handled: In both countries, inefficiency increased with volumes of milk handled suggesting that small-scale traders were more competent in realising higher profitability. As latter shown by results of cluster analyses (section 3.2.2.5), low milk quality was a significant problem among the large-scale milk agents in Ghana perhaps predisposing them to losses through spoilage. This is a significant finding, in that it points towards technical barriers to increased economies of scale in marketing.

Trader type and milk source: In Ghana, milk retailers and hawkers were significantly less inefficient[2] (P=5%) compared to traders selling own produced milk. This may be due to the method used to cost own-produced milk in this analysis. The traders dealing in own produced milk made profits both as producers and market agents. To enable inclusion of only that part of profits made through milk marketing, means of prices paid out to milk producers by other traders who procured milk from them were used as estimates of milk costs for the traders dealing in own produced milk.

In Tanzania, market agents who sourced their milk from wholesalers tended to be more efficient (P=10%) compared to those selling own-produced milk while those procuring from vendors were more inefficient (P=5%). Most of the traders who sourced milk from vendors were themselves also vendors, which often left very small market margins for them. The implication is that vendors who attempt to perform the role of additional intermediary in a channel where intermediaries already exist, face difficulty in managing a viable enterprise.

Age of trader: Age of the trader was found to be highly significant as a determinant of efficiency in Ghana. Older traders are more efficient, a factor attributable to the social networks created over time.

[2] 'Less inefficient' means 'more efficient' and is used despite being a little confusing because the econometric method analysed sources of inefficiency in profitability

Source of capital: The effects of credit use on inefficiency are mixed. In Ghana, traders who used personal savings to start their business were less inefficient (more efficient) than those who sought credit facilities. Since loans are informal and obtained through social networks, the cost of credit was not obtained. Traders who use informal credit may simply be poorer managers. Also, credit facilities sometimes present unique problems: timing of fund disbursement and repayments may interfere with business cash flows. Tanzanian market agents who used their own savings to start their business tended to be more inefficient (P=1%) compared to their compatriots who used credit, the reverse of the case in Ghana. It could be that own savings alone were not sufficient for optimal investments in the milk business in Tanzania, which we have seen to be more complex. In general, it may not be possible to explain the credit results, which are based on a relatively small proportion of credit users (some 10% of market agents), and are likely to be associated with other management factors.

Location and distance from urban centre: As expected, the milk agents in Tanzania were more inefficient with increasing distances from urban centres (Dar es Salaam and Mwanza towns) (P=1%). Recall that demand and consumption of milk tend to be highest in urban centres. Increasing distances from the urban centres implies reduced access to major markets, and potentially higher transactions costs as well as simply higher transport costs.

Agents in Mwanza were more inefficient than their counterparts in Dar es Salaam. Essentially, the demand, consumption and prices of milk are expected to be lower in Mwanza than in Dar es Salaam because Mwanza is a relatively smaller town. In addition the higher competition in Dar is likely to drive the least efficient agents out of the business.

In Ghana it was also evident that traders in urban and peri-urban areas were significantly less inefficient (P=5%) compared to their counterparts in the rural areas. Increased competitiveness, bigger volumes and higher prices in the urban areas are some of the possible reasons for this. There is also increased availability of nutritional, hygiene and market information in urban areas.

Training: Training in milk quality control and testing had no significant effect on inefficiency. Since none of the reported training was formal, it is likely that the trainings were inappropriate or ineffective in imparting the intended skills on the market agents. Loose enforcement of standards by government monitoring agencies may also dampen the motivation to apply strict quality control by the market agents.

In summary the results of determinants of profitability and efficiency among the milk market agents in Ghana and Tanzania show that levels of efficiency in profitability may differ across countries together with the factors determining profitability and efficiency. The role of credit seems to vary considerably, but these results are likely to be confounded with other factors such as level of management expertise. Some consistent results are nevertheless available: trader efficiency is impeded by infrastructure and distance to markets, and by increased scale. Trader efficiency is increased by age and experience, but is not apparently affected by level of training.

2.2.5 *Conclusions – market mechanisms and efficiency*

Smallholder producers and consumers have relied mainly on informal markets for raw or traditional products, and on a variety of small traders/vendors. This study further reinforces that knowledge, and clarifies the level of variability in operation and in efficiency between different types of market agents. Much of the variability can be linked to differences in supply and demand levels in particular locales, and to characteristics of different product types.

An important outlet in most cases is direct sales to neighbours, which are restricted to a locality and is usually not available in milk-surplus areas, which require that milk be moved be moved further afield to demand centres. Nevertheless, where this outlet is available, such as in Kumasi zone in Ghana and around Dar es Salaam, it provides reliable incomes and markets opportunities. Such channels may require little in the way of intervention, and are typically not included in policy measures.

Where milk is in surplus and must be moved to demand centres, the role of the traders is crucial in providing market access to small producers. The small quantities of milk they typically market daily requires the labour-intensive services of small traders, and ensures that collection using expensive transport and equipment is generally non-economic, so result in markets that rely principally on inexpensive transport, equipment and labour. Some key findings related to these traders, and policy and development implications:

- Tanzania has generally a much more complex and developed informal milk market, which is characterised by a) a greater degree of market concentration than in Ghana (at least in the case of Dar), b) more use of mechanised transport, c) longer distances for liquid milk delivery (although *wagashi* in Ghana also travels long distances), d) greater use of contracts.

- a large proportion of milk is not handled by intermediaries, but is sold directly from producer to consumer (particularly in Kumasi and Dar es Salaam), suggesting that in many cases market intermediaries are not needed.

- a great deal of transportation is by either foot or bicycle, in many market channels, demonstrating sustainable low reliance of mechanisation.

- while product differentiation is particularly important in Ghana (driven by need to convert milk to form with longer shelf life, or to add value), liquid milk remains the most important product in both countries.

- Value addition, in the form of *wagashi* making, is demonstrated to be a means of generating higher profits. The opportunities for value addition are however limited by demand for differentiated products. In Tanzania for example, where demand is currently almost all for liquid milk, shifts in demand to other products would be needed to create such opportunities.

- Written contracts between market agents are relatively rare. Tanzania, with it's more developed markets, displays greater use of informal unwritten or written contracts. In Ghana, only 20% of agents had any sort of contract, even informal, while in Tanzania some 60% of agents had some sort of agreement on transactions.

- Use of both plastic and metal containers is common in both countries. Use of better quality metal containers is however more common in Tanzania. There are clear opportunities to raise quality and food safety by increased use of metal containers.

- Milk prices are not necessarily higher in and around urban demand areas. Relatively low prices in Accra compared to Kumasi demonstrates that local supply conditions will partially determine prices, and that opportunities for producers and traders can occur even in the hinterland, where markets may not be anticipated.

- Conversely, on average more remote rural areas generally display lower prices at all levels of the market, reflecting supply/demand and transport costs in reaching demand centres.

- Cooperatives (in Tanzania) are seen to operate at a loss. This apparent lack of sustainability of operation would seem to confirm the common experiences of dairy cooperatives in many settings in Africa and South Asia. Where they suffer from un-professional management, cooperatives have been observed to be an unsustainable market mechanism. A large number of successes remain, however, and policy and development agencies should continue to search for successful collection marketing solutions as an alternative for small farmers.

- Good profits are available to market agents at several levels of the milk channels, from producer-sellers, traders and wholesalers, and retailers, most at small scale of operation. This provides a powerful argument for informal milk markets as one mechanisms for rural and urban income generation.

- There do not seem to be many instances of market agent "exploitation" of farmers and/or consumers, demonstrated by excessive profits (not market margins, which do include costs). In a few cases, such as wholesalers in Ghana, profit margins per liter of over $0.10 suggest that there may be some undue market power. Greater participation in the market would reduce that, as demonstrated by the Tanzanian examples.

- Profitability is shown to be associated with higher use of capital and hired labour, and in Ghana with use of metal cans and with greater transport costs. Overall, these suggest that increased profitability can be achieved with investment in more intensive, sophisticated enterprises, pointing at opportunities for those agents who are particularly entrepreneurial.

- Conversely, inefficiency is increased with an increase in scale of operation, which suggests that the opportunities in more intensive enterprises are limited by scale. Increased scale may require greater procurement and distribution costs per unit due to large numbers of both small producers and small consumers. Removing obstacles to increased scale of operation may be one policy goal with the aim of improving efficiency in the system overall. Currently however, these results mean that small scale operators still retain an advantage, securing income and employment opportunities for the poor.

- Training is not shown to be a significant determinant of improved efficiency. However, age of trader, reflecting experience, is shown to be very significantly associated with greater efficiency. This suggests that existing training, which is informal, does not impart the knowledge needed, which only comes with experience. This clearly points towards opportunities for improved training of market agents, which is likely to improve both efficiency and food safety.

Since formal processing of all the milk produced may not be achieved in the near future, the best option may be to improve milk-handling (milk preservation, hygiene, quality control and sanitation) techniques so as to minimise public health risks associated with informally processed. The results above point to some ways to do this: through improved training in hygiene and management, improved infrastructure to reduce transactions costs, and measures to reduce barriers to participation and increase competitiveness. More research may be needed to better understand the apparent lack of economies of scale in milk marketing using traditional technologies.

Chapter 3. Milk-Borne Public Health Risks in Dairy Product Markets

This section deals with the milk borne public health risks, and focuses on the results of laboratory testing of milk and dairy product samples, but also uses some of the economic results from Section Two in its analysis.

3.1 Research Activities

3.1.1 Approach

The approach taken to analyse milk-borne public health risks conformed to the model that became widely accepted in analysing food safety and setting standards (also applied in animal, plant and environmental health) in the early 1990s and adopted by the Codex Alimentarius Commission since 1995 (FAO/WHO, 1995). The three stages implied in this approach are: (1) risk assessment, (2) risk management and (3) risk communication. These steps emphasise the need to use appropriate measures to arrive at the overall goal of attaining optimal food safety as perceived by informed stakeholders and consumers.

To assess risk, the study quantified major milk-borne public health hazards associated with traditional/informal dairy product marketing pathways and quantified the probability and magnitude of the health risks associated with specific hazards. In addition, exposure to the hazards was assessed and the likelihood of adverse health effects estimated. The principles of the Hazard Analysis Critical Control Points (HACCP)[3] system were used as a tool and guideline. Arising from this evaluation, recommendations were made on how to manage the risks and protect human health in light of the economic trade-offs that should be considered. Stakeholder workshops were held before, during and at the end of the studies to obtain stakeholder inputs and to initiate the process of communicating the risk information. In addition, representatives of market agents and extension workers were trained at the end of the study to equip them with the new knowledge gained.

3.1.2 Data collection

Information from PRAs was used to select areas considered by key informants to have dairy marketing as an important activity within each site. In both countries, data were collected in these areas by questionnaire from randomly selected traders during the wet and dry seasons. The sampling of market agents varied by their location and type. All bulking centres (large cooperative societies and

[3] HACCP is a systematic approach to ensuring food safety that has become widely adopted in formal food processing in the last decade. Its origins date back to the early 1960's when it was first coined to ensure safe foods for astronauts. It involves five main steps to identify and assess severity of risk and control of biological, chemical and physical hazards as follows: 1) assessment of risks in the food chain, 2) determination of the critical control points (CCPs) and 3) critical limits (CL) for ensuring food safety, 4) development of monitoring systems, and 5) implementation of procedures for verification.

assemblers and wholesalers) were sampled. Smaller scale market agents, producer-sellers, vendors, retailers) were identified through local informants and sampled at a selected area (or along a route in the case of Mwanza) up to 30. For areas/routes with more than 30 milk traders, selection was made to cover all major urban/retail sites in the area. In Greater Dar, market agents were sampled in 8 areas (including Tanga and Morogoro), 5 in Mwanza, 5 in Accra and 7 in Kumasi.

Milk and dairy product random samples were obtained from the market agents in two different seasons and a 50 ml milk sample collected each time. In Ghana, 230 and 189 samples were collected in the dry and wet seasons, respectively, and in Tanzania, 561 and 715 samples were collected in the dry and wet seasons, respectively (Table 20). An attempt was made to sample the same respondents in the second season. When this was not possible, an alternate was chosen. Attempts were made to collect more than one sample per respondent where product differences warranted it.

Table 20. Number of dairy product samples collected from various cadres of market agents in each site and season

Market agents	**Dar es Salaam**		**Mwanza**		**Accra**		**Kumasi**	
	Dry	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**
Dates (month/ year)	11/99-1/00	5/00 -6/00	10/00	4/00-5/00	*3/00-6/00*	7/00-10/00	12/99-3/00	7/00 - 9/00
Cooperatives	4	8	0	0	0	0	0	0
Producers	85	65	51	56	48	50	86	67
Processors	0	0	0	0	6	4	15	14
Wholesalers	22	15	0	0	29	20	6	6
Vendors/ Mobile traders	53	44	104	118	0	0	0	0
Retailers	233	390	8	11	14	6	26	22
Total	**397**	**522**	**163**	**185**	**97**	**80**	**133**	**109**

3.1.3 Laboratory hazard analysis

A set of two sterile and non-sterile dairy product samples were collected for each product from each respondent and immediately kept in a cold box with ice for laboratory analyses. Tests requiring immediate analyses (bacterial counting, specific gravity, Brucella Milk Ring Test and peroxidase boiling test) were done in either of two sites in each country depending on proximity of the site of sampling. In Tanzania, the tests were done at either the Department of Animal Science, Sokoine University of Agriculture (SUA) in Morogoro or the Veterinary Investigation Centre (VIC) in Mwanza. In Ghana, the tests were done at either the Department of Animal Science, Kwame Nkurumah University of Science & Technology in Kumasi or at the Animal Research Institute in Achimota, Accra. Following coliform bacterial counting, samples of growing colonies were inoculated into a nutrient medium for later sub-culture in selective media and biochemical tests to identify general *E. coli* and type 0157:H7. Milk samples for use in other tests (butterfat determination, Brucella enzyme linked immunosorbent assay (ELISA), *Mycobacterium* speciation, antibiotic and antibacterial residues) were frozen and tested later. Details of laboratory analyses and flow chart are presented in Annex 1.

All inputs required for the milk-borne health risk investigations were achieved as intended except for a belated realization that a functional Mycobacterium laboratory was lacking in Ghana. This meant that the BTB study could not be conducted in that country as originally planned. A minor change also occurred in the conduct of the BTB study in Tanzania. The study was sub-contracted to investigators of a DFID-AHP sponsored project (Ref. R7357) who were already planning to do a larger investigation of the prevalence and transmission dynamics of BTB in Tanzania.

3.1.4 Data analysis

Laboratory hazard analysis results and data collected by questionnaire were entered into MS-ACCESS and MS-EXCEL and analysed in STATA. Analyses were conducted to describe sources and pathways of marketed milk and milk products; assess milk bacteriological quality; quantify the prevalence of zoonoses (*Brucella abortus, E. coli 0157:H7 and Mycobacterium bovis*); assess presence of potentially harmful levels of antimicrobial drug residues in marketed milk; assess milk handling practises by market agents; assess the influence of market factors (e.g., pathways, market concentration and profit margins) on milk quality; and, conduct a quantitative risk assessment of milk-borne public health hazards. Dar es Salaam and Accra were considered to be high market access (HMA) areas while Mwanza and Kumasi were considered to be relatively lower market access (LMA) areas. National standards set by Tanzania were used to evaluate the quality of the milk samples as no such standards were identified in Ghana.

Following the descriptive analyses including comparisons with set standards, multiple regressions were conducted on each hazard response with significant observations for the analysis. Appropriate regressions were also conducted separately for each type of dairy product if the number of observations allowed it. Ordinary least squares (OLS) were conducted on total bacteria counts, coliform bacteria counts and SNF responses while maximum likelihood logistic regression models were used to obtain odds ratios (OR) and estimate relative risks (RR) for drug residues above EU maximum residue limits (MRLs) and positive *Brucella abortus* test results. For each hazard response, tests of significance (significant p-values, OR or RR) were used to identify significant associations with site, area within site, trader type, sources and pathways of marketed milk, time, distance, milk temperature, period in business and milk handling practices. Only factors considered to be potentially important in explaining variations in each response were included as explanatory variables. Significant ($p<0.10$) risk factors were considered potential critical control points (CCPs).

In addition, multivariate analyses in SAS were conducted to identify associations among principal components and clusters of market agents, their efficiency[4] and milk quality indicators. These analyses were used to refine the CCPs along various market pathways. Only milk-handling risk factors that had significant associations with any of the milk quality indicators (total bacteria counts, coliform bacteria counts and SNF) were included in this analysis.

[4] Estimated through the Stochastic Frontier Function equation in LIMDEP

3.2 Outputs

3.2.1 Description of quality and hazards in marketed milk

3.2.1.1 Adulteration

Commonly applied indices for assessing adulteration of milk are specific gravity (SG) and butterfat content (BF). SG is the measure of choice that can easily be applied in the field to assess adulteration with added water. It is however significantly influenced by BF because the more BF in milk, the lower the SG as BF has SG<1 kg/litre. Normal ranges for SG and BF% of whole bovine milk are 1.026-1.032kg/litre at 20^{o}C, 3.25-6%, respectively. A standardized index that combines the two indices, solids-not-fat (SNF), can be derived using the Richmond Formula as follows: SNF=(0.22xBF+(0.25xSG[5])+0.72. The above ranges for SG and BF give an SNF range of 8.5-9.4%. The lower ranges of these figures were used as benchmarks for determining milk that is likely to be adulterated with added water or removal of butterfat.

The overall means of adulteration indices are given in Table 21. All the means fell within normal ranges for bovine milk though it is notable that mean BF in milk samples from Ghana was relatively lower and SNF relatively higher compared to milk samples from Tanzania. This may indicate removal of butterfat (cream) by traders because milk from zebu cows often has higher BF than milk from other bovine breeds.

Table 21: Overall means for adulteration indices

Parameter	**Tanzania**			**Ghana**			**Normal Range**
	N	Mean	SD	N	Mean	SD	
Specific gravity (kg/l) at 20^{o}C	786	1.027	0.005	344	1.030	0.003	1.026 - 1.032
Butterfat %	1206	3.65	1.44	337	3.25	0.99	3.25 - 6.0
Solids-not-fat %	749	8.31	1.32	337	8.83	1.15	8.5 – 9.5
Total solids %	749	12.04	2.12	337	12.09	1.59	11.7 – 13.5

Addition of water varied widely by site and season (Table 22). There was no apparent variation in the proportion of adulterated samples between types of market agent. Overall, 31% and 17% of fresh milk samples collected in Tanzania and Ghana, respectively, were adulterated with added water (SG<1.026kg/litre). Corresponding proportions of adulterated samples as determined by the standardised measure of SNF<8.5% were higher (49% and 37% in Tanzania and Ghana, respectively) but with less variation within the same site. Adulteration was particularly common in Mwanza where about two-thirds of market agents adulterated their milk (SNF<8.5%).

