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SWEET POTATO KETCHUP: FEASIBILITY, ACCEPTABILITY, AND PRODUCTION COSTS IN KENYA

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ABSTRACT

Ketchup sauce is increasingly a popular condiment used as a flavouring ingredient in fast-food businesses in East African urban areas. It is one of a myriad of products that can be made using sweet potato *(Ipomoea batatas)* roots. We assessed the feasibility, consumer acceptability, and cost of production for a ketchup sauce made by substituting tomatoes with sweet potatoes. The final product, in which up to 80% tomatoes were substituted with sweet potato, was found to be organoleptically acceptable in Nairobi. The yellow flesh colour of the sweet potato had a good influence on the final consumer preference of the product. Adding sweet potato to the ketchup formulation had little influence on the final pH, which ranged from 3.8 to 4.1. Titratable acidity values ranged from 0.36 to 0.60 g (acetic acid) per 100 g sauce. Shelf life test indicated that a ketchup sauce incorporating sweet potato could safely be stored for 2 to 3 months. The addition of sweet potato in the ketchup formulation significantly reduced the production cost of the sauce.

Key Words: East Africa, French-fries, *Ipomoea batatas*, post-harvest, sauce

RÉSUMÉ

En Afrique de l'Est, la sauce "ketchup" devient de plus en plus un condiment populaire pour aromatiser les frites dans les commerces urbains d'aliment prêt-à-emporter; en plus, elle est parmi plusieurs produits dont on peut fabriquer à partir de la patate douce. Dans cet article, nous avons évalué la faisabilité, l'acceptabilité par les consommateurs et le coût de production de cette sauce, fabriquée en substituant de la matière première habituelle, de la tomate, par de la patate douce. La sauce dont le remplacement de la tomate par de la patate douce est allé jusqu'à 80%, a été trouvé acceptable sur le plan sensoriel. L'utilisation de la patate douce à chaire jaune a eu un effet bénéfique sur la préférence du produit par les consommateurs. L'addition de la patate douce dans la formulation de cette sauce a eu peu d'influence sur le pH final du produit, et ce dernier a oscillé entre 3,8 et 4,1. L'acidité titrable a varié entre 0,36 et 0,60 d'acide acétique par 100 g de sauce. Le test de durée de vie du produit a montré que le produit fini pouvait être entreposé pendant 2 à 3 mois sans détérioration ou danger pour les consommateurs. L'addition de la patate douce a réduit sensiblement le coût de production de la sauce.

Mots Clés: Afrique de l'Est, après-récolte, frites, *Ipomoea batatas*, sauce

INTRODUCTION

Sweet potato (*Ipomoea batatas*) is an important food crop in East Africa, and plays a major role as a famine reserve for many rural and urban households. This is because of its tolerance to drought, short growth period, and high yield with limited inputs on relatively marginal soils (Ewell, 1993; Bashaasha *et al.*, 1995). Its utilisation is currently very narrow; it is essentially consumed boiled in the fresh form. The limited range of ways and availability on the market of adapted processing technologies in which sweet potato is utilised in the East Africa region, seriously undermine the potential benefits which the crop can offer to farmers and consumers (Hagenimana *et al.*, 1998). It is unlikely that further genetic development of the crop will be successful unless full attention is paid to its end uses as food, animal feed and as an industrial raw material.

There is a myriad of products that can be made using low priced sweet potato as a major ingredient (Ge *et al.*, 1992). Sweet potato processing into products with a taste and appearance similar to other marketable processed items has proven to be cost-effective enough to make them competitive (Hagenimana and Owori, 1997; Omosa, 1997), and manufacturing of these products would benefit:

- farmers through creation of better markets for sweet potato and participation in an integrated production-processing-marketing system to add value to their produce;
- food processors through the use of a reliable, low price, abundant and nutrient-rich raw material; and
- consumers through the access to low-priced and nutritious products.

