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Perspectives in Composite and Alternative Flour Products

Invited Paper

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ABSTRACT

This paper reviews the work carried out in recent years on composite and alternative flours, for bread and other products, with special emphasis on their potential in the Developing Countries. Technologies are now available for composite flour products and are in an advanced stage of development for wheatless products. Criteria for successful implementation include suitability and availability of raw materials, acceptability of technologies and of products, and correct economic and political environment.

DEFINITIONS

Composite flours may be considered firstly as blends of wheat and other flours for the production of leavened or unleavened baked products, and of pastas; or secondly, wholly non-wheat blends of flours or meals for the same purposes, and for indigenous foods such as porridges and for snack foods.

It should be noted that these flours serve two different functions: firstly, to lower or remove the use of wheat or other staple by partial or total substitution, for economic and / or political reasons; secondly, and not discussed here, to change the nutritional characteristics of the product, for example by protein, vitamin, or mineral enrichment: this is of marginal relevance in economic terms and is, with the exception of calcium addition, of doubtful use for nutritional requirements.

HISTORY

The subject of composite flours has been reviewed several times (for example Dendy, 1988; Fellers, 1987; D de Ruiter, 1978; Dendy et al., 1970), and bibliographies have been published (Dendy and Kasasian, 1975, 1977, 1979). In the first of these it was noted as long ago as 1975 that "though there is vast amount of scientific and technical research, one remains amazed at how little has been published on the economics of composite flour. In addition to lack of literature on economic evaluation, there is very little on actual implementation: there must be few technologies that have been so thoroughly researched and so little applied".

One reason for this was that the subject proved ideal for academic study: it was easy to attract funding and students could carry out the research with minimal resources. The scientific journals at that time seemed ever willing to publish papers on composite flour and the illusion of original research was thus easy to maintain. This may sound unkind, and, in any case, the objectives of post-graduate research are not only to make new discoveries, but to train researchers.

Actual consumer trials were rare, though in Colombia, Kenya, Nigeria, Sri Lanka and Sudan these were successful. In laboratories well-equipped by external resources, the quality of composite bread was much higher than the all-wheat bread which local bakers produced with their crude equipment, lack of process control, and infested flour.

The total number of directly relevant publications now exceeds 500. However, only three economic studies have been published (Edmunds, 1970, de Buckle, 1988, Dendy and Trotter, 1988).

The subject breaks down logically into raw materials and products, these being divided between a) leavened and b) unleavened products, c) porridges, d) pasta and e) snack foods. It is to leavened breads that the greatest research effort has, rightly, been expended. When FAO surveyed composite flour programmes in 1980 there were 72 programmes on bread, 36 on biscuits, and 21 on pasta, with nothing reported on other foods (FAO, 1980, quoted by Faure, 1988).

TABLE I

PRODUCTION OF STARCHY STAPLES in million tonnes per annum

REGION or Country	POPULATION 1989 millions	C CEREALS production	R ROOTS production	R/4 ROOTS cereal equivalent	(C + R/4) TOTAL STAPLES cereal equivalent	C/(C+R/4) CEREALS as % TOTAL STAPLES	R/4(C+R/4) ROOTS as % TOTAL STAPLES	TOTAL STAPLES Cereal Equivalent Cal/cap/diem	Total Grain Imports (Trade)
WORLD	5205	1865	615	154	2019	92.4	7.6	3825	199
Developed	1243	880	204	51	931	94.5	5.5	7381	91
Developing	3962	985	412	103	1088	90.5	9.5	2709	108
AFRICA total	629	91	120	30	121	75.1	24.9	1898	27
ASIA total	3050	822	242	61	882	93.1	6.9	2853	89

Table 2

Papers published on Composite Flour
excluding protein enrichment, milk substitutes, weaning foods, etc