[5] The last two digits of the SG reading is used in the calculation in stead of the actual SG. i.e. 26 is used instead of 1.026

Table 22. Adulteration of milk

Country/site	Dry Season				Wet Season			
	SG<1.026 kg/lt		SNF<8.5%		SG<1.026kg/lt		SNF<8.5%	
	n	%	n	%	n	%	n	%
Tanzania								
Dar es Salaam	37	16	84	38	38	19	97	39
Mwanza	85	61	98	73	67	47	83	61
Ghana								
Accra	11	13	37	46	19	17	31	46
Kumasi	13	18	35	32	19	20	28	30

3.2.1.1. Bacteriological quality of marketed milk

Various bacteria are ordinarily found in milk, as shown in Table 23. These bacteria easily multiply under favourable temperatures to cause spoilage and/or pose health risks through bacterial infection or production of toxins. Some bacteria, such as *Staphylococcus aureus,* if allowed to multiply (normally after milk becomes sour) may produce heat labile toxins that cause illness. Time elapsed since milking and temperature at which milk is stored are the main factors that influence bacterial counts in milk. Even with very minimal contamination, bacteria in milk can multiply beyond prescribed standards within only a few hours if the milk is kept above 10^{o}C. The major milk-borne pathogens of concern are the zoonoses and environmental coliforms of faecal origin. The latter commonly get introduced in milk from poor handling at the farm and along the market pathway. Common sources of fecal bacteria are use of contaminated water and containers that have not been cleaned properly.

Table 24: Bacterial types commonly associated with bovine milk

Bacteria	Effect on milk / consumers
Lactococci*: L. lactis-diacetylactis, L. lactis, L. cremoris*	Flavour production and fermentation
Lactobacillus: *L. lactis L. bulgaricua, L. acidophilus,* *Leuconostoc lactis, Propionibacterium*	Acid production/fermentation
Pseudomonas, Bacillus cereus	Spoilage
Enterobacteriaceae	Pathogenic and spoilage
Staphylococci*: Staph. Aureus*	Pathogenic
Streptococcus*: Strep. Agalactiae,*	Pathogenic
Zoonotic Brucella abortus	Pathogenic
Zoonotic Mycobacterium bovis	Pathogenic
Coliforms (mostly introduced through poor hygiene)	Some are zoonotic and pathogenic (e.g., *E. coli* 0157:H7)
Listeria: *Listeria monocytogenes*	Pathogenic; mainly in unpasteurised cheese

Source: Adapted from O'Connor (1995)

Bacterial counts were high and variable without a clear trend in the descriptive measures as milk moved along the market chain in both countries, and in relation to different seasons, market access and trader type (**Error! Reference source not found.**). Whereas milk quality in the dry season was worse in Tanzania, the reverse was true in Ghana. However the wet season seemed to have negative effects by increasing coliform counts in both countries. While lower TPC was associated with lower market access (Mwanza and Kumasi), the reverse was true for CPC. Producer-sellers had better quality milk as determined by TPC than other traders in Tanzania, but this did not apply in Ghana.

Table 25. Geometric means of coliform (CPC) and total (TPC) plate counts in fresh milk samples and proportion above thresholds for 'good' quality milk defined by the Tanzanian Bureau of Standards..

Source of Sample	**Tanzania**					**Ghana**				
	N	CPC x 10^3	% > 50000 cfu	TPC x 10^3	% > 2M cfu	N	CPC x 10^3	% > 50000 cfu	TPC x 10^3	% > 2M cfu
Season										
Dry season	341	181	55	3,460	69	181	41	23	661	24
Wet season	363	217	58	2,380	59	152	60	27	1,000	20
Market access(site)										
High (Dar/Accra)	381	111	47	3,280	65	149	44	27	1,778	34
Low (Mwanza/ Kumasi)	323	407	67	2,420	63	185	54	23	446	12
Market chain										
Producer-sellers	208	85	61	1,700	44	231	35	20	575	19
Retailers	150	161	40	3,910	34	42	66	33	380	5
Ready to consume products			% > 1 cfu					% > 1 cfu		
Boiled warm	171	<1	64	-	-	-	-		-	-
Boiled cool/chilled	191	<1	30	-	-	85	178	100	-	-
Fermented / Wagashe	181	2	25	-	-	28	31	100	-	-

Bacterial counts and proportions not meeting set standards in Ghana were generally lower but the reasons are not clear. One possible reason may be the relative proportions of the types of traders and where they were sampled: the majority of samples collected in Ghana (78%) were from producer-sellers and the samples were collected at or near their kraals; while in Tanzania, producer-sellers were only 20% of traders and these were mainly sampled at collection points that were some distance from the points of milking. Of major significance is the fact that a high proportion of samples did not meet set standards for coliform counts for ready to consume milk products (heat-treated and fermented/processed) in both countries. This implies recontamination by environmental bacteria after boiling occasioned by lack of good hygiene and emphasises the need for training on hygienic handling of milk prior to and after processing. It is important to note that though recontamination by environmental bacteria seems common after boiling, the risks from major milk-borne zoonoses such as brucellosis are eliminated by the heat treatment.

3.2.1.2. Milk-borne zoonoses

a) Brucellosis

Brucellosis is endemic in pastoral areas of Africa with herd prevalence proportions of 20-30% (Seifert et al., 1996). The major reason for concern over Brucellosis is the debilitating flu-like illness that it causes. *Brucella abortus*, the main pathogen of concern, was tested using two surrogate tests for antibodies to *Br. abortus*, Milk Ring Test and ELISA. The latter is more accurate with higher sensitivity and specificity.

High prevalence proportions of Brucellosis ranging from 13% to 39% were recorded in various sites by the two tests (Table 26). Both tests had moderate agreement in Tanzania (*kappa*=0.38) to high agreement in Ghana (*kappa*=0.84). In Tanzania, higher prevalence was recorded in milk procured from farmers keeping extensively grazed zebu animals that crossbred dairy cattle that are usually kept in smaller herds and sometimes stall-fed. Also in Tanzania, samples obtained from traders who bulked milk such as cooperatives and wholesalers had higher prevalence. However, in Ghana, there was no discernible pattern in prevalence proportions in milk sampled from various cadres of traders. These results show that on average, a consumer who does not boil milk before consumption is at risk of exposure and contracting *Br. abortus* infection every fourth time such milk is consumed or put differently, one in every five consumers who consume milk which is not boiled before consumption is at risk of exposure and contracting *Br. abortus* infection.

Table 26. Numbers and proportions of samples positive on Brucella Milk Ring Test and ELISA .

Country/site	**Dry Season**				**Wet Season**			
	MRT		ELISA		MRT		ELISA	
	n	%	n	%	n	%	n	%
Tanzania								
Dar es Salaam	142	38	89	21	97	37	47	19
Mwanza	18	17	15	13	26	15	46	31
Ghana								
Accra	28	38	21	28	24	39	18	29
Kumasi	24	27	21	23	20	25	17	22

b) *E. coli* 0157:H7

E. coli 157:H7 is a causative agent for haemorrhagic diarrhoea and kidney damage, especially in young and old individuals with weak immune systems. The strain is highly acknowledged as an important animal origin food-borne zoonosis. In both countries, less than 1% of samples yielded *E. coli* 157:H7 (Table 27). This prevalence proportion would imply that a consumer of marketed milk on a daily basis is at risk of exposure to *E. coli* 0157:H7 bacteria at least three times each year. Fortunately this exposure would not translate into an infection if the milk were boiled before consumption, a common practice amongst consumers in both countries.

Table 27. Numbers and proportion of samples (% of coliform positive) screened for *E. coli* and isolation and of strain 0157:H7

Test Details	**Dar**		**Mwanza**		**Accra**		**Kumasi**	
	n	%	n	%	n	%	n	%
Examined for coliforms	383	-	239	-	170	-	250	-
Positive for *E. coli*	69	18	43	18	51	30	50	20
Suspect *E. coli* 0157:H7 on BCM medium	2	<1	1	<1	1	<1	2	<1

c) Bovine TB

M. bovis has been previously reported to be endemic in herds in some focal areas in Tanzania and Ghana (e.g., Kazwala et al. 1998, Bonsu 1998). Results from Tanzania show that out of 641 samples analysed for *Mycobacteria*, 64 (10%) were positive for general mycobacterium species but none yielded *M. bovis*. The atypical Mycobacteria obtained are common in the environment (e.g., soil) and therefore not necessarily of animal origin. Likewise, there was no *M. bovis* isolated from some 40 milk sub-samples from Ghana. Results from the study on human samples obtained from Mwanza that was sub-contracted to investigators in another DFID project in Tanzania (Ref. No. R7357) were still awaited at the time of compiling this report.

3.2.1.3. Antimicrobial (antibiotic and antibacterial) drug residues

The reason for concerns over drug residues in foods has to do with the development of drug resistance and allergies. By killing all but the most potent bacteria strains, antimicrobial abuse promotes drug resistance by putting selective pressure on microbial evolution and helps create 'superbugs' that are immune to attack by common, less expensive antibiotics. Besides adverse health effects, such abuse has long-term implications for health budgets of nations, especially poor countries such as Ghana and Tanzania. Antibiotics and antibacterials in milk also inhibit organisms required in the processing of cultured milk products.

Between 33% and 42 % of the milk collected from various sites in Tanzania and Ghana were positive on Charm AIM test. Though no major overall seasonal variation was observed in samples testing positive for drug residues within each site, seasonal variation was observed among traders in Dar es Salaam milk shed area and a higher proportion of samples (40-60%) testing positive were from those who bulk milk (coops, wholesalers and vendors/hawkers) especially in the dry season. To explain the difference, it was observed that most milk traded by vendors and collection centres is procured from the pastoralists who in most cases do not adhere to withdrawal period for therapeutic drugs, and bulking of these samples does not dilute the concentration of the residues to below acceptable limits. This indicates that the levels of the residues may be quite high. This observation was supported by the higher proportion of samples (40%) from pastoralist producer-sellers in Tanzania that had residues compared to individual dairy farmers with crossbred cattle (33%). Part of the reason for the difference was also considered to be the greater access to information and awareness by keepers of dairy cattle about veterinary requirements of milk withdrawal periods as compared to pastoralists.

There was no significant variation in milk samples with drug residues between the two seasons in Mwanza but a relatively large proportion of samples (42%) collected from producers had drug residues. In Ghana, the proportions of samples from various cadres of traders with drug residues also varied widely from 20% in samples from wholesalers to 48% in samples from *wagashi* sellers.

Table 28. Numbers and proportions of samples positive on Charm AIM Test for antibiotic and antibacterial residues.

Country/site	Dry Season		Wet Season	
	n	%	n	%
Tanzania				
Dar es Salaam	88	35	151	34
Mwanza	59	42	57	38
Ghana				
Accra	32	38	24	33
Kumasi	39	35	37	39

3.2.2 Description of milk handling and quality related market variables

3.2.2.1. Milk market pathways

The most common milk market pathway (31% of traded milk) in Tanzania was milk sales from dairy cattle owners to retailers (Table 29). Nearly all sales along this pathway (77%) were in Dar where intra-urban dairying with crossbred cattle is common. The next most common pathway was from zebu cattle farmers to vendors/hawkers that accounted for 27% of all sales. Most sales along this pathway (69%) were made in Mwanza. In Ghana, most sales (68%) were by producer-sellers who were distantly followed by herdsmen (22%) who mostly sold their milk to wholesalers or assemblers, as they are commonly known in Ghana. All pathways with 10 or more observations were considered important and included in subsequent regression analyses.

Table 29. Milk market pathways in Tanzania

Trader	**Source of milk**						
	Zebu cattle	Dairy cattle	Coop/ Farmer group	Wholesalers	Vendors/ Hawkers	Own farm	**Total (%)**
Coop/Farmer group	1	1	3	1	6	0	12(1)
Producer-sellers	**75**	**59**	0	3	**12**	**88**	**237(20)**
Wholesalers	7	8	0	**10**	5	0	**30(3)**
Vendors/ hawkers	**181**	**13**	0	2	**91**	**11**	**298(25)**
Retailers	**60**	**286**	7	**118**	**74**	**61**	**606(51)**
Total (%)	**324(27)**	**367(31)**	10(1)	**134(11)**	**188(16)**	**160(14)**	**1,183(100)**

NB. Significant pathways with ≥10 observations are in bold text.

Table 30. Milk market pathways in Ghana

Market Agent	Source of milk						
	Stockowner	Herdsman	Processor	Farmer group	Own farm	Mobile trader	Total (%)
Producer-sellers	0		2	1	**235**	0	**238 (62)**
Processor	1	**15**	3	2	**12**	0	**33 (9)**
Wholesaler	0	**41**	3	3	5	1	**53 (14)**
Retailer	0	**28**	6	**16**	7	2	**59 (15)**
Total (%)	1 (0.3)	**84 (22)**	14 (4)	**22 (6)**	**259 (68)**	3 (1)	**383 (100)**

NB. Significant pathways with ≥10 observations are bolded

3.2.2.2. Milk handling practices

Overall, 58% of traders in Tanzania did not use any form of quality control prior to milk procurement (refer to Annex 2). A higher proportion of traders in Dar es Salaam (70%) did not use the measures compared to Mwanza (44%). The most commonly used methods of quality control were visual and use of a lactometer to measure the level of adulteration with added water. Visual check was the major quality control measure among producers and vendors/hawkers and retailers in Dar es Salaam. Lactometer use was particularly common in Mwanza where virtually every vendor and retailer possessed one. The main reason behind this is because it is a requirement by Mwanza Municipal health authorities. However, this did not deter widespread adulteration of milk once the traders were within the urban area as shown by the specific gravity test results that indicate over 50% of samples were adulterated with added water. The market agents admitted to adding water to their milk after passing the designated checkpoints mounted by the Municipal authorities. In Ghana, quality tests were uncommon. Only organoleptic tests were reported in a few cases (Annex 2).

Non-metal (mainly plastic) containers were the most common in Tanzania where 83% of market agents used them. The rest used aluminium cans. A much higher proportion (56%) of traders in Mwanza used the cans compared to Dar where only 6% of respondents used them. Nearly all the aluminium cans in were manually fabricated from disused vehicles body parts and they had several joints that may not be easy to clean. It is therefore not surprising that the average total bacterial quality of milk associated with them was only marginally better (coliform bacterial quality was actually worse). Handling containers used in Ghana were also predominantly plastic with virtually all respondents (99%) using them.

The high perishability of milk requires that some measures be taken to prevent it from souring. In Tanzania, the majority of respondents (76%) did not take any of the common measures to preserve milk between procurement and resale. Those who preserved milk mainly refrigerated it. Similarly, most traders in Ghana (77%) did not preserve milk in any way. Those who preserved milk mainly boiled it.

3.2.2.3. Training

Training in quality control and milk testing is critical to ensuring good milk quality. In Tanzania, only 5% of respondents had received any training, mostly for less than one month.

In Ghana, none of the respondents had received any training. None of the marketing agents interviewed in Ghana had received formal training in milk handling and processing. All respondents interviewed said they had inherited the art from other family members or from friends. Majority of the traders were found lacking in knowledge on hygienic milk handling and basic business management principles.

3.2.2.4. Regression analyses

The regressions (Table 31 and Table 32) show some similarities and differences between each country, market access and production systems for each of the milk quality responses. These associations together with the following results of the principal component and clustering analysis were used to identify critical control points.

Table 31. OLS regression of risk factors associated with liquid milk quality in Tanzania[6]

Parameter	Total bacteria		Coliforms		Solids-not-fat	
	Raw	Heated	Raw	Heated	Raw	Heated
	N=222 R^2=0.51	N=56 R^2=0.92	N=223 R^2=0.32	N=57 R^2=0.73	N=345 R^2=0.56	N=79 R^2=0.29
Study strata						
DAR VS MWANZA [c– –]			– – –	NT	+ + +	NT
Dry vs wet season[b+ c+]		+ +		+ +	– – –	
Quality measures						
LOG TPC	NT	NT	NT	NT		
Log CPC	+ + +		NT	NT	– – –	
SNF			– – –		NT	NT
Market pathways vs Dairy cattle - Retailer						
ZEBU CATTLE - PRODUCERS[A]		+ +		+		– –
Dairy cattle - Producer[a]	+ + +	NT	– – –	NT		NT
Vendors - Producers[a]		NT		NT		NT
Own farm - Producers[a]	NT	NT	NT	NT		NT
Wholesaler - Wholesaler		NT		NT		NT
Zebu cattle – Vendor		NT		NT		
Dairy cattle – Vendor		NT		NT		NT
Vendor – Vendor[b-]		NT		NT	– – –	NT
Own farm - Vendor		NT	NT	NT		NT
Zebu cattle – Retailer						
Wholesaler - Retailer		+ +				
Vendor - Retailer	NT			–		
Own farm – Retailer		NT	NT	NT		
Handling containers vs Plastic						
GLASS BOTTLE	NT	NT		NT	NT	NT
Aluminium can					NT	NT
Cup or glass		– – –			NT	NT
Polythene					NT	NT
Others					NT	NT
Method of cleaning vs using hot water & soap						
COLD WATER & SOAP		–			NT	NT
Cold or hot water & soap					NT	NT

NT= not tested because variable not considered relevant or dropped due to collinearlity or too few observations

Arithmetic signs and their number represent the strength of positive or negative association: Strong (P<0.01) = + + + or – – –; Medium (P<0.05) = + + or – – ; Weak (P<0.1) = + or –.

[a] Producers = producer sellers. Pathways involving producer-sellers sourcing milk from farms (zebu cattle, dairy cattle or own) mostly sold their own milk and some purchased milk in some cases.

[b+] and [b–]: Associated with drug residues in raw milk at the strength represented by the arithmetic signs

[c+] and [c– –]: Associated with *Br. abortus* antibodies in raw milk at the strength represented by the arithmetic signs

[6] The third major product sold in Tanzania, fermented milk, was not subjected to bacterial counting. There were no significant associations between the presence of *Br. abortus* antibodies and any of the risk factors tested.

Table 32. (cont'd). OLS regression of risk factors associated with liquid milk quality in Tanzania[7]

Parameter	**Total bacteria**		**Coliforms**		**Solids-not-fat**	
	Raw	Heated	Raw	Heated	Raw	Boiled
	N=222 R^2=0.51	N=56 R^2=0.92	N=223 R^2=0.32	N=57 R^2=0.73	N=345 R^2=0.56	N=79 R^2=0.29
Source of water vs Pipe						
RIVER					NT	NT
Community pump					NT	NT
Private pump/well					NT	NT
Other					NT	NT
Preservation method vs none						
Boil					NT	NT
REFRIGERATION			+ +		NT	NT
Other method		+ + +			NT	NT
Place of container storage vs shelf/Table						
Refrigerator					NT	NT
Bucket indoors					NT	NT
Bucket outdoors		– –			NT	NT
Floor		– –		– –	NT	NT
Other					NT	NT
Weather vs hot/dry						
Hot/wet		– – –			NT	NT
Cold/wet		NT			NT	NT
Cold/dry		– –		+ +	NT	NT
Quality control vs none						
Lactometer		NT				
Smell	+ +			+ +		
Visual		–				
Match Stick		NT	NT			
Alcohol test		NT	– –			
Other risk factors						
Training received		– –				
Milk kept separate after receiving						
Male gender	– –	+				
Age		– – –				
Hours since collection	**+ +**					
Amount sold per day	+					
Maximum number of sources of milk						
Profit Margin (TSh/l)						

NT= not tested because variable not considered relevant or dropped due to collinearlity or too few observations
Arithmetic signs and their number represent the strength of positive or negative association:
Strong ($P<0.01$) = + + + or – – –; Medium ($P<0.05$) = + + or – – ; Weak ($P<0.1$) = + or –.