Sweet potato is a starchy commodity whose proximate composition, mineral and vitamin content-particularly vitamin A is comparable to various fruits (Woolfe, 1992). This similarity in composition of sweet potato and fruits served as the basis for development of several food products in Asia like candies, jam, juice, and ketchup sauce (Truong, 1992).

Ketchup is a popular condiment now used in daily meals of many urban East Africans, as a flavouring ingredient in various culinary recipes. It goes exceptionally well with one of the fastest growing fast-food industry of French fries in urban areas of East Africa (Walingo *et al.*, 1997). Hollingsworth (1997) recently indicated that the sustained growth in the staggering popularity of fast-food cuisine paralleled a long-term trend towards eating more meals on the go and behavioural changes almost always tended to be convenience driven.

Traditionally, ketchup is prepared from tomatoes (*Lycopersicon esculentum*). Tomatoes are a very perishable and expensive raw material, mainly grown in East Africa using a heavy input of pesticides (Muroki *et al.*, 1997), and their use in processing ketchup dramatically increase the production costs of the sauce. The main characteristics of a fast-food ingredient, however, should be its low price, local availability and be produced in large quantities to meet the high demand.

To overcome the tomato-related problems and reduce the costs of production for the popular ketchup sauce, a study was undertaken to substitute tomatoes by more available and low-priced sweet potatoes in ketchup processing and assess the acceptability of the end product by consumers from Nairobi, Kenya.

MATERIALS AND METHODS

Plant material. Fresh sweet potato roots from Koganesengan (CIP440118 cultivar) and Chinchano (CIP420051 cultivar) were provided by the breeding service of the International Potato Centre (CIP), regional office in Nairobi, Kenya. These cultivars were randomly chosen from a list of 80 cultivars and differed in dry matter content and flesh colour. Sweet potatoes were grown during the short-rainy season of 1996 at the University of Nairobi, at Kabete. Medium-sized sweet potato roots were maintained under ambient air conditions, washed, and processed 3 days after harvest. Ripened *Romav* variety tomatoes used in this study were purchased from a local market in Nairobi.

Dry matter determination. Two whole roots were randomly selected from each cultivar, washed, and divided into small cubes. Dry matter content was determined by drying triplicate 20-g samples at 65°C for 72 hr in a forced-air oven.

Ketchup preparation. Sweet potato roots were washed, trimmed, peeled and cut into chunks and then boiled. The boiled chunks were pureed using a Philips blender type HR2810 Standmixer, and the sweet potato puree consistency was adjusted to a mash by adding water. Tomato juice extraction involved heating of tomatoes before breaking in order to inactivate pectolytic enzymes, which would otherwise lower the quality of the juice and reduce the yield. Heated tomatoes were broken up and then mashed to produce a slurry, which was slowly cooked until a homogeneous product was obtained. The homogeneous slurry was filtered to remove seeds and peels, and the total solids of the juice stepped up to 10% using sugar. The tomato juice and sweet potato mashes were then used to make further trials. Table 1 shows the different combinations of tomato juice and sweet potato slurry. Some combinations required addition of colour adjustment with 100% tomato ketchup as a standard.

The sweet potato and/or tomato slurry was placed in a cooking pan together with a tied muslin bag, containing spices, i.e., pepper *(Capsicum annuum)*, chilli (*Cayenne* pepper), chopped onions *(Allium cepa)* and garlic *(Allium sativum)*, and the required amount of water added and heated slowly to enable the diffusion of the spices from the cloth to the sweet potato and/or tomato slurry. At 15°Brix, salt and sugar were added. Cooking continued until 28°Brix, with vinegar slowly added before the end of cooking. The prepared ketchup was bottled, capped, cooled, and tasted a week after its processing.