	NRI Composite Flour Bibliographies					
	NRI Database CFBIB 1979-1991	G89 (1975)	G111 (1977)	G124 (1979)	Grand Total	as %
Sorghum	23	26	10	7	66	13%
Millets	12	18	8	8	46	9%
Maize	17	54	19	15	105	21%
Chenopods	1	6	1	1	9	2%
Barley & oats	6	15	4	3	26	5%
Rice	18	37	13	7	75	15%
Total Cereals	77	156	55	41	329	65%
Cassava	20	57	11	22	110	22%
Potato	0	11	7	9	27	5%
Sw Potato & aroids	1	12	1	4	18	4%
Yams	2	7	3	7	19	4%
Total roots	23	87	22	42	174	35%
TOTAL	100	243	77	83	503	100%

RAW MATERIALS

Most of the energy and much of the protein needed by mankind for survival comes from cereals, in the case of the developing countries amounting to 90.5% Of the staple foods produced (Table 1).

An examination of the literature shows the order of publications on composite flour as being: cassava, maize, rice, sorghum, the millets, potato, barley, sweet potato and yams (Table 2).

Much of the early work used cassava starch, readily available as "tapioca", and giving very good results, even at a 40% admixture with wheat flour. Other starches, such as maize, gave similar results. Nutritional needs were taken care of by adding soya or other high-protein flour to the extent that bread might have 10% protein. Cassava flour was not so successful, as the fibres punctured the dough vesiculations. One third of the papers published are concerned with flours and starches of root and tree crops. Being some 75% water content, these require processing to flours near to the place of production in order to lower costs and reduce losses in storage and transport.

In selecting raw materials for use as alternatives of whatever kind one must consider the following criteria: a) compatibility - that is to say, suitability for end use and b) availability and cost at point of use. This last is the most important and, until recently, the most overlooked.

Table 3 *

Suggested Levels for Non-Wheat Moieties in composite flour bread
(as % of total flour)

Commodity	protein content	range of levels used	realistic maximum
maize	8–10	18 - 30	30
sorghum	8–10	15 - 50	30
millets	8–10	10 - 30	30
barley	8–10	10 - 30	30
rice	8–10	10 - 25	25
cassava flour	1–2	13 - 30	30
cassava starch	0	10 - 50	50
yam	2–4	10 - 30	20
potato	2–4	6 - 30	30
sweet potato	2–4	15 - 30	30

NB. Wheat flours were of various strengths

* from NRI databases, bibliographies, and other sources

a) Compatibility - suitability for end use

Compatability has been the concern of many of the 500-plus papers referred to in Table 2: just how much non-wheat material can be included in a composite to make a product reasonably similar, though probably not identical, to that which it attempts to simulate?

Table 3 summarizes work carried out on composite flour bread in the past 25 years in many institutes worldwide. Leavened bread of the conventional Western type is, for reasons discussed elsewhere (Dendy, 1988; Dendy, et al., 1970; Fellers, 1987), more difficult to make from composites or non-wheat materials than are other products. It would seem that for most commodities, however well prepared for incorporation, there is a limit of 30%. Beyond that the product ceases to resemble bread, though it may have selling characteristics of its own - a point that deserves more emphasis.

The Basic Criteria for the quality of raw materials are:

firstly: for a composite, wheat flour of reasonable strength - preferably over 12% protein (N x 5.7);
secondly: clean, fine flour from the non-wheat source. This should be free from specks of coloured bran or, in the case of roots, skin, and of as low a coarse fibre content as is attainable. The colour should be as white as possible and free from any taint or strong odour.
thirdly: the raw materials must be consistent, so as to give a predictable performance.

In small scale operations using locally available materials such as fresh cassava, these points may not be as important (Crabtree et al., 1978)

b) Availability and Cost at point of use

Some composite flour programmes failed because of lack of a regular supply of raw materials. Wheat mills have no difficulty in arranging regular imports. However, to arrange for thousands of tonnes a year of any agricultural product to be bought and brought, either processed or not, from perhaps many small farms to a central point, requires an extremely high level of planning, a good transport infrastructure, suitable storage, plus the technological capability to ensure high and consistent quality.