[7] The third major product sold in Tanzania, fermented milk, was not subjected to bacterial counting. Logistic regression tests between the various risk factors and the presence of *Br. abortus* antibodies in liquid milk did not yield any significant associations.

Table 33. OLS regression of risk factors associated with liquid milk quality in Ghana[8]

Parameter	Total bacteria (N=250; R^2=0.30)	Coliforms (N=251; R^2=0.18)	Solids-not-fat (N=278; R^2=0.13)
Study strata			
Accra vs Kumasi			– –
Dry vs wet season			
Quality measures			
Total bacteria	NT	NT	– – –
Coliform bacteria	**+ + +**	NT	**+ + +**
Solids-not-fat	– – –	**+ + +**	NT
Peroxidase test positive			NT
Market pathways vs Farm_Producer (own milk)			
Herdsman_Processor [a++]	+ +		
Herdsman_Wholesaler		**+ + +**	– –
Herdsman_Retailer			
Farm_Processor			
Milk handling (use vs no-use)			
Sponge	– – –		NT
Plastic container		**+ +**	NT
Soap			NT
Cold water			NT
Boils milk	NT	NT	NT
Water source vs piped water			
Community ground pump			NT
Private ground pump water			NT
Other source of water			NT
Community dam	+ +		NT
Water from tanker	+		NT
Other factors			
Male vs female			
Age			
Bulked milk			
Refrigeration	NT	NT	NT
Milk sale volume			
Number bulked [a–]			
Time since collection(hrs)			
Profit margin (Cedis/lt)			
Amount of milk left			
Perod in business (mths)			

NT= not tested because variable not considered relevant or dropped due to collinearlity or too few observations
Arithmetic signs and their number represent the strength of positive or negative association:
Strong (P<0.01) = + + + or – – –; Medium (P<0.05) = + + or – – ; Weak (P<0.1) = + or –.
[a++] and [a–] : Associated with drug residues at the strength represented by the arithmetic sign

[8] The number of observations for other milk products was low and could not be regressed.

Milk handling and market factors associated (p<0.1) with indicators of milk quality (TPC, CPC and SNF) in the regression tables were included in principal component analysis. All pathways with 10 or more observations were included regardless of their level of association with milk quality indicators. The means of variables included in the analysis are in Table 34 and Table 35.

Table 34. Means of variables available for principal component and cluster analysis in Tanzania

Variable	Tanzania - Raw Milk Mean (n=346)	SD	Tanzania - Heated Milk Mean (n=226)	SD
Study strata				
High market access (Dar)	0.58	0.50	0.94	0.22
Dry season	0.53	0.50	0.34	0.47
Quality measures				
Log of Total Plate Counts	6.65	1.03	6.34	0.84
Log of Coliform Plate counts	5.29	1.27	4.80	1.11
Solids-not-fat (SNF)	7.99	1.39		
Market pathways				
Dairy cattle – Retailer	0.06	0.24	0.38	0.49
Zebu cattle – Producers	0.09	0.28	0.03	0.17
Dairy cattle – Producer	0.03	0.18	-	-
Vendors – Producers	0.02	0.13	-	-
Vendor – Vendor	0.14	0.35	-	-
Zebu cattle – Retailer	0.03	0.16	0.06	0.24
Wholesaler – Retailer	0.01	0.09	0.18	0.38
Vendor – Retailer	0.03	0.16	0.10	0.30
Milk handling				
Quality control by smell	0.01	0.11	0.03	0.17
Quality control by visual check	-	-	0.09	0.29
Containers cleaned with soap	-	-	0.52	0.50
Hot and wet weather	-	-	0.18	0.39
Cold and dry weather	-	-	0.52	0.50
Male gender	0.83	0.38	0.55	0.50
Other covariates				
Time since collection (hrs)	1.57	3.30	-	-
Amount sold per day (lts)	62.93	152.87	-	-
Efficiency (%)	0.68	0.23	0.86	0.20

Table 35. Means of variables available for principal component and cluster analysis in Ghana

	Ghana - Raw Milk Mean (n=246)	SD
Study stratum		
High market access (Accra)	0.45	0.50
Quality measures		
Log of Total Plate Counts	5.98	1.40
Log of Coliform Plate Counts	3.60	1.23
Solids-not-fat (SNF)	8.78	0.91
Market pathways		
Own Producer seller	0.72	0.45
Herdsman - Processor	0.01	0.11
Herdsman – Wholesaler	0.15	0.36
Herdsman – Retailer	0.03	0.18
Own Farm – Processor	0.01	0.11
Milk handling		
Plastic container	0.91	0.29
Cleaning with hot water	0.30	0.46
Use of community dam water	0.02	0.14
Use of water from tanker	0.21	0.41
Efficiency (%)	0.80	0.16

3.2.2.5. Principal component analysis of milk quality

These variables were included in principal component analysis following the method described by Gockowski and Baker (1996) by selecting those eigenvalues with principal components greater than one. The eigenvalues correspond to each of the principal components and represent a partitioning of the total variation in the sample of market agents. Since the associated eigenvectors are orthogonal, the principal components represent jointly perpendicular directions through the space of the original variables and are uncorrelated with each other. The selected principal components were rotated through varimax rotation option to improve interpretability.[9]

[9] The rotated principal components are also uncorrelated after an orthogonal transformation.

Table 36. Principal components associated with quality of raw and heated milk in Tanzania.

Principal Component	**Eigenvalues >1**		**Proportion of total variation**		**Cumulative proportion of total variation**	
	Raw	Heated	Raw	Heated	Raw	Heated
1	3.10	2.43	0.17	0.15	0.17	0.15
2	1.67	1.66	0.09	0.10	0.27	0.26
3	1.20	1.59	0.07	0.10	0.33	0.36
4	1.13	1.49	0.09	0.09	0.39	0.45
5	1.12	1.37	0.06	0.09	0.46	0.53
6	1.07	1.25	0.06	0.08	0.52	0.61
7	1.04	1.04	0.06	0.07	0.57	0.68
8	1.02	1.00	0.06	0.06	0.63	0.74
9	1.02	<1	0.06	<1	0.69	<1

Table 37. Principal components associated with quality of raw milk in Ghana.

Principal Component	**Eigenvalue**	**Proportion of total variation**	**Cumulative proportion of total variation**
1.00	2.45	0.17	0.17
2.00	1.87	0.13	0.31
3.00	1.32	0.09	0.40
4.00	1.30	0.09	0.50
5.00	1.13	0.08	0.58

The selected principal components (PC) with eigenvalues greater than one together explain 69%, 74% and of total variation for market selling raw and heated milk in Tanzania, respectively, and 58% for market agents selling raw milk in Ghana. In all three cases, the strongest principal component explains between 15% and 17% of total variation. The low proportional values illustrate the lack of close association between the individual variables or sets of variables.

The orthogonal rotated correlation coefficients of the original variables are shown in Table 38. The coefficients with weights >0.5 were used to define the axes extracted.

Table 38. Results of the principal component analysis of raw milk in Tanzania showing weights of first eight axes extracted following varimax rotation[a]

Factor	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**	**F8**	**F9**
Variable	EFFIC	LMQ	NOINT1	VENDINT1	NOINT2	PSDC	WHOLINT	VENDINT2	SMELLTST
Study strata									
High market access	0.80	-	-	-	-	-	-	-	-
Dry season	-	-	-	-0.56	-	-	-	-	-
Quality measures									
Log of Total PC	-	0.77	-	-	-	-	-	-	-
Log of Coliform PC	-	0.74	-	-	-	-	-	-	-
Solids-not-fat (SNF)	0.70	-	-	-	-	-	-	-	-
Market pathways									
Dairy cattle - Retailers	-	-	0.92	-	-	-	-	-	-
Zebu cattle Producers	--	-	-	-	-	-0.59	-	-	-
Dairy cattle - Producer	-	-	-	-	-	0.76	-	-	-
Vendors – Producers	-	-	-	-	-	-	-	0.95	-
Vendor – Vendor	-0.63	-	-	-	-	-	-	-	-
Zebu cattle – Retailer	-	-	-	-	0.91	-		-	-
Wholesaler - Retailer	-	-	-	-	-	-	0.87	-	-
Vendor – Retailer	-	-	-	0.71	-	-	-	-	-
Milk handling									
Quality control by smell	-	-	-	-	-	-	-	-	0.93
Quality control by visual check	-	-	-	-	-	-	-	-	-
Containers cleaned with soap	-	-	-	-	-	-	-	-	-
Hot and wet weather	-	-	-	-	-	-	-	-	-
Cold and dry weather	-	-	-	-	-	-	-	-	-
Male gender	-	-	-	-	-	-	-	-	-
Other covariates									
Time since collection (hrs)	-	-	-	0.51	-	-	-	-	-
Amount sold per day (lts)	0.50	0.50	-	-	-	-	-	-	-
Efficiency (%)	0.80	-	-	-	-	-	-	-	-

[a] Only Weights >0.5 or <0.5 are presented and corresponding variables used to define respective axes

Key:

EFFIC: Efficient

LMQ: Low Milk Quality

NOINT1: No intermediary1

VENDINT1: Vendor Intermediary1

NOINT2: No intermediary1

PSDC: Producer-seller – dairy cattle

WHOLINT: Wholesaler intermediary

VENDINT2: Vendor Intermediary2

SMELLTST: Smell test done

The first axis extracted in the PC analysis of raw milk samples in Tanzania (Table 39) is abbreviated EFFIC because it is highly correlated with efficiency, high market access (sales in Dar), SNF, non vendor-to-vendor milk sales and moderately high volumes of milk sales. The second axis (LMQ) is highly correlated with both high total bacterial and coliform counts, indicating general poor quality of the milk, and high sales volumes. The remaining axes mainly define specific pathways and the use of a quality control test (smell). The vendor-retailer was moderately associated with long duration since milk collection.

Table 39. Results of the principal component analysis of heated milk in Tanzania showing weights of first seven axes extracted following varimax rotation[a]

Factor	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**	**F8**
Variable	**DRYHOT**	**EFFIC**	**HMA**	**NOINT1**	**LMQ**	**SMELLTST**	**PSDC**	**NOINT2**
Study strata								
High market access	-	-	0.82	-	-	-	-	-
Dry season	0.89	-	-	-	-	-	-	-
Quality measures								
Log of Total PC	-	-	-	-	0.83	-	-	-
Log of Coliform PC	-	-	-	-	0.77	-	-	-
Solids-not-fat (SNF)	-	-	-	-	-	-	-	-
Market pathways								
Dairy cattle - Retailers	-	-	-	0.85	-	-	-	-
Zebu cattle - Producers	-	-	-	-	-	-	0.87	-
Dairy cattle – Producer	-	-	-	-	-	-	-	-
Vendors – Producers	-	-	-	-	-	-	-	-
Vendor – Vendor	-	-	-	-	-	-	-	-
Zebu cattle – Retailer	-	-	-	-	-	-	-	0.87
Wholesaler – Retailer	-	-	-	-	-	-	-	-
Vendor – Retailer	-	-0.74	-	-	-	-	-	-
Milk handling								
Quality control by smell	-	-	-	-	-	0.74	-	-
Quality control by visual check	-	-	-	-	-	-	-	-
Containers cleaned with soap	-	-	-	-	-	0.67	-	-
Hot and wet weather	-	-	-0.74	-	-	-	-	-
Cold and dry weather	-0.86	-	-	-	-	-	-	-
Male gender	-	-	-	-0.50	-	-	-	-
Other covariates								
Time since collection (hrs)	-	-	-	-	-	-	-	-
Amount sold per day (lts)	-	-	-	-	-	-	-	-
Efficiency (%)	-	0.80	-	-	-	-	-	-

[a] Only Weights >0.5 or <0.5 are presented and corresponding variables used to define respective axes

Key:

DRYHOT: Dry season/ hot weather
NOINT1: No intermediary1
PSDC: Producer-seller - dairy cattle
EFFIC: Efficient
LMQ: Low Milk Quality
NOINT2: No intermediary2
HMA: High market access
SMELLTST: Smell test done

The first axis extracted in the PC analysis of heated milk samples in Tanzania (Table 42) is abbreviated DRYHOT because it is highly correlated with dry season when it is also usually hot. The second axis, abbreviated EFFIC, is highly correlated with efficiency and pathways that do not involve vendors to retailers. The third axis, abbreviated HMA, is highly correlated with sales in Dar and negatively correlated with hot and wet weather. The remaining axes define specific pathways except for the fifth axis (LMQ) that highly correlated with both high total bacterial and coliform counts, and the sixth axis that is correlated with the use of a quality control test (smell).

Table 40. Results of the principal component analysis of raw milk in Ghana showing weights of first seven axes extracted following varimax rotation[a]

Factor	F1	F2	F3	F4	F5
Variable	**EFFIC**	**HMA**	**LMQ**	**PSP**	**HERDHS**
Study stratum					
HMA	-	0.82	-	-	-
Quality measures					
Log of Total Plate Counts	-	-	-	-	-
Log of Coliform Plate counts	-	-	0.55	-	-
Solids-not-fat (SNF)	-	-	-	-	0.50
Market pathways					
Own Producer seller	-0.83				
Herdsman - Processor	-	-	-	-	0.80
Herdsman – Wholesaler	0.81	-	-	-	-
Herdsman – Retailer	-	-	-0.62	-	-
Own Farm – Processor	-	-	-	0.80	-
Milk handling					
Plastic container	-	-	0.56	-	-
Cleaning with hot water	-	-	-	-	-
Use of community dam-water	-	-	-	0.72	-
Use of water from tanker	-	0.72	-	-	-
Efficiency (%)	0.56	-	-	-	-

[a] Only Weights >0.5 or <0.5 are presented and corresponding variables used to define respective axes

Key:

EFFIC: Efficient
HMA: High market access
LMQ: Low Milk Quality
PSP: Producer-seller to processor
HERDHS: Herdsman's milk with high solids

Similar to the PCs identified in Tanzania, efficiency, abbreviated EFFIC, is one of the first axes extracted from the variables in Ghana (Table 43). The axis is also highly associated with the herdsman to wholesaler pathway and negatively associated with sale of own milk (own producer seller). The second axis extracted is highly associated with sales in Accra that represent relatively high market access (HMA) compared to sales in Kumasi. This axis is also associated with use of water from tanks (roof water). The third axis defines low milk quality due to association with high coliform counts. This axis is also associated with use of plastic containers and negatively correlated with herdsman to retailer pathway. The other two axes mainly relate to producer-seller to processor and herdsman to processor pathways, respectively. The latter is also correlated with high solids in milk indicating non-adulteration.

Clustering analysis

The FASTCLUS procedure in SAS was then used to assign a cluster to each observation to try to find homogenous groupings of market agents and pathways. The procedure employs a standard iterative algorithm for minimising the sum of squared distances from the cluster means. Each observation is assigned to only one cluster. Several clusters were investigated and two to three clusters finally chosen to differentiate the observations along the various axes selected for the different product types (Table 41). The variables have mean 0 and variance 1. Positive means indicate levels higher than the overall sample means and vice versa for negative means.

Table 41. Clustering of 346 market agents selling raw milk in Tanzania using new variables

Cluster	Freq	Means									(Litres sold/day)	ACRONYM
		EFFIC	**LMQ**	**NOINT1**	**VENDINT1**	**NOINT2**	**PSDC**	**WHOLINT**	**VENDINT2**	**SMELLTST**		
1	329	-0.11	-0.11	0.03	0.00	0.06	0.04	-0.04	0.00	0.03	31.9	**SSNQ**
2	17	**1.97**	**2.12**	-0.50	0.11	-1.06	**-0.75**	**0.66**	-0.1	**-0.65**	683.2	**LSEFFPQ**

NB. Relatively significant mean values in respective axes are bolded

Key:

EFFIC: Efficient
LMQ: Low Milk Quality
NOINT1: No intermediary1
VENDINT1: Vendor Intermediary1
NOINT2: No intermediary1
PSDC: Producer-seller – dairy cattle
WHOLINT: Wholesaler intermediary
VENDINT2: Vendor Intermediary2
SMELLTST: Smell test done

Two clusters were identified among market agents selling raw milk in Tanzania (Table 41). The first cluster comprises 95% (329/346) of market agents who sell small quantities of milk averaging 32 litres/day and is neutral with regard to milk quality, efficiency and other axes extracted in the principal component analysis. This group is abbreviated here as small-scale neutral quality (SSNQ). The other group comprises only 5% (17/346) of milk market agents, mainly wholesalers selling larger volumes of milk (683 litres/day) who are also more efficient. This group however suffers from lower quality of milk and is abbreviated as large-scale efficient poor quality (LSEFFPQ). It therefore seems that traders who expand their businesses to sell more milk risk more losses through milk spoilage due to bacterial growth and this may be a hindrance to the expansion of the businesses and may partly explain why the majority continue to be small scale.

Table 42. Clustering of 226 market agents selling heated milk in Tanzania using new variables

Cluster	Freq	Means								(Litres sold/ day)	ACRONYM
		DRYHOT	**EFFIC**	**HMA**	**NOINT 1**	**LMQ**	**SMELLTST**	**PSDC**	**NOINT 2**		
1	79	**-0.35**	0.08	0.06	-0.07	**0.90**	-0.15	0.00	-0.06	39.9	**SSPQ**
2	37	-0.07	-0.15	-0.25	0.05	**-1.51**	-0.09	-0.07	-0.27	60.0	**LSGQ**
3	110	0.28	-0.01	0.04	0.04	-0.14	0.13	0.03	0.13	37.6	**SSNQ**

NB. Relatively significant mean values in respective axes are bolded

Key:

DRYHOT: Dry season/ hot weather
EFFIC: Efficient
HMA: High market access
NOINT1: No intermediary1
LMQ: Low Milk Quality
SMELLTST: Smell test done
PSDC: Producer-seller - dairy cattle
NOINT2: No intermediary2

Three clusters were identified among market agents selling heated milk in Tanzania (Table 42). In contrast to raw milk traders, the clusters identified are more sharply divided by levels of milk quality sold and less so on the basis of scale of business (range = 38 – 60 litres/day) and efficiency. The group that sells the worst quality milk comprised 35% (79/226) of milk market agents that sell about 40 litres/day on average (abbreviated small scale poor quality (SSPQ)) and the group selling relatively better quality milk comprised 16% (37/226) of traders selling little more milk (60 litres/day). The cluster is abbreviated here large-scale good quality (LSGQ). A larger group of smaller traders comprising 49% of the agents is largely neutral with regard to all factors considered. It is abbreviated here small-scale neutral quality (SSNQ).