Carotenoid determination. Carotenoid content was determined as described by Imungi and Wabule (1990). Total carotenoids were extracted in acetone from 2-10 g samples of fresh sweet potato roots or tomatoes until the extract was colourless. The acetone solution was transferred to a separating funnel and the pigment was transferred into petroleum ether (40-60°) and the acetone layer discarded. The petroleum ether extract was brought to 100 ml and then, 25 ml of the extract was concentrated using a rotary vacuum evaporator at 30°C. The residue was dissolved in 1 ml of petroleum ether, and the solution introduced onto a silica gel chromatographic column with β-carotene (C-9750, approx. 95%, Sigma, St. Louis, USA) as standard. Separation was run using petroleum ether and the β-carotene fraction collected. Absorbance was read at 440 nm using a spectrophotometer. Concentrations were determined by comparison with a standard curve developed using pure β-carotene from Sigma.

Other measurements. pH, total soluble solids, and total titratable acidity were determined according to standard food analysis methods (Pearson, 1976).

TABLE 1. Experimental combinations of sweetpotato slurry and tomato juice

Combinations		Actual quantities				
Sweet potato (% dry weight)	Tomato (% dry weight)	Sweet potato mash (g)	Tomato slurry (mL)	Water (mL)	Food colour (mL)	Caramel (mL)
100	0	140	0	830	50	0.5
90	10	126	127	747	35	0.5
80	20	112	224	664	32	0.4
70	30	98	321	581	25	0.2
60	40	84	418	498	16	0.0
50	50	70	500	415	16	0.0
0	100	0	1000	0	0	

Sensory evaluation. Sensory analysis of ketchup quality was performed by an untrained panel consisting of 20 students and staff of the Department of Food Science and Nutrition, University of Nairobi, in a laboratory designed for sensory testing of foods. Ketchup samples were evaluated for quality acceptability (taste, flavour, colour, and overall acceptability) on a 9-point hedonic scale of 1=extremely dislike and 9=extremely like (Watts *et al.*, 1989). Analysis of variance using the Statistical Package for Social Sciences (SPSS) programme was carried out to compare the difference in ketchup quality as affected by the addition of sweet potato. Where significant differences were found, the Least Significant Difference (LSD) test was run to sort out the homogeneous subsets at $P \leq 0.05$.

Shelf life test. The accelerated shelf life test was used (Gooding and Duckworth, 1957). Ketchup samples were held at 55°C, 75-80% RH, and at this high temperature, each day stability of the pH and total soluble solids was considered to be equivalent to one month stability of the product in the real conditions.

RESULTS AND DISCUSSION

Raw material composition. Some characteristics of the raw material are shown in Table 2. Chinchano (CIP420051) sweet potato cultivar had the highest dry matter of 30% and tomatoes, the lowest. The colour of the raw material was, respectively, yellow, white and red for Koganesengan (CIP440118), Chinchano (CIP420051) sweet potato cultivars, and tomatoes. β-Carotene content was higher in yellow fleshed sweet potato cultivar than in the white, confirming previous results of Takahata *et al.* (1993), Ameny and Wilson (1997), Low *et al.* (1997), and K'osambo *et al.* (1998) that the intensity of orange colour of the flesh of sweet potato roots is attributed to high carotenoid content.

Product characteristics

Colour. The colour of ketchup ranged between yellow and red (Table 3). Standard ketchup made from tomatoes was dark orange, almost red and similar to that where sweet potato substituted tomato up to 60%. The colour of all the products was highly pleasant and was dark yellow for ketchup made from 100% sweet potato, cultivar Koganesengan (CIP 440118). Flesh colour of the root had good influence on the end product. We noted that yellow-fleshed sweet potato, cultivar Koganesengan (CIP 440118), required less food colour than the white-fleshed coloured cultivar Chinchano (CIP420051), and this trend was expected to be more pronounced if the colour of sweet potato were deep orange.

pH. The pH of the product was measured using a pH meter (Pye Unicam, model 290 Mk2). pH is an important measurement of eating quality since it contributes to taste. Table 3 shows the pH for the ketchup produced using different combinations of sweet potato and/or tomato. The pH of the ketchup was acidic and ranged from 3.8 to 4.1. Addition of sweet potato in the recipe had little influence on the pH of the product. This acidic range guarantees the keeping quality of the product in storage (Lopez, 1980).