Climate and soil are also of paramount importance. With much of the world's agricultural land already fully used just to provide subsistence farmers with their needs, not every country has an agriculture capable of producing increased quantities of grains or roots for new uses. Rural as well as urban populations have increased to the extent that the surpluses once potentially available for the towns are disappearing. Less, rather than more land is available for these surpluses. Thus it is probably only possible to grow surpluses for conversion to alternative flours by adopting modern, highly intensive, agriculture - and this must be done if the burgeoning urban populations are to be fed from local resources: the urban population of the developing countries will exceed 50% by the year 2020.

Cost considerations will also limit availability of raw materials. Production costs can sometimes be made up of a high percentage of external currency - for example, in Zambia in 1988, 73% of local wheat production costs, using modern farming technology, were in foreign exchange, so that the savings made by local production compared to importation were really quite low. For small-scale production by traditional agriculture, even if there is a surplus, it will be small and scattered, with ensuing problems of collection; and with increased cost of transport and of quality control. Proper supervision to ensure clean and uniform material is labour and technology intensive.

Transport costs for the local raw materials, for whatever use, will be paramount in determining whether the alternative flour is economically viable in the predetermined political climate. In developing countries the cost of road transport - and there is rarely much else - is made up mainly of external costs. The trucks, tyres, fuel and most of the cost of the road itself - in some cases even the tarmac - are hard currency external charges. As with the cost of production and processing, every case must be assessed on its own merits: all one can do is highlight points to consider. In 1988 it was found that the cost of transport in Tanzania - a country where composite flour ought to succeed - was over ten US cents per tonne kilometer. Thus, the cost of transporting sorghum from a principal producing region (Dodoma) to the capital (Dar) was some 50% of the cost of imported wheat landed there at world prices at the then legal rate of exchange.

Two principal points emerge from this discussion: 1) that the raw materials for alternative flours must be produced and processed as near to the production or user point as possible and 2) that competing imports must either be banned or costed at their true value. This will mean devaluation of currency to the level of the parallel rate, and costing grain imports at a true and unsubsidized production cost, eliminating from the costing the subsidies given to the farmers of Europe and North America.

Processing costs of the cereals and root crops can be high in terms of external currency: essential ingredients for the end use - such as yeast, hardened fats, emulsifying and oxidizing agents - may have to be imported. It is possible for developing countries to manufacture yeast, glyceryl monostearate, and hydrogenated oils - indeed, some do so already. The capital cost of the plant to manufacture these will, in part, be external, as will the education in technology needed to run such enterprises. Nonetheless, the cost is not high in terms of the benefits, and can be considered part of an essential industrial base.

Cereals.

Cereals are durable and give high yields of usable food material; they can therefore be transported to the mill and processed into suitable flours.

The traditional method of processing local cereals is quite labour intensive, inefficient and time consuming with often very low yield and poor quality flour. Modern milling systems are therefore essential if good quality flours are to be made. If wheat mills are available, as is usually the case, then these can be used with little modification to manufacture improved flour from maize, sorghum or pearl millet by using the new semi-wet milling technique in a conventional roller mill (Cecil, 1986). By this method red sorghum can be milled to almost white flour using a standard roller mill, but, instead of tempering the grain with the conventional 2 to 4% water, as for wheat, "unprecedentedly high quantities of tempering water - as much as 20% - are necessary". The technique can be used for co-milling, tempering the wheat with 2% and the other grain with 20% added water (Crabtree and Dendy, 1979). This technique would be particularly appropriate in countries where there is a surplus of roller-milling capacity, as happens when strong Governments ban or limit wheat imports.

Other new technologies are available for preparing flours from sorghum or one of the millets - such as the PRL (Prairie Research Laboratory, Canada) or the Schüle Decomatic dehullers. The product is a pearled grain which can be milled to flour by simple hammer milling.