Table 43. Clustering of 246 market agents selling raw milk in Ghana using new variables

		Means					(Litres sold/ day)	ACRONYM
Cluster	Freq	EFFIC	HMA	LMQ	PSP	HERDHS		
1	43	**0.94**	**0.56**	**0.92**	-0.27	-0.13	45.0	**LSEFFPQ**
2	67	-0.03	**-0.46**	0.22	-0.16	**0.68**	15.7	**SSNQ**
3	136	-0.28	0.05	**-0.40**	0.17	-0.30	20.2	**SSGQ**

NB. Relatively significant mean values in respective axes are bolded

Key:

EFFIC: Efficient
HMA: High market access
LMQ: Low Milk Quality
PSP: Producer-seller to processor
HERDHS: Herdsman's milk with high solids

In Ghana, all the three factors of efficiency, market access and milk quality (coliform counts) are important in differentiating the three clusters identified among market agents selling raw milk (Table 44). The first cluster comprising 17% (43/246) of traders is associated with relatively higher volumes of milk sales (45 litres/day) higher efficiency, high market access (Accra) and low milk quality and is abbreviated as **LSEFFPQ.** The second cluster comprises 27% of traders (67/246) that sell only 16 litres/day on average. The cluster is also negatively associated with high market access and mainly comprises milk sales on a particular pathway from herdsmen to processors and high solids in milk (non-adulteration). It is abbreviated here **small-scale neutral quality (SSNQ).** The last group comprises the remaining 55% of traders that also sell small quantities (20 litres/day) but have relatively better quality milk. It is abbreviated here as **LSGQ.**

Table 44 and Table 45 give the means and proportions of milk quality and market variables for each of the five clusters identified. Some large differences with regard to the factors used to isolate the clusters are evident; particularly differences (within and between product types) in milk quality, volumes traded and market access.

Overall trends between the product types indicate that poorer quality raw milk was associated with high market access (Dar and Accra), higher volumes of sales and high efficiency. This indicates some trade-off between market access, scale of business and efficiency on one hand and efficiency on the other hand. This was however not the case with heated milk (only analyzed for Tanzania). It is also noteworthy that the groups associated with poor quality milk in Tanzania (both raw and heated milk) were also associated with a high proportion of adulterated milk. Since the relationships with time since collection were not clearly established, the relatively poor quality milk among some clusters most likely relates to poor handling practices, which however cannot be easily specified because of generally similar practices among the traders. Though bacterial counts were significantly lower among heated milk samples, it does seem that marked recontamination does occur. However, as noted earlier, risks from zoonoses are still eliminated by boiling.

Table 44. Means and proportions of milk quality and market handling variables for clusters identified in Tanzania.

Type of milk product	Raw		Heated		
Cluster No.	1	2	1	2	3
Relative scale of business within product type	Small	Large	Small	Large	Small
Abbreviation	SSNQ	LSEFFPQ	SSPQ	LSGQ	SSNQ
Number of market agents	328	17	79	37	110
Study strata					
High market access (%)	55.3	100.0	94.9	89.2	96.4
Dry season (%)	53.5	35.3	17.7	35.1	44.6
Quality measures					
TPC (geometric mean) $x10^3$	3,981	19,953	6,310	79	3,162
% 'Bad milk' (>2,000 x 10^3 cfu)	69.3	94.1	87.3	0.0	65.4
CPC (geometric mean) $x10^3$	200	1,585	1,000	8	20
% 'Bad milk' (>50x10^3 cfu)	27.9	64.7	27.9	0.0	0.0
Solids-not-fat (SNF) %	7.9	9.4	9.2	8.6	9.2
% SNF <8.5%	38.3	94.1	82.6	50.0	75.7
Market pathways					
With intermediaries	47.9	0.0	41.1	44.8	32.9
Without intermediaries	52.1	100.0	58.9	55.2	67.1
Milk handling					
Quality control by smell	1.2	0.0	0.0	2.7	5.5
Quality control by visual check	-	-	10.1	16.2	6.4
Containers cleaned with soap	-	-	46.8	54.1	55.5
Hot and wet weather	-	-	12.7	24.3	20.0
Cold and dry weather	-	-	70.9	55.0	40.0
Male gender	83.9	58.8	53.2	64.9	53.6
Other covariates					
Time since collection (hrs)	1.6	0.4	0.8	0.3	1.0
Amount sold per day (lts)	30.9	683.2	39.9	60.0	37.6
Profit margin (Tz Sh/month)	25,951	-1,122,419	236,378	-163,070	221,344
Profit efficiency	0.53	0.89	0.73	0.70	0.74

Table 45. Means and proportions of milk quality and market handling variables for clusters identified in Ghana

Type of milk product		Raw	
Cluster No.	1	2	3
Relative scale of business	Large	Small	Small
Abbreviation	LSEFFPQ	SSNQ	SSGQ
Number of market agents	43	67	136
Study stratum			
HMA	69.8	29.9	48.5
Quality measures			
TPC (geometric mean) $x10^3$	316,228	251	316
% 'Bad milk' (>2,000 x 10^3 cfu)	100.0	6.0	8.8
CPC (geometric mean) $x10^3$	40	50	1
% 'Bad milk' (>50x10^3 cfu)	44.2	49.2	0
Solids-not-fat (SNF) %	8.5	9.3	8.6
% SNF <8.5%	51.2	80.6	53.7
Market pathways			
Own Producer seller	51.2	68.7	80.2
Herdsman - Processor	0.0	4.5	0.0
Herdsman – Wholesaler	39.5	11.9	9.6
Herdsman – Retailer	0.0	6.0	2.9
Own Farm – Processor	0.0	1.5	1.5
Milk handling			
Plastic container	95.4	91.0	89.7
Cleaning with hot water	32.6	38.8	25.7
Use of community dam water	4.7	0.0	2.2
Use of water from tanker	27.9	14.9	21.3
Other covariates			
Amount sold per day (lts)	45.0	15.7	20.2
Profit margin (Cedis/month)	486,046	342,983	361,991
Profit efficiency (%)	0.79	0.77	0.68

3.2.3 Identification of critical control points

The results of the regression and multivariate analyses and the descriptive analyses in the preceding sections were used to identify critical control points (CCPs) associated with specific risk factors of handling and market channels. These may be taken as indicative of areas where interventions to improve milk quality may be targeted. Plausible explanations for the CCPs are given where possible.

CCPs for Total Plate Counts

The regression analysis shows that the study sites (and the difference in market access and production systems that they represent) did not significantly influence total bacterial counts in raw milk. The only pathway associated with significantly higher total bacteria (compared to dairy cattle-to-retailer pathway) was from dairy cattle-to-producers sellers in Tanzania. In Ghana the only pathway associated with significantly higher total bacteria (compared to sales of own milk) was the herdsman-to-processor pathway. The specific milk handing practices that significantly raised total bacteria in raw milk were a) in Tanzania: quality control by smell (probably because the milk was already suspect); female gender, longer hours since milking and higher quantities of milk sold; and b) in Ghana: non use of sponge for cleaning utensils, use of water from community dam and tanks.

A significant proportion of milk sold in Tanzania was heated/boiled and could be subjected to regression analysis of milk quality indicators. There was some seasonal effect with the dry season being significantly associated with higher total bacteria than the wet season. Two pathways were associated with significantly higher total bacteria compared to dairy cattle to retailer pathway: the zebu cattle to producer sellers and wholesaler-to-retailer pathways. Handling methods that had significant raised total bacteria in heated milk compared to various alternative handling methods were plastic containers, container storage on shelves/table, hot and dry weather, lack of training, male gender, and lower age.

The clustering analysis and means for each cluster reveal that larger scale market agents in both Tanzania and Ghana sold raw milk with higher average total bacterial counts (hence poorest quality) and proportion of 'bad milk' than other clusters of smaller scale market agents.

CCPs for Coliforms Counts

As was evident in the descriptive statistics, raw milk from Mwanza had significantly higher coliform counts compared to Dar. This reflects poor hygiene standards. Higher SNF (indicating non-adulteration) lowered coliform counts in samples from Tanzania whereas the opposite effect was observed in Ghana. This difference cannot be easily explained but is probably related to the quality of the water being used by traders to adulterate milk. Milk passing through the dairy cattle-to-retailer pathway had significantly more coliform counts than milk passing through dairy cattle-to-producer pathway in Tanzania, while in Ghana, the two pathway with significantly higher coliforms compared to own milk sales was the herdsman-to-wholesaler pathway. The positive association between refrigeration of milk and higher coliform counts in Tanzania (practice not recorded in Ghana) is contrary to expectation, but may reflect the storage of milk that has already been handled un-hygienically. The association that is easier to explain is that between non-use of alcohol test to check milk quality before reception and higher coliform counts. The alcohol test is simple and reliable and allows one to avoid buying suspect milk that can get spoilt quickly. This practice was also not recorded in Ghana.

The effect of season was similar for total bacteria and for coliforms in heated milk. Dry season was significantly associated with higher coliform counts compared to the wet season. One pathway, the zebu cattle-to-producer sellers had milk with significantly higher coliform counts compared to dairy cattle-to-retailer pathway, which in turn had significantly higher coliform counts than milk passing through the vendor-to-retailer pathway. Handling methods that had significant raised coliform counts in heated milk compared to various alternative handling methods were storage place of containers on the shelf/table versus floor; cold/dry versus hot/dry weather; and, quality control by smell versus no quality control.

In contrast with Ghana where there were no significant differences in coliform counts between clusters of raw milk traders, in Tanzania, the larger scale market agents sold raw milk with significantly higher average coliform counts and higher proportion of ‘bad milk’ than other clusters of smaller scale market agents.

CCPs for Adulteration

There were strong associations between adulteration of milk and site and season, especially in Tanzania. Milk samples from Mwanza were strongly associated with lower SNF (indicating adulteration with added water), especially in the dry season. This may indicate the tendency to add water to milk during periods of low milk supply and probably higher prices. In Ghana, Accra was associated with milk with lower SNF. The association between bacterial counts and SNF in milk were mixed: whereas higher total bacteria counts were not significantly associated with SNF in Tanzania, there was a strong positive association in Ghana. And whereas higher coliform counts were negatively associated with SNF in Tanzania, the reverse was true in Ghana. There were few associations between SNF and the various pathways in both countries. In Tanzania, only milk ferried through the vendor-to-vendor pathway had significantly lower SNF compared to the dairy cattle-to-retailer pathway for sales of raw milk; and only the zebu cattle-to-producer sellers pathway significantly lower SNF compared to the dairy cattle to retailer pathway for sales of heated milk. In Ghana, only the herdsman-to-processor pathway had milk with significantly lower SNF than own milk sales. The clustering analysis shows that nearly all the milk sold by larger scale traders in Tanzania was adulterated.

CCPs for Antimicrobial residues

As already noted in the descriptive statistics above, the prevalence proportions of antibiotic and antibacterial residues were very high in both countries. The overall drug residue prevalence proportions of over 30% indicate that that a consumer of locally produced milk will be exposed to the residues every third time he /she consumes milk. Table A1 shows it would be very easy to go beyond the acceptable daily intake (ADI) for the various drugs. There were only minor but significant differences in the prevalence of samples with drug residues between sites and seasons in Tanzania. In Ghana, the herdsman-to-processor pathway had significantly proportion of samples with residues compared to own milk sales and the lower the number of bulked samples, the higher the prevalence of drug residues. The critical control point for beginning to tackle this problem is to raise awareness amongst policy makers besides conducting farm-level studies to define causal relationships as a basis for designing targeted extension materials.

CCPs for Brucellosis

Likewise, the prevalence of *Br. abortus* antibodies as detected by the ELISA test was quite high and evenly distributed among most risk factors. There were some differences by site and season in Tanzania with Mwanza having significantly more milk samples with the antibodies compared to samples from Dar, especially in the dry season. Emphasis for control for Brucellosis should be in raising consumer awareness to boil milk before consumption.

3.2.4 Conclusions - milk-borne public health risks

These recommendations are made based on both the health risk assessments described here and the recommendations of stakeholders gathered in both countries in March 2002 to discuss the research results and recommendations for interventions.

1. The overall bacterial quality of marketed milk was quite low irrespective of the scale of business. Poorer quality milk was found to be associated with unhygienic handling practices that do not promote good milk quality such as adulteration and non-use of milk quality control tests, indicating that there is big room for improvement. The overall poor quality of milk may be partly explained by the near absence of trained milk handlers in both countries (only 5% were trained in Tanzania and none in Ghana). The lack of training may therefore be considered the most critical control point. There is therefore the urgent need to institute a) simple and practical training courses in quality control and the hygienic handling of milk for milk handlers and b) set up institutions for longer term training to act as a back-up for extension services. Stakeholders mentioned community development centers such as "Folk Centres" and the vocational Training (VETA) Centres in Tanzania as ideal for institutionalizing the simple training programmes.

2. The high prevalence of samples with antimicrobial drug residues that imply every third cup of milk consumed (whether raw or heat pasteurised) has unacceptable levels of the residues is a major cause for concern. The long-term implications for widespread development of drug resistance among the poor populations in both countries (and other countries in similar circumstances) may be grave. Two recommendations to begin to address this problem are: a) creation of more awareness among policy makers and b) further research to more clearly define the problem and how it can be addressed, especially at the farm level where non-compliance regarding withdrawal times following drug therapy is likely to be a major cause.

3. Antibodies to Brucellosis were also common, especially in bulked milk samples originating from extensive cattle systems. Since milk-borne zoonotic pathogens are easily destroyed by heat, the common consumer practice of boiling of milk before consumption should be reinforced through public education and media campaigns. In addition, market agents and consumers should be educated to ensure that any milk product offered for direct consumption has been heated before hand. The latter especially applies to consumption of fermented milk products since fermentation alone does not destroy the pathogens.

4. The enforcement of health regulations to improve the quality of marketed milk such as those mounted in Mwanza by municipal authorities is clearly not working. It is therefore clear that such efforts should be complemented or

replaced by alternative methods of ensuring good milk quality. It is recommended that an approach that would encourage compliance is for market agents to be trained as recommended in 1) above, coupled with public intervention with incentives to promote self-regulation.

5. The use of cooling facilities to reduce bacterial growth and spoilage was uncommon. There is need therefore to identify alternative practical and affordable technologies to reduce bacterial growth, such as the Lactoperoxidase Milk Preservation system, and to promote such technologies in areas where they can make a difference.

Chapter 4. Processing of Traditional Dairy Products

This section covers the analysis of processing of the traditional fresh cheese, *wagashi*, in Ghana.

4.1 Research activities

4.1.1 Data gathering methods

Three complementary methods were used for gathering the data needed to conduct the analysis. These included a rapid appraisal of cheese processors, a structured survey of cheese processors, and laboratory experiments and analysis of alternative wagashi processing strategies.

4.1.2 *Rapid appraisal of cheese processors in the Kumasi peri-urban area*

A rapid appraisal was undertaken in the peri-urban areas of Kumasi and Accra during April-June 1999 to examine the constraints to dairy product marketing and processing.

The objectives of this appraisal were to:
Characterise dairy production and marketing systems

- To examine the constraints to dairy product marketing and processing
- To provide baseline information for the design and conduct of a formal marketing survey

Participatory Rapid Appraisals (PRAs) were conducted with cattle owners, herdsmen and other people representing producers, dairy products marketing agents (including processors) and consumers. Non-standardised interviews, group discussions and field observations were combined in order to obtain information in two peri-urban zones (Kumasi and Accra). There were 12 and 7 study sites in the Kumasi and Accra peri-urban areas respectively. Other interviews were undertaken with key informants who were considered to be knowledgeable about dairy products marketing and processing. Not all of these respondents were living in Kumasi or Accra peri-urban locations. Itinerant traders for example, cover large distances carrying dairy products (mostly wagashi cheese) to markets. For the study, purposive sampling (as opposed to probability sampling) was used to facilitate the inclusion of important milk producing and consuming areas.

Dairy processors were asked to describe the seasonality of their activities, the level of dairy product procurement and sales, prices, main sources, distances to sources, outlet markets, transaction costs, processing techniques and equipment and main constraints.

4.1.3 Survey of cheese processors

To complement the rapid appraisal, a questionnaire survey was designed to generate further information about production processes and constraints prior to laboratory tests to establish the efficacy of local production techniques for *wagashi*. Thirty-three cheese processors, all female, were interviewed in five locations in the Ashanti Region, the majority of respondents were located in the peri-urban areas of Kumasi. The results can be found in section 4.2.

4.1.4 Laboratory experiments

Following the PRA and survey of processors, laboratory evaluation of *wagashi* processing was undertaken to examine:

- the optimum quantities of coagulant (rennet) required
- ways of increasing the yield of cheese
- methods for extending shelf-life.

4.1.5 The use of Calotropis Procera *(Sodom's Apple) as a coagulating agent*

The sap extracted from Calatropis Procera (also known as Sodom's Apple) contains a coagulant with an action similar to rennet and is the preferred coagulating agent used by *wagashi* producers in Ghana.

Scientists are aware of the many uses of this extract of *C. procera.* In addition to its rennet properties it has medicinal uses as an antiseptic, an aphrodisiac and as a poison to kill animals. During this research it became apparent that Ghanaian processors use different quantities of coagulant. Laboratory experiments were therefore designed to investigate the optimum quantity for maximum yields of *wagashi* production.

4.1.5.1 Research on increasing yields

A simple experiment was designed to examine the effect of introducing cheesecloth to the production process during the separation of curds and whey. Traditional processors use perforated calabashes for this separation and it was observed in the field that small fragments of curd passed through the calabash and were wasted.

4.1.5.2 Research on extending shelf-life

During the course of this research it became evident that the main constraint to marketing *wagashi* was the short-shelf-life (high perishability) of the product. Due to the lack of any simple and appropriate technology processors resort to daily boiling.

Laboratory research examined the efficacy of extending the shelf-life of *wagashi* by immersing newly made cheese in brine. Brining is known and practised by *wara* processors in Benin and Nigeria, but hardly known by processors in Ghana, though about 20% of the processors use small quantities of salt during frying of *wagashi*.

A laboratory experiment was undertaken on the use of brine at three levels of concentration (5%, 10% and 15%). *Wagashi* was prepared in the normal way and one kilogram of cheese was soaked in these concentrations overnight (approximately 12hours). The cheese were removed from the brine and pressed for about 20 minutes and stored at room temperature for 12-14 days. Immersion in brine was repeated on the third day.

A second experiment compared the effect of boiling and brining (10%). *Wagashi* was prepared in the normal way and one sample subjected to daily boiling, the second sample to brining (overnight or 12 hours) on days 1, 3, 6, and 9. The third sample was a control and not subjected to any preservation. Each sample was stored at room temperature for a period of 10 days. Physical changes in the appearance, odour and texture were recorded.

4.1.5.3. Consumer acceptance of brined wagashi

Laboratory experiments determined that brined *wagashi* had a longer shelf-life to other forms of preservation. Consumer acceptance of the brined product was therefore essential before this procedure could be extended to processors. *Wagashi* was prepared in the normal way and stored in different levels of brine concentrations at 5%, 10% and 15% overnight. The product was then removed and stored at room temperature for three days.