Total soluble solids. Total soluble solids were between 29 and 35° Brix. Table 3 shows the range of total soluble solids in ketchup made using different combinations of sweet potatoes and tomatoes. The total soluble solids according to the Kenya Bureau of Standards regulation should

TABLE 2. Some characteristics of the main raw materials used in ketchup preparation

Material	Flesh colour	Dry matter (%)	β-carotene content (mg/100 g dry weight)
SWEETPOTATO			
Koganesengan (CIP440118)	Yellow	23.9	0.42
Chinchano (CIP420051)	White	30.0	0.11
TOMATO	Red	7.9	0.79

be minimum 28° Brix (Kenya Bureau of Standards, 1990). Therefore, these ketchup formulations meet the minimum requirement for the Kenyan consumers.

Titratable acidity. Total titratable acidity was determined in the ketchup by direct titration with NaOH and calculated as percent of acetic acid. All the combinations involved an equal amount of vinegar. Titratable acidity values ranged from 0.336 to 0.600 g acetic acid per 100 g ketchup (Table 3). The variability in the titratable acidity observed within different combinations may be due to the initial acidity in the raw material or to the length of cooking time after the vinegar was added. Also, apart from ketchup samples made from 100% tomatoes, other combinations required colour adjustment by red and/or yellow food colours after the vinegar had been added to the product. Vinegar having a pronounced influence on colour, the high value of titratable acidity observed in the ketchup made from 100% tomato could be explained by the fact that in such samples, no colour adjustment was required. Therefore, cooking time after the vinegar was added, was generally less than for other combinations, involving less chemical changes in the product.

The Brix to acid ratio reported in Table 3 is an important characteristic for the ketchup since it is an indication of the product sweetness with implications on the taste and the eating quality. A very high ratio indicates a sweet product; when too low, it means an acidic product although the acidic taste might be masked by the sugar.

Our results in Table 3 indicate that ketchup samples having sweet potato had very high ratios. Samples where up to 60% of tomato was substituted by cultivar Chinchano (CIP420051) sweet potato had a ratio Brix to acidity similar to that of 100% tomato ketchup. However, more substitution of the tomato increased that ratio (Table 3). This was explained by the high sugar content found inherently in the sweet potato which increased when more and more sweet potatoes were used into the recipe.

Sensory evaluation. The main sensory attributes of sweet potato and tomato ketchup are shown in Table 4. Ketchup made from Koganesengan (CIP440118) sweet potato cultivar had a generally

TABLE 3. Main characteristics of sweet potato and tomato ketchup

Combinations			Ketchup characteristics			
Sweet potato (% dry weight)	Tomato (% dry weight)	Colour	pH	Total soluble solids (°Brix g acetic acid/100g ketchup)	Titratable acidity	Ratio (Brix/Acidity)
Chinchano (CIP420051)						
100	0	Orange	3.8	34	0.336	101.2
90	10	Orange	4.0	33	0.384	85.9
80	20	Orange	4.0	31	0.408	76.0
70	30	Orange	4.1	30	0.390	76.9
60	40	Dark orange	4.1	35	0.588	59.5
50	50	Dark orange	3.8	33	0.564	58.5
0	100	Dark orange	4.0	34	0.600	56.7
Koganesengan (CIP440118)						
100	0	Dark yellow	3.9	31	0.363	85.4
90	10	Light orange	4.0	32	0.447	71.6
80	20	Light orange	4.0	31	0.417	74.3
70	30	Orange	4.1	30	0.507	59.2
60	40	Orange	4.1	29	0.486	59.7
50	50	Dark orange	4.1	34	0.597	57.0