With proper preparation, up to 20 or even 30% non-wheat flour can be used in a composite.

Root crops

Processing of cassava into starch involves washing and peeling of the roots, which are then wet-milled in a hammer mill and washed through a mesh and the starch is collected in concrete pits. It will settle quite swiftly, and the supernatant water can be run off, the starch dug out and sun-dried: it is not necessary to use centrifuges and other expensive equipment for the processing of cassava starch.

For other roots, the processing involves cleaning, peeling, slicing, drying - perhaps in the sun or a solar dryer - and hammer-milling to flour. Unlike cereals, roots are extremely dirty when delivered, so that washing is very important. A plentiful supply of clean water, preferably chlorinated, is essential. Because of their relative perishability compared to cereals, root crops must be processed near to the place of production.

Protein Supplements

The use of soya as protein supplement has often been discussed in papers on composite flour as being nutritionally desirable, but at the level of 10 to 20% addition needed it will give the bread a strong flavour even with high quality soya. Researchers tended to forget that protein supplements are not commonly available in most developing countries in the quality required, if at all. As with the emulsifying agents so often needed to provide good crumb structure, supplements are very expensive in terms of external currency. Other protein flours derived from already available raw materials, including groundnuts, coconuts and leaves, were experimented with but gave bread of poor flavour, colour, structure or volume. Protein supplements are necessary if root crop flours or starches are used, but are not needed if the alternative is of cereal origin.

PRODUCTS

LEAVENED BREADS

Dendy and Trotter (1988) have described how the bread habit was acquired in developing countries unable to grow wheat, and they examined the possibilities for reducing or eliminating wheat imports.

There are four possible ways of continuing the bread habit yet controlling the expenditure on imported wheat:

i) to use composite flour;
ii) to use a wheatless alternative;
iii) to increase the imported price of wheat, thus making bread a luxury food;
iv) to produce wheat locally.

One must remember that any attempt to adjust wheat consumption patterns is a highly political issue. However, increasing the price of imported wheat could encourage the use of composite flour. iii) and iv) are outside the scope of the present discussion and are adequately covered elsewhwere (Dendy and Trotter, 1988; Andrae and Beckman, 1985).

Unfortunately for the economies of these tropical and usually poor countries, imported wheat must be paid for in hard currency, as must most of the cost of milling, transport, and, as already noted, where the climate is suitable, of growing wheat. The donation in aid programmes of wheat, rather than a cereal which is already grown locally, perpetuates the bread habit, leading to a dependence on imported food (for a full discussion of the economics of this see Dendy and Trotter, 1988; Andrae and Beckman, 1985).

i) Use of Composite Flours - blends of wheat and non-wheat flours.

The opportunities exist for composite flour where some wheat is available locally or can be imported without undue economic strain, and local flours can be blended into the wheat flour for breadmaking.

Table 3 showed the proportion of non-wheat material that can reasonably be incorporated into conventional leavened bread.

At the SADCC/ICRISAT International Workshop on Policy, Practice and Potential Relating to the Uses of Sorghum and Millets in 1988 it was acknowledged that in composite flour there was mature technology awaiting adoption, and that "in wheat importing countries and countries with some but insufficient local wheat, composite products should be given high priority". The knowledge is available from at least eight regional or international technological institutes. Breeders at the CGIAR institutes are now aware of the criteria needed for new varieties even better suited to use in composites than those currently available. Problems of adoption are mainly economic and political.

ii) Wheatless bread

Wheatless bread is even older in concept than composite bread, but until recently attracted little attention from scientists. Leavened foods are attractive and easier to digest than unleavened, so that it has always been thought desirable to try to leaven, by a fermentation or by the use of the steam generated during baking. However, efforts to make a material which is truly like bread have not yet succeeded due to technological difficulties in producing a stable structure without the inclusion of wheat or its extracted gluten. Whether or not it is legitimate to describe such foods as "bread" is debatable, as in many countries bread is defined by law to be a wheaten product. Laws, however, can be changed, and in a world where wheat is less available than previously for the developing countries, and with transport costs set to rise as fossil fuels become more scarce, it is the wheatless products from alternative flours that will be needed.