Wagashi samples at each brine concentrations were cut into small pieces and fried using fresh cooking oil following normal practice observed in Kumasi market. Each fried piece of *wagashi* was wrapped in aluminium foil and labelled A [5%], B [10%], and C [15%] brine).

A total of 102 panelists were presented with the three samples and they were invited to choose one at random (blind tasting) in Kumasi, Ejura and Mampong districts in locations where *wagashi* is commonly sold. After tasting, the panelists was offered a piece of bread to clear the palate before tasting another sample. They were then asked to rank the products in terms of which *wagashi* was preferred for taste, texture etc. Panelists were also asked to comment on the freshness of the product. The responses were recorded and entered into a database.

4.1.6 Activities to deliver outputs

4.1.6.1 Training of trainers

Following the results obtained from the consumer acceptance study, one-day training sessions were organised in four locations for the *wagashi* processors. A total of 51 *wagashi* processors, market agents and retailers in Ejura, Nsuta, Mampong and Kumasi peri-urban areas participated in the training sessions along with 2 representatives of the agricultural extension service.

Demonstrations were made of the various steps in processing including:

-the correct quantity of *Calotropis procera* (coagulant) to use
-how to improve yield of cheese by using cheesecloth (muslin)
-producing cheese in a hygienic environment
-prolonging the shelf life of cheese using a 10% brine solution
-increasing returns to *wagashi* production.

An *ex ante* analysis following training was undertaken (after 6 months) to assess the adoption rate of recommended practices.

4.1.6.2. Assessing profitability and cost of production

Making use of the data generated by the dry and wet season economic and public health surveys the costs of production for *wagashi* were calculated.

4.1.6.3 The drafting and production of extension literature

Following all research and training activities a simple extension leaflet was drafted and printed.

4.2 Outputs

The project log frame stipulated 2 outputs for the research related to processing. Those included:

- Output 5. Consumer preferences for dairy products identified
- Output 6. Simple, cost-effective and energy efficient technologies for processing and prolonging shelf-life of dairy products devised and adapted.

4.2.1 Results of the rapid appraisal

The appraisal concluded that:

- Most herdsmen prefer to sell fresh milk direct to consumers or market agents at the kraal
- Kraal sales do not require any investment in marketing (transport, containers etc)
- Farmgate milk prices are relatively high ($0.3/litre compared with $0.2 in East Africa)
- During periods of oversupply milk is converted to *wagashi*
- *Wagashi* is marketed exclusively by women, often the wives of herdsmen
- There is both a national and international trade in *wagashi*, although the majority of consumers are northern Ghanaians located in Kumasi and Accra. *Wagashi* also moves from the Accra zone to the neighbouring Republic of Togo.
- There are no formal contractual arrangements between suppliers, market agents or consumers of dairy products.

Major marketing constraints identified include:

- The short shelf life of fresh milk and *wagashi*

- Some transport owners refuse to carry *wagashi* (odour and wet product)
- Poor access to capital and credit by *wagashi* processors and high costs of production
- The seasonal nature of *wagashi* processing
- Variability in the quality of *wagashi* (KNUST, 1999)

4.2.2 Survey of cheese processors, Ashanti Region

Thirty-three cheese processors, all female, were interviewed in five locations in the Ashanti Region, the majority of respondents were located in the peri-urban areas of Kumasi.

4.2.2.1 Wagashi production

Approximately half (48%) of processors interviewed were small-scale producers, using less than fifteen litres of milk per day. The majority had no formal training in milk processing and had learnt their trade from family members.

Table 46. *Wagashi* processing centres and scale of operations in the Kumasi Zone

Location	**Frequency**	**Percent**
Ejisu	5	15.2
Ejura	12	36.4
KMA	5	15.2
Mampong	9	27.3
Nsuta	2	6.1
Scale of Operation (day)		
Large (>30 litres)	6	18.2
Medium (15-30 litres)	11	33.3
Small (< 15 litres)	16	48.5
Training source		
Family	26	78.2
Formal	2	6.1
Self-tuition	5	15.2

All processors receive milk for *wagashi* production before 10am. None use lactometers to test for adulteration and the majority subject the milk to a visual inspection only. Most attempt to process the milk within one hour of purchase. More than 90% of milk is processed within 4 hours of purchase .

Table 47. Milk delivery time, quality assessment and storage duration before processing

Item	Frequency	Percent
Time milk received		
7:00 AM	9	28.1
8:00 AM	6	18.8
9:00 AM	11	34.4
10:00 AM	6	18.7
Quality test used		
Clot on boil test	7	21.2
Visual assessment	26	78.8
Duration of storage before processing		
Immediately	1	3.0
1 hr	21	63.6
2 hr	3	9.1
3 hr	3	9.1
4 hr	2	6.1
>4hr	3	9.1

4.2.2.2 *Processing and preservation methods*

The majority of processors (87%) use firewood as their fuel source for boiling/heating the milk. The only other fuel used is charcoal. No processors have dedicated premises and use their domestic kitchen or process the cheese outside over an open fire (if weather conditions permit)

Table 48. Fuel sources, place of processing and quantity of coagulants used.

Item	Frequency	Percent
Energy Source:		
Firewood	29	87.9
Charcoal	4	12.2
Where processed		
Indoors	4	12.2
Outdoors	29	87.9
Coagulant used:		
Calotropis procera	33	100.0
Age of leaves/bark:		
Young	3	9.1
Old	23	69.7
Both	7	21.2
Quantity of coagulant used/litre		
< 3leaves	1	3.0
4 leaves	4	12.1
5 leaves	5	15.2
6 leaves	7	21.2
7 leaves	5	15.2
more leaves	11	33.3

All processors use the locally available *Calatropis procera* as a coagulant for *wagashi* production. The older leaves are preferred to young leaves or bark as the best source of active ingredient. The actual quantity of coagulant used per litre of milk varies enormously between processors. The optimum amount was not known and was therefore considered worthy of further laboratory investigation.

Some processors use certain additives for both aesthetic reasons and to improve preservation/shelf-life. A dye is used to colour the cheese once the curds have formed (Table 49). A red dye is extracted from sorghum sheath by boiling with the cheese. Some processors believe that sorghum sheath has both aesthetic and preservative qualities.

Table 49. Preservation methods used

Item	Frequency	Percent
Additives		
Dye	16	57.1%
Salt	7	25.0%
None	5	17.9%
Purpose of Additive		
Aesthetic	15	55.6%
Preservative	10	37.0%
Taste	1	3.7%
Acid coagulation	1	3.7%
Type of dye		
Sorghum sheath	23	92.0%
Others	2	8.0%
Salting		
Yes	15	45.5%
No	18	54.5%
Method of salting		
During coagulation	14	93.3%
On rind	1	6.7%
Ratio of salt to milk		
10g:4lit	11	73.3%
10g:3lit	3	20.0%
10g:2lit	1	6.7%
Pressing of cheese		
Yes	4	12.1%
No	29	87.9%
Method of pressing		
Own weight in mould	22	84.6%
Putting weight	4	15.4%
Length of pressing		
>4hrs	9	100.0%

Salt is used as an additive by 45% of processors. In more than 90% of cases this is added during the production of curds, during coagulation of the milk. It is not clear what the purpose of this additive is but given the low concentrations it is likely to have an impact on the taste of the cheese rather than preservation. The highest concentration used was 5g/litre of milk ().

Only 4 out of 30 processors reported pressing curds, adding weights to the curds to expel moisture (excess whey). Most processors simply allow the curds to drain under their own weight in calabash moulds. Pressing is limited to 4 hours only, to ensure that the cheese retains the desired characteristics, which the market demands (i.e. soft cheese).

Less than 10% of processors report regular failure of their milk to coagulate Most failures are preventable as they are associated with over heating (boiling over) of the milk. This information suggests that there is little adulteration of milk, processors are skilled in *wagashi* production, milk is usually processed within the optimum period following purchase and that the coagulant has effective rennet properties.

Table 50. Respondent assessment of processing failure.

Item	Frequency	Percent
Does processing fail		
Yes	30	90.9
No	3	9.1
Reasons for failure		
Milk boils over	26	86.7
Others	4	13.3
Other reasons for failure		
Colostrum used	9	34.6
Adulteration of milk	6	23.1
Milk kept long before processing	11	42.3
Frequency of failure		
Seldom	22	73.3
1in 4 batch	4	13.3
1 in 10 batch	4	13.3
Prevention of failure		
Colostrum	6	24
Check for dilution of milk	5	20
Process immediately	14	56

4.2.2.3 Extending shelf-life

The most common means of extending shelf-life of *wagashi* is boiling the cheese (in water) on a daily basis until sold. This method is used by 60% of processors (). The addition of salt is also used by about 20% of the sample interviewed, but in very small quantities (), usually during the processing procedure. Only 1 out of 30 processors had access to refrigeration. One processor reported using other (unidentified) herbs as a preservative. Two processors reported using drying as a preservation technique. Cheese is air or sun dried or fried to expel moisture and extend shelf-life. Visits to Kumasi market confirmed that one of the most popular products purchased by consumers is fried cheese. Frying produces a drier, harder product that is consumed as a snack or added to cooked dishes as an alternative to meat. Dyeing also takes place at the final point of sale (prior to frying). *Wagashi* is therefore fried prior to sale and as some processors also sell directly to local consumers they probably fry to satisfy this market.

Table 51. Methods of extending shelf life of *wagashi*

Item	Frequency	Percent
Methods for prolonging shelf-life		
Daily boiling	20	60.6
Salting	7	21.2
Drying	2	6.1
Dyeing	2	6.1
In fridge	1	3.1
Other herbs	1	3.1

Most processors (66%) store their cheese before sale in covered (with a cloth or plastic) aluminium bowls or basins. Plastic bags are used in a small number of cases, mostly as a means of storage rather than as packaging. These methods of storage are used to minimise contamination and for their ease of use. Containers and packages used are all locally available.

Table 52. Storage and packaging

Item	Frequency	Percent
Type of packaging		
Polythene-bag	2	6.1
Covered metal bowl	22	66.7
Uncovered metal bowl	2	6.1
Plastic container	7	21.2
Reasons for choice of container		
Prevent contamination	18	54.6
Easy transportation	7	21.2
Convenience	8	24.2

4.2.2.4 Consumer preferences

The majority of processors (66%) report that their customers, both wholesalers and consumers, prefer the fresh undyed *wagashi*. About one quarter of the sample (27%) produce a fresh, dyed product.

Table 53. Consumer preferences (processors responses)

Item	Frequency	Percentage
Consumer preferences		
Fresh undyed	22	66.7
Fresh dyed	9	27.3
Fried undyed	2	6.1

4.2.2.5 Discussion

The survey confirmed that the production methods used by small-scale processors in the Kumasi peri-urban zone are similar to those reported in the literature available on *wagashi* production in West Africa (Kees, 1995). Discussions with processors following the completion of the questionnaire and subsequently (informal discussions were held with processors on several occasions during the year 2000) established that their major constraints were associated with:

- Shortages of milk during the dry season
- The time required and cost (firewood and labour) for preservation (daily boiling)
- Low prices and poor returns (profits)

Poor demand was not reported as a constraint, suggesting that there is a market for most of the cheese that is produced, in fact some processors pointed out that more could be sold during the dry season if more milk were available at this time. Some processors have herdsmen as husbands and reported that they prefer to market fresh milk, as the returns are higher. Processing is therefore used as a method of preserving excess milk by these households rather than as a means of adding value. The processor who purchases milk on a daily basis is however a specialist cheesemaker providing cheese for the peri-urban consumer in both Kumasi and Accra.

The survey confirmed the need to investigate an optimum processing procedure, in particular the amount of coagulant required. Another issue that arose was the importance of devising methods of improving shelf-life and reducing spoilage to improve the quality of the product that processors and wholesalers deliver to the market and to ensure the delivery of a safe, fresh product for consumers.

Laboratory analyses

Laboratory analyses were undertaken to determine:

- The optimum quantities of vegetable rennet required to form *wagashi*
- Optimising yield by use of cheesecloth
- Extending shelf-lfe using brine
- The effects of boiling and brining on shelf-life

Experimental data were subjected to analysis of variance technique (ANOVA) using SPSS version 8.0 (1997) software. Fisher's protected least significant difference test was used to compare paired means, and difference between means were considered significant at $P<0.05$.

A comparison of the coagulation efficiency of the leaves and stems of *Calotropis procera* in '*Wagashi*' production.

The objectives of this experiment were to:

- Determine the correct quantities of coagulant required for optimum yield of cheese
- Determine the pH, time and temperature at which coagulation occurs
- Determine crude protein and dry matter content of cheese
- Compare the efficiency of the leaves and stem of *Calotropis procera* in terms of yield of cheese

Procedure

The leaves and stems of the shrub *Calotropis procera,* also called 'Apple of Sodom' (Figure 6), traditionally used by *wagashi* processors were used as the coagulant. The tender leaves and stems of the plant were washed and ground. Ten grams (10g) of the ground plant was added to 50ml of strained milk. The mixture was stirred and allowed to stand for 5 to 10 minutes. The plant material was then removed using a cheesecloth. The extract obtained was referred to as the stock solution.

Several concentrations of the stock solution were prepared. The process was repeated using 15g into 75ml of milk, 30g into 150ml of milk and 45g into 225ml of milk for both leaves and stems. L1, L2, L3, and L4 represented 10g/50ml, 15g/75ml, 30g/150ml and 45g/225ml of the leaves portion whiles T1, T2, T3 and T4 represented 10g/50ml, 15g/75ml, 30g/150ml and 45g/225ml of the stem portion. A summary of the cheese production process is illustrated in .

Figure 6: Calotropis procera ('Apple of Sodom') plant

One litre of fresh milk was measured into an aluminium container. This was heated to a temperature of 55^{o}C. The stock solution, 10g/50ml, was then added to the heated milk (one litre) to give a concentration of 9.5 g leaves or stem per litre of milk (9.5g/*l*). It was stirred and the preparation further heated until coagulation occurred. This procedure was repeated using all stock solutions indicated above resulting in the following concentrations for both leaves and stems; 10g/50ml, [9.5g/*l*]; 15g/75ml, [14g/*l*]; 30g/150ml, [26g/*l*]; and 45g/225ml, [38g/*l*].

In all, there were eight treatments and three replicates resulting in 24 experimental units. The pH of the fresh milk, the temperature at which the stock was added, the time taken to coagulate and the final temperature at which coagulation occurred were measured. Yield of *wagashi* was measured as the weight of curd obtained in grams per litre of milk used for the coagulation. Cheese samples were taken for dry matter and crude protein determination.

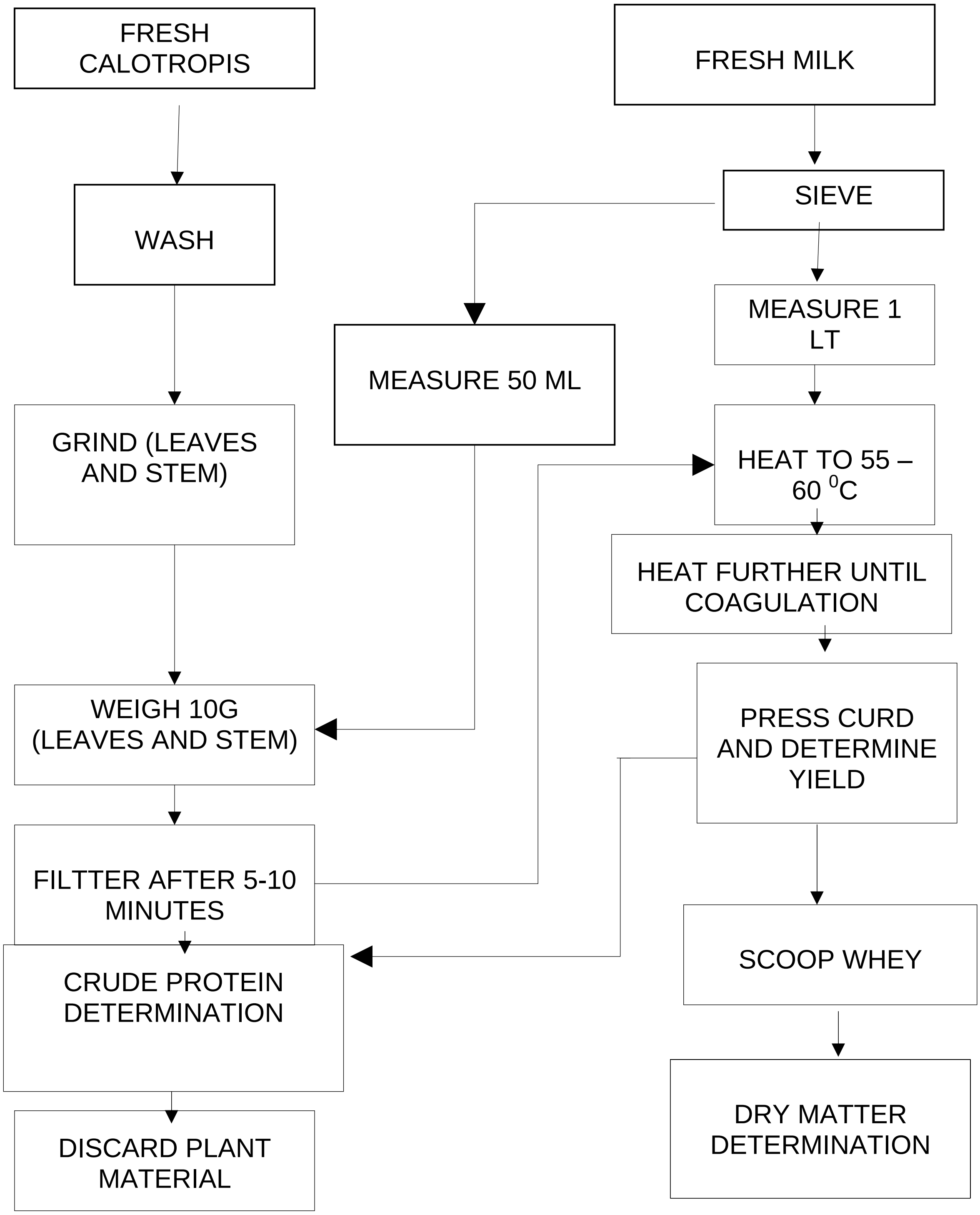


Figure 7: Flow charge showing *wagashi* (cheese) preparation

Results and discussion

Table 54 shows the effects of the different lead concentrations on pH, temperature and rate at which the cheese forms. Two leaf concentrations, (L_1 [9.5g/*l*] and L_2 [14g/*l*] did not result in coagulation This can be attributed to the low concentrations of the plant protease in the leaves and is consistent with the findings of O'Connor (1993) who reported variable concentration of plant sap in different parts of the plant.