higher score of acceptability for taste, aroma, appearance, and overall acceptability when the substitution was above 80%. However, at such high level of tomato substitution, the ketchup was not acceptable to most of the consumers. Cultivar Chinchano (CIP420051) made an acceptable ketchup up to the substitution of 70% (Table 4), while Koganesengan (CIP440118) scored high acceptability up to substitution of 80%. The highest scoring combination was of 100% tomatoes which got a mean of 8.2 as the most preferred ketchup followed by the ketchup made from the substitution of 50% using cultivar Chinchano (CIP420051) sweet potato. Our results suggest that a good choice of sweet potato cultivar could highly enhance the sensory scores, especially the taste and overall acceptability. Using Student t-test, taste and overall acceptability were higher for the yellow-fleshed cultivar than for the white-fleshed one at 1% level. We also observed that the yellow colour of the sweet potato flesh had a good influence on the panellist preference for the ketchup.

Shelf life test. The pH and total soluble solids (° Brix) measurements were taken as major indicators for the stability of the ketchup. Figure 1 shows the pH variation during the test of shelf life of ketchup samples where 100, 70, 50, and 0% sweet potato cultivar Koganesengan (CIP440118), was used in the recipe. There was a clear decrease in pH from the second day indicating an acidification of the product. This may be due to hydrolysis of inherent starch to glucosidic products by acetic acid at high temperatures. The total soluble solids showed a slight increase, which was not significant. The colour of the product tended to darken with increase in storage days and the consistency of the products changed slightly. These changes were, however, significant for the

TABLE 4. Main sensory attributes of sweet potato and tomato ketchup

Combinations		Sensory panellist scores[a]				
Sweet potato % of the dry weight	Tomato % of the dry weight	Taste[b]	Aroma[b]	Appearance[b]	Overall acceptability[b]	Panellist preference (rank)
Chinchano (CIP420051)						
100	0	5.1±2.0	5.2±1.5	5.4±1.5	5.1±1.8	5.1(11)
90	10	5.7±2.0	6.5±1.3	6.4±1.0	6.2±1.9	6.3(9)
80	20	6.1±2.1	6.4±1.5	6.8±1.3	6.4±1.5	6.4(8)
70	30	6.6±1.6	6.5±1.4	6.9±1.2	6.8±1.3	6.8(6)
60	40	6.5±2.1	6.5±1.6	7.7±1.0	7.0±1.4	7.0(4)
50	50	7.3±1.5	6.8±1.3	7.5±1.1	7.3±1.3	7.3(2)
0	100	8.0±0.7	8.0±0.8	8.0±0.8	8.2±0.7	8.2(1)
Koganesengan (CIP440118)						
100	0	6.1±1.6	6.0±1.6	5.0±1.5	5.8±1.5	5.8(10)
90	10	6.6±1.4	6.3±1.5	6.4±1.2	6.7±0.9	6.7(7)
80	20	6.7±1.5	6.7±1.0	6.8±1.0	7.0±0.8	7.0(4)
70	30	7.1±0.9	6.8±0.7	7.0±0.8	7.1±0.7	7.1(3)
60	40	6.9±1.2	6.4±1.2	7.1±0.9	6.9±1.3	6.9(5)
50	50	6.7±1.8	6.7±1.3	7.2±1.1	7.0±1.2	7.0(4)

[a] Quality characteristics were evaluated on a 9-point hedonic scale of 1=extremely dislike and 9=extremely like
[b] Mean ± STD

sample made using 100% sweet potato. The changes observed during the shelf life test indicated that the ketchup incorporating sweet potato could safely be stored for 2 to 3 months.