The discovery by de Jongh (1961) that a dough structure could be formed using starch with surfactants such as glyceryl monostearate was taken up by his colleagues Kim and de Ruiter, who applied it to their work on wheatless breads, and studied the effect of various structural agents including pregelatinized starch on dough stability, developing a cassava bread.

Casier et al., (1976) described a process for making wheatless bread from sorghum and millet, using water insoluble pentosans isolated from wheat and rye as the structural agent. However, the drawback of using most emulsifiers, surfactants and various structural agents is their limited availability and high cost in developing countries.

Interest in wheatless bread was revived in 1988 as a result of Morton Satin's description of a method for making wheatless bread without the use of emulsifiers or surfactants. The method relies on gelatinizing a portion of the non-wheat flour, which becomes highly viscous and helps in stabilizing the dough structure (Satin, 1988).

Recent work carried out at NRI for FAO has confirmed the possibilities of using pregelatinized starchy materials to provide structure to a leavened bread. Though not quite like wheaten bread, the products are attractive, and the concept is deserving of further research and, later, good promotion. Work at NRI on rolls from 100% sorghum flour confirms that it is with small goods that we can incorporate the greatest proportion of sorghum.

The 1988 ICRISAT meeting emphasised that countries with little or no wheat production should direct both breeding and processing research to wheatless products. Wheatless "bread" has tremendous potential (Satin, 1989), and, unlike composite flour bread, has been little researched either technically or economically. For the latter, one suspects that the same political and pricing considerations are as paramount as in the case of composite flour products.

The technology is not yet "on the shelf" for wheatless bread as it is for composite flour bread. Alongside improvements to the wheatless bread technology must be appropriate publicity: these are to be thought of as new foods, not poor substitutes.

UNLEAVENED BAKED GOODS

i) Unleavened Bread

Unleavened bread forms the basic food of many people: chapattis (roti) in South Asia, tortillas in Latin America, sorghum flatbreads in N.Africa and Arabia, oatcakes in Scotland.
Some literature has been published mainly from India, on the use of sorghum alone or in mixtures with wheat for chapattis. Indeed, some three-quarters of the sorghum grown in India is used for chapattis.
Though problems of dough cohesion exist, these can be overcome relatively easily. The CFTRI group found that varieties of sorghum with good dough rolling characteristics - and hence good cohesion in the chapatti - showed lower gelatinization temperature, higher peak viscosities, higher setbacks in the viscograph. Amylose, protein and prolamine fraction content had no relation to rolling quality (Chandrasekera and Desikachar, 1983)

ii) Other Baked Goods - especially biscuits and cookies

Biscuits and cookies can be made successfully from composites and, less easily from wheatless flours. For biscuits containing high levels of sugar and fat, and using, conventionally, wheat flour of low gluten content there is less need for gluten.

In West Africa a popular form of commercial unyeasted product is "cabin bread". This is a hard biscuit made from wheat flour, salt, water and a carbonating agent: the gluten binds the whole together so that the dough, which is developed in powerful mixers, adheres well. Work at NRI shows that this type of biscuit can be made from sorghum or maize flour, using a custard process, in which some of the flour is boiled in water, and then the rest of the flour is added. The gelatinized starch binds the dough together so that it may be rolled and cut. Successful pilot scale trials have been carried out.

PORRIDGES, DUMPLINGS, ETC

These are made by cooking a slurry of meal or flour in water. All cereals are used. The various products have been described (Murty and Rooney, 1984). Some are fermented - usually by lactic fermentation using a barm or the native spores on the grain. Both thin and thick porridges are used: the latter being of a cake-like consistency and called dumplings or knödeln in Europe: the former, called gruels, are drinkable. Whatever the base cereal, and porridges are found throughout the world and throughout History, one principle holds for thick porridges, dumplings and cakes - that the product sticks together well, so that pieces may be broken from the lump. Thus, the starch must be gelatinized so as to bind the whole.