Table 54. Treatment effects on temperature, time to coagulation and pH of *wagashi* (cheese)

	TREATMENT						
	Leaves (g/l)		*Stem (g/l)*				
PARAMETERS	L_3 (26)	L_4 (38)	T_1 (9.5)	T_2 (14)	T_3 (26)	T_4 (38)	S.E
pH of Milk	6.3	6.3	6.3	6.3	6.3	6.3	0.24
pH of Cheese	6.4^a	6.4^a	5.8^b	5.7^b	5.8^b	5.8^b	0.60
Temp. at coagulation (°C)	84.3^a	81.8^{ab}	78.7^a	78.3^{ab}	73.7^b	74.2^b	4.17
Temp. difference (°C)	23.6	20.8	22.4	21.8	17.9	18.5	-
Time to coagulation (Minutes)	22.7^{ab}	19.0^{ab}	26.7^a	21.7^{ab}	14.7^b	13.7^{bc}	4.1
Rate of temp. increase (°C/min)	1.04	1.09	0.84	1.00	1.22	1.35	-

Differences in superscripts indicate statistical significance ($p<0.05$)

pH of milk and cheese

There were no significant differences between the pH of milk used for all treatments. The pH ranged from 6.30 to 6.32. Low pH is to some degree responsible for the coagulation of milk at room temperature. Bank (1998) reported that casein protein precipitates at a pH of 4.6. Acidity is normally caused by the action of lactic acid producing bacteria or the presence of colostrums (Adda *et al.*, 1988).

A comparison of the pH of cheese formed from extracts of the leaves and stem of the plant indicated significant differences between the two. The leaves produced cheese with higher pH values. The lowest pH was 5.77 and the highest 6.43 suggesting the presence of a proteasnase type enzyme in the extracts. The pH of cheese like any other organic substrate has an effect on bacterial growth. Low pH as well as high pH is known to inhibit bacterial growth. The pH of the cheese formed from the stem portion of the coagulant could therefore have an influence on shelf life since bacteria are normally responsible for the deterioration of cheese in storage.

Temperature and formation of curds

Temperature and time at coagulation (curd formation) decreased with increasing quantities of both leaves and stem (Table 55). As indicated earlier treatments L_1(9.5g/*l*) and L_2(14g/*l*) did not coagulate. L_3 (26g/*l*) coagulated at the highest temperature of 84.3°C and took 22.8 minutes. The longest time taken was 26.7 minutes by T_1. The leaves portion had higher rates of temperature increase. The differences in the rate of temperature increase, coupled with the differences in the pH of the cheese formed may explain the non-coagulation of cheese sometimes experienced by Fulani women when processing cheese under village conditions. Heat hastens coagulation and high temperature of up to 95°C is reported to liberate the toxic substances in *Calotropis procera* (O'Connor, 1993).

Dry Matter (DM)

The DM values ranged from 44.11% to 49.04%. There were no significant differences between the DM of T_2, T_3, and T_4. However, significant differences were observed between T_4 and L_3. The dry matter increased with increasing levels of stem and leaves.

Crude Protein (CP)

There were significant differences between the crude protein of T_4 and T_1 and between T_4 and L_3 and L_4. The highest crude protein value obtained was 40.1% (T_4) and the lowest 36.85 (L_3). Crude protein values rose with increasing amount of both stem and leaves. These increases can be attributed to the fact that more casein is coagulated per litre of milk in these treatments. There was more efficient coagulation with increasing concentration of the coagulants, with the stem extracts being more efficient than the leaves for the same concentrations of extract. The crude protein values obtained were similar to the mean protein value (40.76%) obtained by Padmore (2001) but were much higher than the value (24%) obtained by Mathias *et al.* (1998). The crude protein values indicate that '*wagashi*' is a highly nutritive food.

Table 55. Treatment effects on protein content and yield of *wagashi*.

	TREATMENTS						
	Leaves (g/l)		Stem (g/l)				
PARAMETERS	L_3 (26)	L_4 (38)	T_1 (9.5)	T_2 (14)	T_3 (26)	T_4(38)	S.E
Dry Matter (%)	44.11^b	47.14^{ab}	44.13^b	48.84^a	49.04^a	48.91^a	2.049
Crude Protein (%)	36.85^{bc}	37.47^b	37.49^b	38.14^{ab}	39.67^{ab}	40.10^a	1.143
Yield (g/l)	205.28	220.35	207.38	213.62	223.23	219.52	25.601

Differences in superscripts indicate statistical significance ($p<0.05$)

Yields of wagashi

No yield was obtained for L_1 and L_2 as coagulation did not occur. This could be attributed to a possible low concentration of vegetable rennet in L_1 and L_2. The yields obtained for other treatments are comparable to the yields (0.22kg/l) reported by Sunu-Attah (2001). There were no significant differences between the yield obtained for all treatments. However, yields increased with increasing amounts of both stems and leaves.

Conclusions

Results from the experiment indicate that the use stems of *Calotropis procera* for coaguation is likely to be more efficient than the use of leaves. Leaves may also result in the *wagashi* taking a greenish colour, which might not be desirable to the consumer. Stems should therefore be recommended as the best parts of the plant for *wagashi* production. Where stems are in short supply 26g/*l* of leaves can be used to coagulate a litre of milk. Amounts above this will result in the *wagashi* taking a greenish colour. Further work is required to establish a means of extracting the plant sap and preserving it for use over a long period.

Improving yields of wagashi

The traditional *wagashi* production technique uses perforated calabashes to separate the curds from the whey. This process results in the loss of some of the curds through the perforations. Reducing these losses will improve the yield of cheese. The objective of this experiment was therefore to investigate the effect of using cheesecloth to separate curd and whey.

Procedure

Five litres of fresh milk was purchased from local herdsmen and *wagashi* produced in the normal way (see Figure 7). After the visible separation of the curds and whey, the curds were scooped into a perforated calabash and pressed in a locally fabricated press (Table 57) for about fifteen minutes to remove excess whey. Following pressing, the curd was weighed. This procedure was repeated with the perforated calabash lined with cheesecloth.

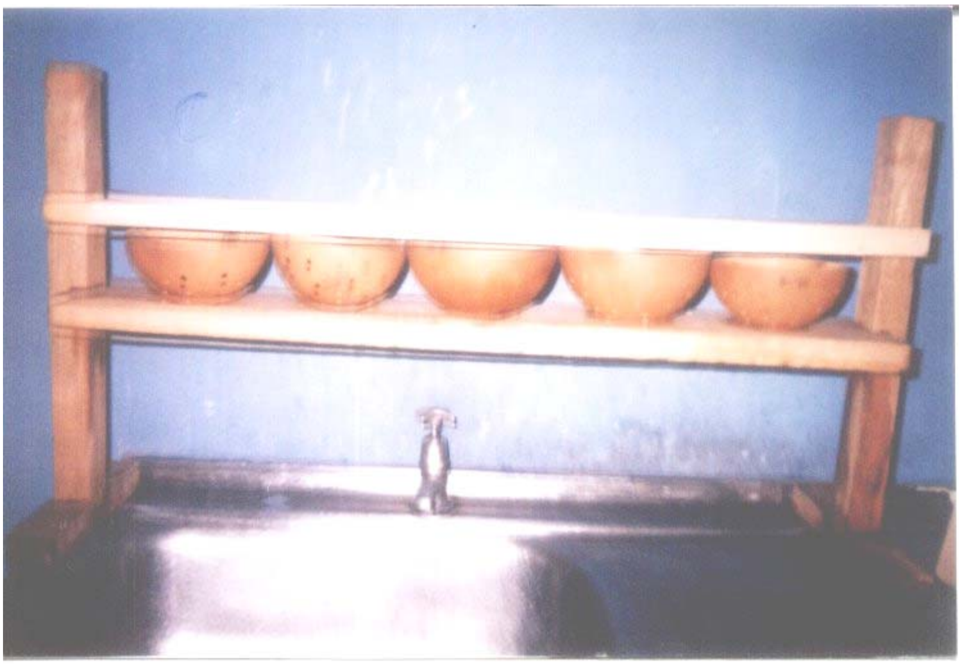


Figure 8: Locally manufactured cheese press.

Yield

Displays the yields of cheese (*wagashi*) obtained from the cheese produced in the traditional manner (perforated calabash) and cheese produced in perforated calabash lined with a cheesecloth.

Table 56. The impact of cheesecloth on yield

Parameter	Mean yield of cheese g/l milk	S.E
Traditional method	259.3	1.65
Yield of cheese using calabash lined with cheesecloth	269.7	3.55
Mean yield	264.5	2.67

The results demonstrate that lining the calabash with cheesecloth resulted in a 4.01% increase in yield of *wagashi*. This difference was statistically significant ($p<0.05$). This increase can be attributed to the smaller pore size of the cheesecloth, which improves the efficiency of curd collection with little curd loss compared to the traditional method. The mean yield of 264.5g/l/milk obtained was higher than 220g/l milk obtained by Sunu-Atta (2001) and 200g/l milk reported by Otchun *et el*. (1991) and Eguonlety *et al*. (1994).

Improving shelf-life of wagashi using brine

As outlined in section 4.2.5 shelf-life of *wagashi* is a major concern for producers and retailers who resort to placing the cheese in boiling water (on a daily basis) to ensure the product remains saleable for as long as possible. It is difficult to extend the shelf-life of the product using this method beyond one week. The objective of this experiment was to examine the effect of various brine concentrations on the preservation of '*wagashi*'. Brine is known to have preservative effects and is commonly used to preserve cheese in southern Europe and parts of north Africa (O'Connor, 1993).

Procedure

Wagashi was produced in the normal way (). Common salt (NaCl) at the rate of 5g, 10g and 15g was dissolved in 100ml of fresh, clean water to produce 5, 10 and 15% brine solutions. 200g of *wagashi* was immersed in the three brine solutions overnight (12 hours) and removed and stored on shelves at room temperature. Samples were then taken for the chemical and microbial analyses. Brine treatment was carried out every 3 days for 12 hours. The samples were stored as described above. Further samples were taken for analysis on days seven and fourteen respectively.

Chemical and microbial analysis

Plates were prepared by dissolving 1g of peptone in100ml of distilled water. 90ml dilutions were placed in bottles which were capped and autoclaved at1.05kg/cm2 and 121^{0}C for10 to 30 minutes. The dilutions were cooled at 40^{0}C.

10g '*wagashi*' samples were mashed and transferred into the dilutent. The bottles were capped and placed on a mechanical shaker (vortex mixer) and shaken for 10 minutes. 10ml of each sample was immediately taken from the centre of the suspension and moved to a fresh 90ml blank solution of the dilutent with sterile pipette. This established the $1/10^{-3}$ dilution. The bottles were capped, vigorously shaken and 10ml of the suspension was removed as described above. The sequence was continued until the dilution of 10^{-8} was reached.

1ml of the freshly mixed suspension was pipetted onto the media (standard plate agar) for total viable count and violet red bile agar for total coliform count. Beginning with the most dilute bottle the process was repeated for all dilutions.

Immediately after pouring the plates were carefully swirled to thoroughly mix their contents. The media was allowed to solidify. After which it was inverted and placed in an incubator.

The samples were incubated for 24 hours at 26^0C. After which the plates were removed and the colonies were counted:

$$\text{Number of colony forming units/g sample} = \frac{\text{(mean plate count X dilution factor)}}{\text{Weight of sample X initial dilution}}$$

Results

There were no significant differences between the dry matter contents of the different brine treatments (Table 58). This may be caused by the repeated submersion of the samples in brine on days 3, 6, 9 and 12. The dry matter value of 44.6% obtained put *wagashi* in the range of soft cheese as reported by De (1980) and Sunu-Atta (2001).

Table 57. Treatment means for crude protein, dry matter, total viable count (TVC) and total coliform count (TCC) of *wagashi*.

	Brine treatment level (percentage) w/w.			
Parameter	**5%**	**10%**	**15%**	**S.E**
CP%	32.18^a	31.31^a	31.43^a	0.44
DM%	44.05^a	44.95 ^{a}	44.08 ^{a}	1.22
TCC	2,334.58 ^{a}	677.50^b	85.75 ^{b}	381.26
TVC	99,083.33 ^{a}	35,625.00 ^{b}	6,516.67^b	10,057.19

Differences in superscripts indicate statistical significance (p<0.05)

There were no significant differences in the crude protein levels for the three brine treatments. There were however significant differences in the level of bacterial growth between 5% brine treatment and 10% and also between 5% and 15% but there was no significant difference between the 10% and 15% brine treatments.

The 5% brine treatment recorded the highest count for TVC and TCC ($9.9x10^4$ and $2.33x10^3$) followed by the 10% treatment ($3.56x10^4$ and $6.77x10^2$). The 15% treatment recorded the lowest count for both TVC and TCC, $6.51x10^3$ and 86 respectively. The low bacterial count can be attributed to the preserving property of salt. Salt inhibits the uptake of water for growth by micro-organisms (Prescott *et al*., 1996).

4.2.2.1 Comparing the effects of boiling and brining for *wagashi* preservation

Traditional *wagashi* processors, wholesalers and retailers often resort to boiling their cheese to increase its shelf-life. This experiment was designed to compare this traditional method with that of brining over a period of 10 days. '*Wagashi*' was produced in the normal way (Figure 7). One sample was subjected to a 10% brine treatment (see section 4.3.3), one sample to daily boiling and a third sample was the control (no treatment).

The parameters observed included:

- Color
- Texture
- Odor

Results

For days 1-3 there was no observed differences in the colour of the *wagashi* of the three treatments. By day 4 the control had begun to deteriorate and thereafter displayed a rapid decline in appearance.

The boiled sample maintained a reasonable appearance for about one week and then began to deteriorate more rapidly. The brine treated cheese maintained a fresh appearance for the duration of the experiment despite being stored at room temperature (i.e. under similar conditions to the local small-scale processor).

The odour produced by all three samples was similar (fresh cheese smell characteristic of *wagashi*) for the first 2 days of the experiment. A bad odour was detected from the control on day 3 while the boiled sample and the brine treated sample still smelt fresh. By day 4, there was a diminished intensity in the smell of the boiled sample. This continued throughout the period of observation and the sample produced almost no odour by day 10. The brine treated sample maintained the normal cheese odour throughout the period of the experiment although there was a slight reduction in the intensity of the odour by day 10. The loss in odour of the boiled sample might be due to the loss of fat as a result of continuous heating on days 3, 6 and 9. The preservative nature of salt accounts for the fresh consistency of the brine treated sample (Prescott, *et al*,.1996).

Similar textures were observed for the three samples on days 1 and 2. By day 3 the control was slimy and soft compared to the other samples. By day 4 the boiled sample had developed a fibrous nature, which continued in intensity throughout the 10-day period. The brine treated sample maintained its consistency throughout the experimental period. The fibrous nature of the boiled sample may be attributed to the repeated heating caused by dipping in boiling water (Gilmore *et al*., 1997).

Table 58. Changes in the appearance, odour and texture of *wagashi* subjected to 3 different methods of preservation

	10% Brine	**Boiled**	**Control**
Appearance (colour)			
Day 1	Normal	Normal	Normal
Day 2	Normal	Normal	Normal
Day 3	Normal	Normal	Normal
Day 4	Normal	Normal	Yellowish
Day 5	Normal	Yellowish	Brownish
Day 6	Normal	Yellowish	Brown with black spots
Day 7	Normal	Brownish	Brown with black spots
Day 8	Normal	Brown with black spots	Moulds
Day 9	Normal	Brown with black spots	Moulds
Day 10	Normal	Moulds	Moulds
Odour			
Day 1	Fresh/cheesy odour	Fresh/cheesy smell	Fresh/cheesy smell
Day 2	Fresh/cheesy odour	Fresh/cheesy smell	Slight bad odour
Day 3	Fresh/cheesy odour	Fresh/cheesy smell	Bad odour
Day 4	Fresh/cheesy odour	Less cheese odour	Bad odour
Day 5	Fresh/cheesy odour	Less cheese odour	Bad odour
Day 6	Fresh/cheesy odour	Less cheese odour	Bad odour
Day 7	Fresh/cheesy odour	No cheese odour	Bad odour
Day 8	Reduced cheesy odour	No cheese odour	Bad odour
Day 9	Reduced cheesy odour	No cheese odour	Bad odour
Day 10	Reduced cheesy odour	No cheese odour	Bad odour
Texture			
Day 1	Firm texture	Firm texture	Firm texture
Day 2	Firm texture	Firm texture	Firm texture
Day 3	Firm texture	Firm texture	Slimy/soft
Day 4	Firm texture	Firm texture	Slimy/soft
Day 5	Firm texture	Fibrous	Slimy/soft
Day 6	Firm texture	Fibrous	Slimy/soft
Day 7	Firm texture	Fibrous	Slimy/soft
Day 8	Firm texture	Fibrous	Slimy/soft
Day 9	Firm texture	Fibrous	Slimy/soft
Day 10	Firm texture	Fibrous	Slimy/soft

4.2.3 *Consumer acceptance of brined* wagashi

A total of 102 panelists were presented with the three *wagashi* samples (produced with 3 different concentrations of brine). They were invited to choose one at random (blind tasting) in Kumasi, Ejura and Mampong districts in locations where *wagashi* is commonly sold. After tasting, the panelist was offered a piece of bread to clear the palate before tasting another sample. The panelists were then asked to rank the products in terms of which *wagashi* was preferred for taste, texture etc. Panelists were also asked to comment on the freshness of the product. The responses were recorded and entered into a database. Following data entry frequencies of responses were extracted and analysed. The samples were ranked according to the following criteria, most preferred, second or least preferred.

It was observed that about 52% of the Panelists ranked product "A" [5% brine] as the most preferred followed by product "B" [10%] with 44% ranking it the most preferred and lastly 4% opted for product "C" [15% brine]. Around 85% of panelists commented that all the three levels of brined *wagashi* were of high quality in terms of texture, freshness (rancidity) and taste (with the exception of the 15% brined sample, which was considered too salty).

4.2.4 Training of Trainers

Following the results obtained from the consumer acceptance study, one-day training sessions were organised in several locations for *wagashi* processors. A total of 51 *wagashi* processors, market agents and retailers in Ejura, Nsuta, Mampong and Kumasi peri-urban areas participated in the training sessions along with 2 representatives of the agricultural extension service.

Demonstrations were made of the various steps in processing including:

- the correct quantity of *Calotropis procera* (coagulant) to use,
- improving yields with the use of cheesecloth (muslin),
- producing cheese in a hygienic environment.
- prolonging the shelf life of cheese using a 10% brine solution
- increasing returns to *wagashi* production.

4.2.5 Costs of wagashi *production*

The weekly market survey collected information from a range of different individuals involved in the dairy production and marketing chain. The objective of this survey was to identify marketing constraints and opportunities, market margins etc. and data was collected on the fixed and variable costs of *wagashi* production as well as data on the fresh milk marketing chain. Thus it was possible to extract relevant information from the available data on the production costs and margins of *wagashi* producers.