Production costs. Table 5 shows the calculated costs of a 200-ml bottle of ketchup made using different combinations of sweet potato and tomato. The prices are only indicative, and are based on the raw material bought at the retail stores from Nairobi City Market. The more the concentration of tomatoes used in the combinations, the more expensive the production costs of the ketchup was. The price was Kenya shillings (Kshs) 34.30 (US$ 0.57) for 200 ml of ketchup made out of 100% tomato. When sweet potato was used, the products were much cheaper (Table 5). The substitution of 50% tomato by sweet potato gave a product costing Kshs 22.20 (US$ 0.37) per bottle, for both varieties, while that of a 100% substitution gave a ketchup costing of only Kshs 10.50 (US$ 0.18) per 200 ml.

CONCLUSION

The study has shown that tomatoes can be substituted with sweet potatoes in ketchup manufacture. The sensory evaluation results indicated that the panellists were unable to distinguish combinations containing sweet potatoes between 50 and 80%. They were, however, able to distinguish ketchup having 100% sweet potatoes from other types of ketchup combinations. Flesh colour of the root has a significant influence on the colour of the final product, the orange colour giving a better product. The concentration of sweet potatoes in the ketchup formulation has a significant influence in the

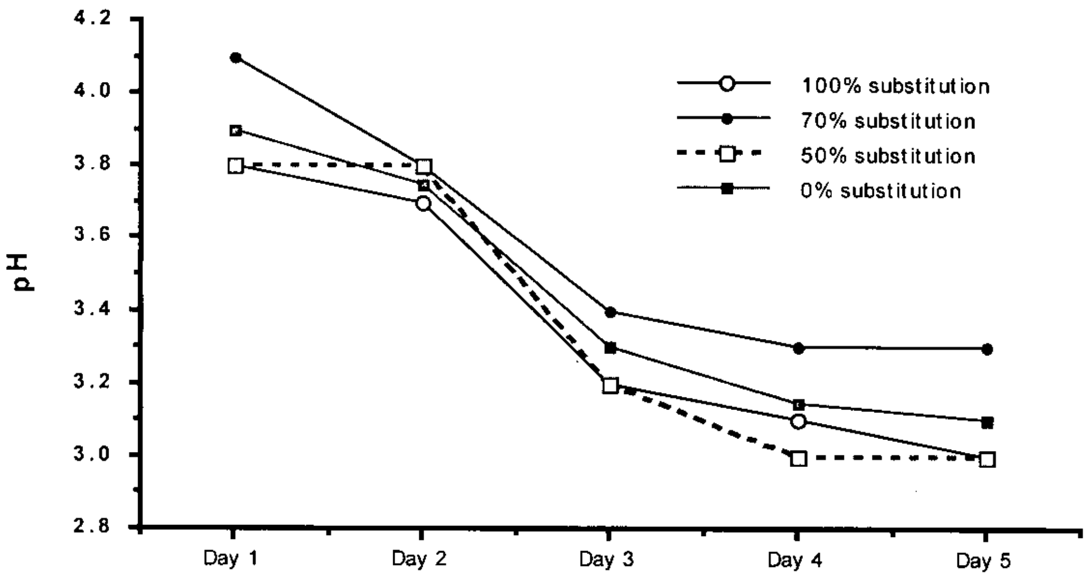

Figure 1. pH variation in the ketchup shelf life test. Samples were incubated at 55°C, 75-80% RH. 100, 70, 50, and 0% represent, respectively, samples where 100, 70, 50, and 0% sweet potato roots of cultivar *Koganesengan* (CIP440118) was used in the recipe.

TABLE.5. Production costs of sweet potato cv. Chinchano (CIP420051) and tomato ketchup

Combinations		Production costs, KShs
Sweet potato (% dry weight)	Tomato (% dry weight)	
100	0	10.50
90	10	13.50
80	20	15.80
70	30	17.90
60	40	20.20
50	50	22.20
0	100	34.30

Kshs = Kenya shillings (1 Kshs. = 0.017US$)

reduction of production costs. More work is still needed in the formulation and adjustment of ketchup texture where 100% sweet potato has been used.

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