Provided that starch gelatinization characteristics are compatible, there seems to be no problem in making these foods from blends of flours.

PASTA PRODUCTS

These manufactured foods are becoming increasingly popular and can be made with almost any raw material. Though the tonnages consumed are low in developing countries, the subject of pasta from composite flour has been researched quite thoroughly. An important point to remember is that there are very few pasta factories in developing countries: thus, if the products are found to be acceptable to the consumers, and at a reasonable price, the market can expand as a new product rather than an inferior substitute as might be the case with composite bread. With few suppliers, the industry should be easy to organize (Faure, 1988).

SNACK FOODS

In the modern world snack foods are becoming increasingly important as sources of nourishment as well as being hedonic foods. The usual substrate is maize.

At NRI we have made extruded snacks with both red and white sorghum and pearl millet, flavoured with cheese or autolysed meat and spices.

To promote the use of local crops to townspeople, much depends on the image as being not coarse or old-fashioned, but modern and "up-market". Snack-foods have a modern and very up-market image, so that the use of local materials will enhance the image of the local grains.

CRITERIA FOR SUCCESS

Criteria for a successful Composite Flour programme have been outlined (Dendy, 1988) and can be applied to any alternative flour technology. One must also bear in mind that it may be necessary to introduce novel processing methods and equipment along with the novel ingredients, thus making the educational element of greater importance.

The following steps are necessary when setting up a programme:

1. An economic study to evaluate the balance between the savings on imports and the investment needed for the purchase of processing equipment.

2. A technical study to determine the level of use of the alternative that may be achieved under local conditions, together with a market survey on the acceptability of the products. Consumer organisations and the press must be won over early on in the programme. Education of the consumer may also be necessary.

3. A definite decision by the Government to proceed with a national implementation programme, followed by a formulation of policy on composites flours and on staple food supply. This is of paramount importance, and must be parallelled by the formulation and adoption of a policy on importation of wheat.

4. A programme of increased production of suitable local crops with the provision of incentives to encourage farmers to grow the commodity. This is also of paramount importance. It may be that cash crops can be more economically exchanged for imported food staples.

5. The selection and installation of processing and blending equipment with due regard to the necessary coöperation of the miller and others already involved in the cereal/root crop based industries.

6. The training of the baker and other "downstream" manufacturers in the use of the alternatives. In the case of bread baking, the bakers must be involved in discussions from the inception of the programme.

7. The formulation of quality standards for the alternative flours and their retail products.

CONCLUSIONS:

What then can one conclude from all the work that has been done - indeed, still is being done - on composite flours and wheatless substitutes?

The raw materials will generally be cereals rather than rootcrops and with increasing desertification and the ongoing change in World climate, the cereals to use will tend to those of the semi-arid tropics - that is, sorghum and the millets.

The breeders and manufacturers should co-operate closely so that varieties are tailored to suit the new end-uses. Purchasers need to impose the quality standards required by manufacturers, offering price incentives so that the farmers grow and offer a uniform, varietally homogeneous, and clean grain.

Good publicity is essential to show that alternative products made from local raw materials are not just poor substitutes. Composite flour and wheatless products can succeed if they are acceptable as foods, at the right price, given good marketing.

With the possible exception of entirely wheatless bread, and certain blends for industrialized indigenous foods, the technologies are mature enough for almost immediate adoption. In every case, what is needed is the political will to do it and the economic environment for it to succeed, free from the artificial pricing of commodities and currencies.

Composite flour products will be used first, but, in the longer term, will be superseded by wheatless products as it becomes uneconomic for suppliers to produce and transport surpluses, and the poorer countries to purchase them.

Composite flour and wheatless products may succeed if they are acceptable as foods, at the right price, given good marketing.

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