Production and sales data from 23 processors (wet and dry seasons combined) is Table 59**.**

Table 59. Production, sales, and profits from *wagashi* production (19 processors)

Production and sales	Mean
Milk purchased/day (litres)	20.57
Wagashi produced/day (kg)	4.31
Value of *wagashi* sales/day (cedis)[10]	35,433
Total variable costs/day (cedis)	1,753
Gross Margin/day (cedis)	16,729
Annual fixed costs (cedis)	94,795
Annual profit margin (cedis)	6,011,586
Profit margin/kg cheese (cedis)	3,203

Milk purchased varied from between 2 and 120 litres per day. The price processors paid for milk varied according to the quantities purchased. Purchases of larger quantities are able to negotiate a favourable price of approximately 500 cedis per litre. Smaller producers must pay in the region of 700-1000 cedis per litre. Data on the actual yield of *wagashi* produced was not gathered by the survey and a standard yield of 0.22kg/litre of milk was used to estimate the amount of cheese produced daily by processors. Estimated production was between less than 0.5kg to and 26kg per day.

Sale prices of *wagashi* were also very variable depending upon whether the processor sold to market agents (wholesalers), directly to retailers or sold their produce directly to consumers. Not surprisingly direct sales realised the highest prices. Sale prices varied between 3,000 to 20,000 per kg.

Average daily variable costs (wet and dry season data combined) are shown in Table 60. Variable production and marketing costs are dominated by transport, fuel and coagulant costs. Other minor costs are associated with dye (sorghum sheath), soap and water. Total variable costs per kg of *wagashi* produced were 841cedis.

Annual fixed costs (see Table 60) are accounted for by the equipment (utensils) required for *wagashi* production. These include:

- Buckets or jerry cans for collecting milk
- Bottles for measuring milk
- Basins for storing *wagashi*
- Calabash or baskets for cheese moulds
- Charcoal stoves and boiling pans for boiling milk
- Sieves, pestles and mortars, ladles

[10] 1US$ = 7100 cedis, September 2001

Table 60: Variable costs of *wagashi* production (19 processors)

Variable costs	Mean/day	Mean/kg
Transport	516	253
Packaging	64	33
Colour (sorghum sheath)	75	54
Coagulant (*Calatropis*)	173	85
Salt	38	23
Fuel	395	240
Water	103	28
Soap	144	86
Other	47	10
Total	1,753	841

Annual variable costs using the CRF (capital recovery factor) were calculated using the following formula

(15) $$CRF = z\frac{(1+i)^n}{[(1+i)^n - 1}$$

Where i is the interest rate (8%) and n is the number of years, in this case the lifetime of the capital item.

Average annual fixed costs (23 processors) were calculated to be 94,795cedis. Average annual profits were calculated to be 6 million cedis (US$857) and average profits per kg of *wagashi* produced 3,203 cedis (US$0.46).

4.2.6 Extension materials

Following research and training activities a simple extension leaflet was designed. A total of 1,000 copies were printed and distributed to the Ministry of Food and Agriculture.

4.2.7 Conclusions – processing

This research has established that *wagashi* production is primarily a means of preserving surplus milk production. However, it is an important source of animal protein for poor urban families in the Kumasi and Accra metropolitan areas. It is consumed mostly by those members of the population who have their origins in northern Ghana and Burkina Faso.

Laboratory experiments have demonstrated that:

- the use of stems of *Calotropis procera* for coagulation is more efficient than the use of leaves
- the optimum quantity of stem is 25g per litre of milk
- cheese yields can be improved by 4 % with the use of a cheesecloth during the production process
- placing a cheese in a 10 to 15% brine concentration for 12 hours significantly improves shelf-life from 3 to 14 days

Consumer acceptance surveys have confirmed that a 10% brine solution produces *wagashi* of acceptable texture and flavour for consumers. The use of brine as a means of preservation also reduces the need for daily boiling of *wagashi,* which reduces the resources, expended by processors on labour and fuel.

Many processors have a direct (family) connection with the producers of milk (husbands who work as herdsmen) and often therefore are not required to outlay cash to acquire milk for processing. The larger processors tend to operate as commercial businesses and purchase larger quantities of milk for which they are able to negotiate a favourable price.

Wagashi processing business are generally small operations with a limited turnover and with a limited amount of capital invested in production. The introduction or promotion of simple innovations such as brining and sieving (using muslin cheese-cloths) will reduce the costs of production, increase yields while producing a safer product for the consumer with a longer shelf–life. A total of 51 processors were trained to brine their cheese during August 2001. Early indications are that most trainees have adopted these simple technologies.

Consumer acceptance studies have demonstrated that 15% brine *wagashi* was the least preferred, while laboratory studies showed this level of brine provided the best level of preservation. Further research is required to examine the potential for de-brining to make this brined product more acceptable to consumers while maintaining good preservation characteristics.

Chapter 5. Contribution of Outputs

5.1 Summary of contribution of project outputs

Although the three major sets of project activities and outcomes were presented separately above, the contribution of project outputs is here presented in a combined manner. This is because many of the contributions of the projects results from combined outcomes of the project activities.

The outputs of the project have been achieved in that problems in the target milk markets were identified and quantified, and training materials and policy options were developed to help deal with these. These are aimed at improving not only the welfare of small market agents and farmers themselves, but also the resource-poor consumers who are the main buyers of these indigenous products. A key to enabling these outputs to contribute to the project goals are a) the strong linkages developed for dissemination of training materials and information, b) the important links established with policy-makers in both countries, and c) linkages between project partners and long term multilateral dairy development efforts, particularly FAO, and with other non-project countries.

Consequently, there are three major sets of contributions of the project's outputs:

a) Training and extension materials
b) Policy influence/impact in the project countries
c) Impact on the development agenda of multilateral dairy development efforts in other developing countries

The training and extension materials developed are listed in the project publications below. A new generic training manual that is being developed is discussed further under the section below on current and planned project follow up. Policy impact and impact on multilateral development agenda are also discussed in more detail in the same section.

5.2 Further studies needed

5.2.1 Economies of scale in marketing

The efficiency results from both Ghana and Tanzania showed clearly that efficiency declined with larger volumes of milk handled by market agents, suggesting dis-economies of scale in milk marketing. On one hand, this suggests that small scale agents are competitive and may not be threatened by increased industrialation or growth in milk markets for some time. On the other hand, this also creates a barrier to development, in that small agents will be constrained from scaling up and developing their businesses. Further research is needed into better understanding the reasons for these apparent scale barriers.

5.2.2 Technologies to improve milk quality

The project found significant problems with bacterial growth in many different market channels, even where appropriate containers were being used. This is simply because refrigeration/cooling is not economic or practical in most cases.

Although this may not pose a health threat due to consumer boiling/heating of products before consumption, it nevertheless is a main cause of spoilage and losses. There is need therefore to identify alternative practical and affordable technologies to reduce bacterial growth, such as the Lactoperoxidase Milk Preservation System (LPS), and to promote such technologies in areas where they can make a difference. Although LPS has been tested and proven technically, the economics remain uncertain, as well the viability of the institutional and organisational arrangements needed to employ it in a sustainable manner among small farmers. Some research along these lines is currently being conducted by ILRI and partners in Kenya.

5.2.3 De-brining of wagashi

A primary constraint to use of brining to extend the shelf-life of wagashi was consumer acceptability of the resulting product. Further research is required to examine the potential for de-brining to make this brined product more acceptable to consumers while maintaining good preservation characteristics.

5.2.4 Understanding informal/traditional milk markets elsewhere

At a general level, the project was one of the first anywhere to closely examine the functioning of informal/traditional milk markets in developing countries. At the same time, these markets remain by far the largest sector of the dairy industries in developing countries not just in SSA, but also in South Asia and in Latin America. A great deal more research is needed to understand these markets in all their diversity, and to understand how the formal-informal gap can be bridged in such a way as to retain small agent participation while at the same time improving product quality and safety. This project has provided a very sound starting point to addressing these issues, but further research is needed to look at similar markets in other countries. One indirect project outcome is a new project in India, applying the same methods. More on that below.

5.3 Current and planned project follow up

5.3.1 Follow up in project countries

In Ghana, the project findings and materials have been directly taken up by new FAO project begun in 2002, entitled the “The Training Programme for the Small-scale Dairy Sector.” The managers of that project attended and addressed the final stakeholder workshop, and confirmed those linkages. Also in Ghana, as a result of one of national project leaders role as a senior economic advisor to the new government, the policy information developed has received high level visibility, as evidenced by the address made by the Minister of Food and Agriculture at the final stakeholder meeting, and his mention of use of project findings in the new livestock sector development efforts being funded by the African Development Bank.

In Tanzania, close linkage has existed since the project initiation with the Austoproject dairy development activities, who work to train farmers and market agents, and who will be able to take up the training materials. Further, the national project leader in Tanzania sits on the official Dairy Policy Task Force, insuring that the project's policy implications will have direct impact on the continuing development of Tanzania's dairy policy. As an example of these high level linkages, some project results were reported at a dairy stakeholder gathering chaired by the Tanzanian President, Mr. Mkapa. At the Jan 2004 LPP workshop on dissemination proposals, further publication of project dissemination materials are were planned, as well as new dissemination activities in the form of serialised radio dramas.

5.3.2 Project outcomes and follow up across developing countries

5.3.2.1 LPP and FAO related information platforms

Several new initiatives are helping to disseminate project outcomes. ILRI is participating in an FAO project entitled the "FAO Action Programme For The Prevention of Food Losses Levels and Causes of Post-Harvest Milk and Dairy Losses In Sub-Saharan Africa And The Near East." This development project addresses losses due to poor milk hygiene in Kenya, Tanzania, Uganda, Ethiopia and Syria and through ILRI's participation, uses the LPP project's findings and methodology for addressing the informal and traditional markets where most of these losses occur. As part of that project, ILRI will manage a web and CD-based information platform to make available materials to support national players in milk markets. Some of this information will include the LPP project material.

This FAO information platform will eventually be linked to a new LPP Dairy Toolbox being developed by ILRI and partners. It is intended that eventually this will lead to a comprehensive FAO-led DairyNet, an electronic network to provide information to support small dairy farmers and small market agents in developing countries. Project findings will play a key role in informing these stakeholders and policy makers about issues facing indigenous dairy markets, and in providing materials to help address them.

5.3.2.2 Generic dairy training materials

The project developed a great deal of information as to how best to design training for small scale market agents, and developed some of those training materials for the project countries. However, more generic materials would allow these to be used in other countries across Africa in particular. Towards this end, the project country manager in Tanzania, Prof L Kurwijilla, during a sabbatical at ILRI during 2004, will help develop a generic training manual. It is hoped that this will be supported by an LPP dissemination grant.

5.3.2.3 Regional dairy policy consultations

One indirect project follow up activity is the participation of several project partners (Dr Omore and Prof Kurwijilla) in a regional activity led by ECAPAPA the policy branch of ASARECA , the Assoc. of Agricultural Research in East and Central Africa. This aims to harmonize dairy policies between countries in the region, focusing particularly on markets a trade, including major emphasis on addressing informal markets. The project has played a considerable role in providing information to this process.

5.3.2.4 New research on informal markets: India

The project has helped to highlight the role of informal and traditional markets in developing countries, developed methods to study them , and also showed that there are means to address them constructively. Partly as a result, ILRI was approached by development agencies in India to lead a new study to look at informal and traditional milk markets there. That project, working with Swiss SDC funded CALPI livestock development project, is now being developed. It should be noted that in terms of volume India's informal milk market, which has never been systematically studied, is approximately the same scale as total North American milk production, and is greater in volume than total global trade in dairy products in terms of liquid milk equivalents. This new study thus has the potential to have significant impact through informing policies and development interventions in the large Indian market. The role of the LPP project in contributing to this new study can be seen the fact that the quantitative methods and questionnaires developed in the LPP project will be directly used in the new study.

Through its Market-Oriented Smallholder Dairy Project, and its Livestock Policy Analysis Programme, both of which contributed to this project, ILRI will build on the project outcomes to develop similar research in other countries. Having already completed similar studies in Kenya, research is being developed for South Asia, and well as potentially at sites in Central America. The aim is to provide a strategic overview of issues and potential solutions for the huge indigenous dairy markets that dominate the dairy sectors in developing countries, and which to date have not been systematically studied. The frequent failure of dairy development efforts that assume a Western, pasteurised milk model is one consequence of this lack of strategic knowledge.

5.4 List of publications and dissemination materials

5.4.1 Publications

MDOE, N.S.Y., K.R. MNENWA, S. STAAL, R.L. KURWIJILA, W.E. J. JOSEPH, A. OMORE, and D. BARTON (2003). Role of Milk marketing in Poverty Alleviation in Tanzania: The Case of Milk Producers and Traders in the Dar-es-Salaam Milk Shed. Tanzania Veterinary Journal 21 (2): 74-82.

OMORE, A., STAAL, S. J., KURWIJILLA, L., OSAFO, E., ANING, K.G., MDOE, N., AND NURAH, G. (2001) Indigenous Markets for Dairy Products in Africa: Trade-Offs Between Food Safety and Economics. *Proceedings of Symposium on Dairy Development in the Tropics*, Utrecht Univ., Netherlands. Nov. 2, 2001. pp. 19-24.

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MDOE, N.S.Y., MNENWA, K.R., KURWIJILA, R.L., JOSEPH, W.E., STAAL, S. J., OMORE, A., and BARTON, D. (2000). Economics of milk marketing in Dar-es-Salaam milkshed. Proceedings of the first University Wide Scientific Workshop held at SUA, 5-7 April 2000, forthcoming

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MDOE, N.S.Y., MNENWA, K.R., KURWIJILA, R.L., JOSEPH, W.E., STAAL, S. J., OMORE, A., and BARTON, D. (2000) Entrepreneurship in milk marketing: The need for assistance. AGREST Conference Series., Volume 4: 18-27.

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STAAL, S. J, OMORE, A., KURWIJILLA, L., OSAFO, E., BARTON, D., ANING, K.G., MDOE, N., AND NURAH, G (2004). Improving Public Health and Marketing in Indigenous African Dairy Markets: Synthesis of Findings from Research in Ghana and Tanzania. MOSD Research Report. International Livestock Research Institute, NRI, University of Science and Technology, Sokoine University of Agriculture, and Animal Research Institute. In press.

5.4.2 Internal Reports

OSAFO, E.L.K., BARTON, D., NURAH, K.G., MATHIAS J. (1999) Milk marketing, production, processing and public health in Ghana: A review of literature. University of Science and Technology, Kumasi, and Animal Research Institute, Accra. December 1999. 30 pp.

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ANNEX 1. DETAILS OF LABORATORY METHODS

Determination of fresh milk density

Addition of water or solids was tested by specific gravity (SG) using a lactometer with or without a thermometer. SG readings 500 ml measuring cylinders were either done at a standardised milk temperature of 20^{o}C or a temperature correction factor applied later[11]. The standard of 3.25% butterfat was used to classify proportions of milk samples below acceptable limits.

Determination of butterfat content

Butterfat content was determined using the Gerber method. Briefly, 10 ml of concentrated sulphuric acid (specific gravity = 1.820 kg/litre), was first pipetted into a Gerber butryometer followed by addition of 11ml milk and 1ml amyl alcohol. The mixture in the butyrometer was tightly closed, contents thoroughly mixed, centrifuged at 1200rpm for 5 minutes after which the butyrometer was placed in a water bath at 60-63^{o}C for at least 3 minutes before reading the butterfat percentage.

Determination of solids-not-fat and total solids

The results of the above two tests were applied to calculate solids-not-fat (SNF) and total solids (TS) using the Richmond formulae[12] as follows: %SNF= (0.22 x BF + (0.25 x SG)+ 0.72) and TS = SNF+BF.

Determination of total and coliform plate counts

Samples were assessed for total viable bacterial counts (TPC) and coliform plate counts (CPC) using direct culture methods described by Marshall (1992) and Speck (1984). Serial dilutions of each sample from 10^{-1} to 10^{-8} were prepared in peptone water or phosphated sterile water diluent (0.0425g of KH_2PO_4 per litre and standard pH 7.2).

Various ranges of dilutions (depending on expected variation in counts) for culture of total plate counts ranged from 10^{-3} to 10^{-7} and 10^{-4} to 10^{-8} in Tanzania and Ghana, respectively. From each dilution, 1 ml was transferred using a sterile pipette into a 90-mm diameter disposable petri dish. This was mixed thoroughly with 15 - 20 ml of sterilized (autoclaved at 121^{o}C for 15 minutes) and cooled to 45 – 47^{o}C molten standard plate count agar (APHA-Oxoid) and left to cool down and solidify. Thereafter, plates were incubated in inverted positions at 32^{o}C for 48 hrs. Following this period, plates with colonies ranging from 25 – 250 colony forming units (cfu) were selected, counted using a colony counter and computed following guidelines by Speck, (1984) and TBS.

Various ranges of dilutions for counting coliforms were also applied depending on expected variation in counts. Dilutions ranging from 10^{-3} to 10^{-5} and 10^{-4} to 10^{-8}

[11] Temperature correction factor applied for specific gravity is 0.0025 x milk temperature ±20°C
[12] The SG reading used in the Richmond Formulae is the last two digits (e.g., 30 is used instead of 1.030)

were used in Tanzania and Ghana, respectively, and cultured in molten violet red bile (VRB) agar using the same volumes and procedure as for TPC. After cooling and solidification of the medium, the plates were over-layed with a thin layer of the same VRB medium and incubated at 37^{o}C for 24hrs. Plates showing typical red coliform colonies in the countable range of 15 – 150 cfu per plate were chosen, counted and computed following guidelines by Speck, (1984). The lower range of countable colonies for coliforms (compared to total counts) is advised by KEBS (1976) and was applied to enable comparisons with similar data from Kenya.

Brucella Milk Ring Test

One of the tests applied to test for antibodies to *Brucella abortus* was the Brucella Milk Ring Test (MRT). The test, which was done with positive and negative controls, works on the principle that antibodies to *Br. abortus* present in milk agglutinate with haematoxylin stained *Br. abortus* antigen and rise to the top layer with the fat globules to form a deep blue ring in the cream top layer (Sutra et al., 1990). If no antibodies are present, the cream that separates out is white and the skim milk below is blue. The test often detects a high proportion of false positives (low sensitivity) due to positive reactions from samples taken shortly after parturition, near the end of lactation period, or from mastitic quarters (MacMillan, 1990). The MRT was conducted by pipetting 1 ml of milk into each 1.2ml tubes with fresh milk followed by adding and mixing one drop of stained *Br. abortus* antigen. The tubes were thereafter incubated at 37^{0}C for 1hr.

Indirect Milk ELISA Test

The method described by Neilsen *et al*., (1996) (sensitivity = 95% and specificity = 99%) was adopted. Briefly, polystyrene 96-well flat bottomed plates were coated with 100μl of 0.5mg/well of *Br. abortus* smooth lipopolysacccharide antigen in coating buffer (0.06 M carbonate buffer pH 9.6) and kept overnight in a humid box. The plates were thereafter washed five times with phosphate buffer (0.01M phosphate buffer of pH 7.2 containing 0.05% Tween-20 and 0.15M NaCl), dried and blocked using 200ul/well of 0.1% gelatin and incubated at 25^{0}C for 30 mins. The plates were washed again, dried and milk samples added at 100 μl/well diluted 1:2 in milk diluent (0.01M phosphate buffer, pH 6.3, containing 0.15M NaCl, 0.05% Tween-20, 15 mM EDTA and 15 mM EGTA). The plates were shaken for 2 minutes in an orbital shaker and incubated for 30 mins at 25^{0}C. The plates were then washed and 100μl/well of monoclonal antibody conjugated (dilution 1:1600) to horse radish peroxidase added and incubated for 1hr at 25^{0}C. The plates were washed again, dried and the substrate (0.05M Citrate buffer pH 4.5 containing 1mM hydrogen peroxide and 4mM ABTS) added at 100 μl/well. The plates were incubated for a maximum of 15 mins and the absorbance read at 414 nm. Brucella positive and negative serum and milk controls were included. The control serum samples were diluted 1:50, while milk samples were diluted 1:2 in the milk diluent. Each milk sample was tested in duplicate. The modification in this procedure was that the cut-off value was determined by using twice the mean of the negative control samples (Savingy and Voller,1980).

Isolation of *E. coli* 0157:H7

After counting the coliform forming units on the VRB agar medium, emerging coliform colonies were, examined further for *E. coli* and subsequently 0157:H7 strain. Up to six coliform colonies per plate were purified on MacConkey agar and tryptose agar (Oxoid), and differentiated for *E. coli* by culturing on eosin methylene blue agar (Oxoid) and testing for indole, methyl red, vogues proskaeuer and citrate (IMViC) reactions. Confirmed *E. coli* isolates (IMViC++--) and suspicious weak positives were further cultured on selective indicator Biosynth medium (BCM™0157:H7(+); Biosynth Biochemica, Biosynth International Inc., USA) and incubated at 35oC for 24h to observe any development of blue black colonies of *E. coli* 0157:H7. The BCM™0157:H7(+) medium was prepared according to the manufacturers instructions. Briefly, 80g of the powder was dissolved completely in 1liltre of distilled water containing 5ml N, N-dimethylformammide (Sigma®). After cooling to 50 ^{o}C in a water bath, 5 ml of 0.2% (w/v) Sodium novobiocin (Sigma®) and 0.2 ml of 0.1% (w/v) potassium tellurite Sigma®), both filtered and sterilised, were added to the medium, mixed and then poured into petri dishes. It then allowed to solidify and dry at room temperature.

Sampling and laboratory isolation of Mycobacteriaceae and *M. bovis*

Two approaches were used to isolate *Mycobacteriaceae* and *M. bovis* in particular. The first approach was through direct isolation the milk samples collected following the method described by Kazwala et al., (1998). Briefly, 10 ml of milk sample was transferred into another sterile universal container for decontamination using 4% sodium hydroxide and then neutralised using concentrated hydrochloric acid. Suspensions were then centrifuged at 13,000*g* and the supernatant discarded to leave at least 2ml of the sediment to be used as inoculum for the cultivation of *Mycobacteria* species. This was then followed by primary isolation of the mycobacterium on egg media and Loewenstein-Jenses with added pyruvate. The cultivation and incubation was for a period of 6 weeks with weekly observations of signs of growth. Positive cultures were sub-cultured into another set of media and incubated for another 3-4 weeks for further identification. Identification was by observation of growth and staining to examine acid-fast bacilli (AFB). The presence of AFB was indicative of Mycobacteria. Further characterisation was by biochemical tests. The suspected Mycobacteria was subjected to molecular analysis using polymerase chain reaction (PCR) to speciate *M. bovis.*

The second approach was sampling and laboratory processing of sputum and sub-mandibular lymph node aspirates from of patients suspected to be suffering from BTB. The samples were opportunistically collected from patients in hospitals in Mwanza and processed in the laboratory as described above.

Charm AIM Test

Determination of drug residues was done using the Charm AIM-96 anti-microbial inhibition assay screening kit (Charm Sciences Inc., USA) according to manufacturer's recommendations. The test kit detects β-lactams, tetracyclines, aminoglycosides, macrolides and sulphonamides at levels above maximum residue limits (MRLs) recommended by the EU (Table A2)

Table A1. Detection levels of Charm-AIM-96 for representative drugs, maximum residue limits (MRLs) and acceptable daily intake (ADI)

Antimicrobial drug	Family	Minimum detectable range (μg/kg)	EU MRLs (μg/kg)	Codex MRLs (μg/kg)	Codex ADI[a]
Penicillin G	β-lactam	3-4	4	4	30 μg/day
Sulfamethazine	Sulphonamide	10-50	100	-	50 μg/kg body wt
Gentamicin	Aminoglycoside	30-100	100	-	20 μg/kg body wt
Oxytetracycline	Tetracycline	150-300	100	100	30 μg/kg body wt
Tylosin	Macrolide	40	50	-	-

[a] Acceptable daily intake
Source: Charm Sciences Inc, USA

Briefly, 50μl of each sample was added in duplicate to the supplied microtitre plate followed by 200μl of a mixture of *Bacullis* s*tearothemophilus* spore tablet and lyophilised medium dissolved in 22ml of deionized water. The plate was then sealed and tightly secured by screws and incubated for 3-4 hours. Positive and negative controls were also included in the assay. The positive milk control consisted of antibiotic free milk determined using *Micrococcus lutea* inhibition assay mixed with penicillin G or sulfamethazine standard. 200μl of bacterial spores suspension and lyophilised medium in de-ionized water were added to 50μl of the positive control milk. The negative control consisted of 50μl of negative control tablet dissolved in distilled water and 200ul of the test bacteria and media dissolved in deionized water. Test results were read using colour contrasts and scored from 1-5 (negative = 1-3 and positive = 4-5).

Annex 2: Milk Handling Practices

Description of milk handling practices in Tanzania

Trader	Coop/Farmer group	Producer-sellers	Proces-sors	W/ Sellers	Retailers	Vendors/ Hawkers	Other	Total	(%)
Penalty for delivering unwholesome milk									
None	0	152	NA	0	112	40	0	304	37.3
Buyer rejects	7	23	NA	15	152	240	3	440	53.9
Shared costs	0	0	NA	0	7	29	0	36	4.4
Buyer bears full cost	0	1	NA	0	13	12	0	26	3.2
Other	0	1	NA	0	6	3	0	10	1.2
Total									**100**
Quality control measure before receiving milk									
None	0	166	NA	6	179	110	2	463	55.3
Lactometer	3	7	NA	0	14	134	1	159	19.0
Oduor test	0	2	NA	0	2	4	0	8	1
Visual Check	0	61	NA	1	23	56	1	142	17
Match check	0	5	NA	0	1	0	0	2	0.2
Alcohol test	0	0	NA	0	0	1	0	1	0.1
Boiling	0	6	NA	0	53	2	1	62	7.4
Keep sample	0	1	NA	0	0	0	0	1	0.1
Tasting	0	0	NA	0	0	0	0	0	0
Total									**100**
Training									
No training	4	230	NA	12	286	322	6	860	93.9
Upto one month	3	19	NA	2	9	2	0	35	3.8
Between 1 month and 6 months	0	1	NA	0	0	1	0	2	0.2
More than 6 months	0	5	NA	4	6	1	0	14	1.5
Other	0	4	NA	0	1	0	0	15	0.6
Total									**100**
Water source									
Piped/tap	5	122	NA	12	264	108	6	517	57.3
River/stream	0	22	NA	0	4	16	0	42	4.7
Community ground pump	1	58	NA	2	12	97	0	170	18.8
Roof catchment (rain water)	0		NA	0	0	2	0	2	0.2
Private ground pump/well	1	33	NA	2	2	12	0	50	5.5
Other	0	23	NA		20	79	0	122	13.5
Total									**100**
Mode of cleaning milk containers									
Cold water/soap/ detergent/with sponge/ with steel wool	1	63	NA	7	56	135	1	263	28.7
Hot water/soap/ detergent/with sponge/ with steel wool	4	147	NA	4	230	92	5	483	52.6
Other	2	50	NA	5	16	100	0	172	18.7
Total									**100**
Storage place of containers									
Refrigerator	1	3	NA	1	19	2	0	26	2.8
Basket/bucket indoors	0	3	NA	0	10	2	0	15	1.6
Basket/bucket outdoors	0	4	NA	0	7	2	0	14	1.5
Dipped in water	0	0	NA	0	3	0	0	3	0.3
Polythene bags	0	191	NA	0	2	0	0	2	0.2
On shelf/table	2	40	NA	4	224	95	6	522	56.9
On the floor	3	40	NA	11	11	124	0	189	21
Other	1	19	NA	0	26	101	0	147	16.0
Total									**100**

Description of milk handling practices in Ghana

Trader	Coop/Farmer group	Producer-sellers	Proces-sors	W/Sellers	Retailers	Vendors/ Hawkers	Other	Total	(%)
Penalty for delivering unwholesome milk									
None	0	248	25	33	36	9	2	353	85.1
Buyer rejects	2	3	6	16	4	2	9	42	10
Shared costs	0	1	0	0	5	0	0	6	1.5
Buyer bears full cost	0	0	2	4	2	0	0	8	1.9
Other	0	0	3	1	2	0	0	6	1.5
Total									**100**
Quality control measure before receiving milk									
None	0	243	22	33	41	9	2	350	87.5
Lactometer	0	1	0	0	0	0	0	1	0.3
Oduor test	0	0	0	2	3	2	4	6	1.5
Visual Check	0	6	4	11	0	0	5	31	7.8
Match check	0	0	0	0	0	0	0	0	0
Alcohol test	0	0	0	2	0	0	0	2	0.5
Boiling	0	0	1	0	4	0	0	5	1.3
Keep sample	0	0	0	0	0	0	0	0	0
Tasting	0	2	1	1	0	0	0	5	1.3
Total									**100**
Training									
None	0	3	6	1	0	0	1	6	1.5
Self-taught	0	40	20	13	12	11	4	75	18
Family member	0	195	10	35	33	0	6	300	72.3
Friend/other practitioner	2	14	0	5	3	0	0	34	8.2
Total									**100**
Water source									
Piped/tap	0	48	15	15	17	3	2	100	25.1
River/stream	0	65	8	7	9	4	4	97	24.3
Community ground pump	0	27	5	2	4	2	1	41	10.3
Roof catchment (rain water)	0	0	0	0	0	0	0	0	0
Private ground pump/well	0	46	2	5	15	2	5	73	18.3
Other	2	59	5	20	2	0	0	88	22.0
Total									**100**
Mode of cleaning milk containers									
Cold water/ soap/ detergent/ with sponge	0	164	18	24	33	8	6	255	63.9
Hot water/soap/ detergent/with sponge	0	59	12	13	15	3	2	104	26.1
Other	2	19	5	13	1	0	2	40	10.0
Total									**100**
Storage place of containers									
Basket indoors	0	46	13	1	16	6	3	85	20.8
Basket outdoors	0	4	1	1	0	1	0	7	1.7
Polythene	0	4	0	0	0	0	0	4	0.98

bags									
On shelf/table	0	33	8	14	8	2	4	69	16.9
On the floor	0	142	13	35	22	7	2	216	52.9
Other	2	21	1	1	3	0	1	27	6.7
Total									**100**

ANNEX 1. INDICATIVE SAMPLING AND TESTIMONIES

1. Indicative sampling in Tanzania

Introduction

Results of indicative sampling and testimonies from trained market agents are reported[13]. The follow-up survey of 22 and 17 trained market agents in Dar and Mwanza, respectively, was to assess the initial impact of the communicated risk information during the training and through meetings and leaflets produced during the course of the project. Trainees were exposed to various skills including business management, milk marketing, milk handling and processing between in November 2001 by focussing on specific areas identified as needing attention during the surveys. Results of practice changes and narrations of typical personal experiences of market agents related to milk hygiene, obtained between 5th to 12 March 2002, are presented below.

Results

Practice Changes

Nearly all the market agents interviewed in the indicative survey said that they have achieved significant improvement in their business performance in various areas including processing, milk handling/quality control and in customer care. A subjective assessment ranked personal, equipment and premises hygiene of all trainees as being ‘fair’ or ‘good’. In addition, a few traders had replaced their plastic containers with metallic ones that are easier to clean and nearly all traders who did not have lactometers had purchased one. Whereas only 6% of milk traders were found to keep records during the main market surveys, virtually all of the trained traders kept records in the follow-up survey. Most kept records related to expenditure, but also sales, volumes handled and salaries.

Milk quality indicators

The high variability in the quality indicators, particularly bacterial counts, did not allow meaningful comparisons to be made between the findings in the main survey and indicative sampling considering the small number of respondents in the indicative sampling. However it was observed that in reaction to findings from the main survey that indicated a high prevalence of adulteration in Mwanza with as many as two-thirds of milk samples with SNF<8.5%. Municipal health officials became stricter in enforcing tests for adulteration, and a case of an offender being ordered to pour out adulterated milk was observed. But addition of water still occurred after traders passed checkpoints mounted by health officials. This practice was more common among employed traders.

[13] Similar reports from Ghana were still awaited at the time of writing this report.

Business plans

Only one in every six trainees had drawn business plans at the time of the indicative survey. The specific reasons for this apparent lack of interest were not clear but could be attributed to perceptions that they can get along without doing one or more information is required on the usefulness of drawing such plans. Semi-literacy and the cost of engaging a skilled expert may also play a role.

Plans for the future

The majority of trainees cited the desire to venture in addition dairy related business activities particularly processing of fermented milk, yoghurt and boiling of milk to lengthen shelf life.

Conclusions on indicative sampling

The Tanzanian project leaders expect the traders to adopt more of the disseminated skills as they access the required capital to acquire necessary inputs e.g., containers more compatible with better hygiene and inputs for processing. Regarding adulteration, punitive measures such as testing by regulators and ordering culprits to pour out adulterated milk as was observed during the survey do not seem to be adequate deterrents. Alternative mechanisms to reduce the practice, such as self-regulation and ‘quality seals’ may be a better solution. Though it was not possible to make conclusive statements on technical improvements, in general, it would be expected that improvements on factors identified in the main survey as probable influences on milk quality can have positive impact when acted upon. Narrations of personal experiences below provide some insights into personal benefits received by the market agent clients.

Narrations of personal experiences in Tanzania

Box 1

Mrs. Bupe Muikambo (Small scale milk processor in Dar es Salaam)

Mrs. Bupe Muikambo, commonly called Mama Muikambo because of the respect she has earned among peers, is a small-scale milk processor selling about 30 litrs per day. She is also the chairperson of a self-help group comprising 12 women who engage in a similar business. Asked how she had benefited from the Milk Marketing and Public Health project, Mama Muikambo replies, “I have learnt many things including the need to maintain high standards of hygiene given the milk is a very perishable commodity. I have also understood why maintaining a high level of cleanliness reduces spoilage and wastage. Before the training, I never knew that heating milk to a specific temperature and reducing time to cooling gives the milk and milk product the desired final quality. My customers prefer the milk that I sell now compared to previously”.

Mama Miukambo particularly likes two milk quality control tests that she learnt: use of a lactometer and the alcohol test. “I would like it to be known that I was not the only one ignorant about these tests”, she adds. She went on to say, “Before training, I did not know that cows may have diseases that can pass to human beings is the milk is not heat treated”. She was also able to cite nearly all the micronutrients in milk and their usefulness.

When asked about her future needs and plans, Mama Miukambo replied, “I would like to know where I could receive more training for myself and those I work with. I also wish I could access more capital and various techniques to enable me compete more effectively in the liberalized dairy market”.

Box 2

John Maguta (Milk vendor in Mwanza

John sells about 20 litres of milk per day in Mwanza. When John was asked about his experiences following training, he said: “I am one of those lucky few who got an opportunity to be trained by the project at Sokoine University of Agriculture in Morogoro in November 2001. When the researchers first came to Mwanza in 2000, we were afraid that they would stop us from doing our business of selling milk. But after sometime we realise they were on a mission to help us improve they way we handle the milk. This is important for us because sometimes we get losses when the milk gets spoilt”.

When asked to talk about any changes made after training, John said, “From the knowledge gained, I can now be more emphatic when advising farmers who supply me with milk about the need to milk hygienically, including the need to wash the udder with warm water and to disinfect the teats with a disinfectant in order to prevent mastitis. I have also changed the containers I use for transporting milk from plastic to aluminium cans. I am now able to distinguish poor quality milk by use of a lactometer and alcohol. And I am now selling more milk since my customers are more satisfied with the quality and I get less spoilage. I also now make safe sour milk”.

Box 3

Ms. Mary Sumbya (Producer-seller in Mwanza

Mary sells about 5 litres of raw milk daily. She narrated changes in her practices as follows: "For me, the most important things I learnt in the training are: a) the need for a good environment for my cows, b) hygienic milking, c) hygienic storage and how I could improve milk sales. Since attending the training I have strived to improve the cow shed by putting up a better roof and drainage for the effluents. My milker is now provided with gumboots and overcoat and detergents for cleaning of milk vessels. I have also instructed the milker on proper milking procedure.

d) My cows used to suffer a lot of mastitis but I now I use a teat dip and the disease has reduced significantly. I now use aluminium cans and any milk not sold immediately is kept in a refrigerator.

e) I no longer receive complaints from my customers regarding spoilage of milk when it is heated. I used to sell only raw milk. After the training I am now selling part of my milk after fermenting it properly".

2. Indicative sampling in Ghana

The training was carried out in three districts in Accra, namely Accra Metropolitan Area, Tema Metropolitan Area and Kasoa. The training focussed on educating market agents about hygienic ways of milk handling to improve its safety and shelf life. After the training, 35-40 market agents who had received the training were sampled in the three districts. One or more milk samples were collected from each market agent for laboratory examination of total viable bacteria count (TPC) and coliform bacteria count (CPC). These bacterial counts were then compared with the corresponding results before the training to evaluate the probable impact of the training on milk handling by market agents. The findings are summarised in the table below.

Proportions of milk samples with unacceptable CPC (>50,000 cfu/ml) and unacceptable TPC (>2,000,000 cfu/ml) before and after the training.

	CPC (%)		TPC (%)	
	CPC 1	CPC 2	TPC 1	TPC 2
Overall	28.2	25.8	35.6	70.9
Districts AMA	53.9	50	69.2	58
TMA	13.5	7.7	54.6	85.5
Kasoa	42.4	14.2	35.6	70.9
Market Agents	17.9	36.8	24	58
Producers				
Retailers	28.6	14.2	21.4	85.5

CPC1/TPC1 = Proportion of milk samples with unacceptable CPC/TPC before training CPC2/TPC2= Proportion of milk samples with unacceptable CPC/TPC after training.

Total bacteria population in milk mainly reflects time elapsed since milking and ambient temperature (if milk is not chilled), while coliform bacteria are especially associated with level of hygiene since they are mainly of faecal origin. From the table above, apart from Producers, in all cases, the proportion of milk with unacceptable CPC was lower after the training than before the training. This clearly indicates an improvement in the hygienic handling of milk after the training. TPC appeared to be higher after the training. However, this only reflects the lack of refrigeration facilities and probably the long time lapse between milking and sampling.