Effect of tempe and sodium metabisulphite on the microbiological quality, development of rancidity, and sensory quality of Nile perch (*Lates niloticus*) sausages

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Abstract

The conventional method of beef and pork sausage manufacture was adopted for processing fish sausage from Nile perch (Lates niloticus) *fillets. Four types of sausage were made: sausages with 0.02% sodium metabisulphite (MCS); sausages with 10% tempe (TCS); sausages with 0.02% sodium metabisulphite and 5% tempe (MTCS); and sausages with neither tempe nor sodium metabisulphite (SWTM). The proportions are given based on the weight of the fish fillet. Each type of sausage was divided into two equal halves. One half was stored at 5°C while the other half was stored at 20°C. The keeping quality was monitored over seven days by determination of the total plate count to assess microbial spoilage and extent of rancidity development as measured by absorbance of their light petroleum (40°–60°C) extract at 269 nm. The organoleptic quality was assessed by 18 untrained panelists and 3 trained panelists. It was found that tempe had antimicrobial effects but little antioxidant activity, whereas sodium metabisulphite had little antimicrobial activity but greatly reduced the content of secondary lipid oxidation products and possibly inhibited lipid oxidation. The overall acceptability of the sausages was high (scores of about five points on a seven-point hedonic scale).*

Introduction

Fish are one of the most important sources of proteins in the world. The other sources of animal protein, red meat and poultry, are more expensive, especially in developing countries. In Kenya most of the fish is exported. The most popular fish are tilapia (*Oreochromis* spp) and sardines (*Rastrineobola argentea*), locally referred to as *omena*.

The introduction into Lake Victoria of Nile perch (*Lates niloticus*), which accounts for 60% of the fresh fish caught in Kenya [1], has resulted in a rapid decrease in the tilapia population. Although tilapia is preferred, the Nile perch is the most widely consumed fish in East Africa because of its availability. Large numbers of dead Nile perch, which the fisherman have been unable to sell, can be found on some beaches.

The price of Nile perch varies from Ksh 25.00 to 45.00 per kilogram, which would translate to US$1.02 to $1.87 per kilogram, compared with US$3.80 and $2.25 for chicken and red meat (beef and pork), respectively.

The methods available for preparing fish in East Africa include smoking, sun-drying, deep frying in shortening or fish oil, or frying to make a sauce to eat with *ugali* (a semisolid cake made from cereal flours). Refrigeration is the predominant method of preservation, used by retailers in urban centres and by fish processors who export fish fillets. In Japan and Thailand, fish are used to make sausages, *kamamboko* (meat loaf), and fish protein concentrates [2, 3].

Sausages are readily accepted in many communities. In Japan fish sausages are made by combining fish fillets with seasonings and preservatives, adding binding agents such as starch and rusk, and finally smoking after stuffing in artificial casings and scalding [3].

The major limiting factor in the use of fish is their rapid spoilage at high ambient temperatures, such as those found in the tropics. Fish have inherent proteolytic and lipolytic enzymes in the pyrolic caeca and intestines [4]. The intestines, together with the microbial flora, are responsible for the rapid spoilage of fish after they are caught.

Fish oils are highly unsaturated and are hence susceptible to the development of hydrolytic and autoxidative rancidity [3]. Hydroxyperoxides form the central mechanism for lipid oxidation. According to Farmer's theory, the reactions proceed through a free-radical mechanism [5]. Hydroxyperoxides are themselves nonvolatile and odourless but have a slightly bitter after-

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taste [5]. The secondary products derived from them contribute to the rancid flavours. These compounds include aldehydes, ketones, alcohols, and hydrocarbons [5]. The extent of formation of secondary oxidation products can be assessed by measuring absorbance at 269 nm [6].

Rancidity is normally accompanied by deterioration of flavour and colour changes, loss of vitamins (especially vitamins A and E), and destruction of sulphur-containing amino acids [5]. Side reactions between products of fat oxidation and proteins may cause textural changes as well as lowering the digestibility of protein and hence of amino acids [5].

The shelf-life of fresh fish is limited to 48 hours [7]. It can be prolonged by refrigeration. However, the ambient temperatures under tropical conditions cause rapid melting of ice. The comminution of fish fillets, as in the manufacture of sausage, allows the use of additives for preservation. The most widely used preservatives are nitrites, nitrofurans, sorbic acid, and semicarbazones, all of which inhibit microbial growth [3, 8, 9].

Sodium metabisulphite is an additive known to have fewer health hazards than other preservatives. Metabisulphites are reducing agents and may inhibit lipid oxidation. The antioxidant activity of sulphur dioxide is related mainly to the unbound non-ionic form [8]. Its effectiveness in killing or inhibiting microorganisms is most pronounced at pH values less than 4. Nevertheless, sodium metabisulphite is used in meat products even when the pH would not be expected to be below 5.3 to 5.4.

From a safety point of view, the naturally occurring preservatives in some foods and spices are preferable to chemical additives [9]. Tempe, an Indonesian *Rhizopus* mould-fermented legume, cereal, or cereal-legume mixture, is a low-cost traditional food product. It is one such food that can be used for this purpose. The calculated cost of tempe, taking into account 30% of the total processing cost, is Ksh 44.00 (US$0.73) per kilogram, which is 20% to 50% less than the cost of meat. Thus, tempe is within the reach of members of most socio-economic groups as a major source of protein and vitamins.

Tempe has both antimicrobial and antioxidative properties [10]. Wang et al. reported an antimicrobial compound in tempe [11]. Tempe is also reported to contain 6,7,4-trihydroxyisoflavone, which has antioxidative activity [12].

This paper presents data on the microbial count, pH, lipid oxidation secondary products (as measured by absorbance at 269 nm), and sensory characteristics of four types of Nile perch sausages containing tempe and sodium metabisulphite, during and after seven days of storage at 5° and 20°C. These data are used to compare the antimicrobial effects, extent of development of rancidity, and overall eating quality of the sausages.

Materials and methods

Materials

Refrigerated fish fillets obtained from the Nairobi city market were wrapped in a 200-gauge polythene bag and stored in a freezer at –1°C for preparation the following day. The pre-refrigeration handling history of the fillets was not known. Soya beans were purchased from the Uthiru supermarket in Nairobi. *Kimbo* (a shortening made by East African Industries), starch, and salt were obtained from the Uchumi supermarket in Nairobi. The tempe mould culture (*Rhizopus oligosporus*) was obtained from the Research and Development Centre for Applied Chemistry in Bandung, Indonesia. Casings were purchased from Naturin-Werk, Weinheim, Germany. All chemicals were obtained from Kobian Chemicals in Nairobi.

Preparation of tempe

Whole beans were sorted, washed in clean water, and boiled for 30 minutes to soften the husks. The beans were soaked for 24 hours in an air oven at 35°C in three times their weight of water. The beans were then dehusked by rubbing them between the hands, and the husks were rinsed away with water. The clean beans were cooked in boiling water for 45 minutes. The water was drained, and the beans were cooled to ambient temperature (20°C). The beans were surface-dried in the sun for 3 hours, after which they were inoculated with a starter culture of *R. oligosporus* at the rate of 0.1% based on the weight of the dry beans and packed in 200-gauge polythene bags that had been perforated with a 2-inch nail at intervals of 1 cm. The inoculated beans were incubated in an oven at 35°C for 24 hours, at which time they were evenly covered with white mould mycelia. The tempe was harvested by removing it from the polythene bags and slicing it into $1 \times 2 \times 1$ cm pieces. These were dried in an air-circulating oven at 60°C and then ground in a coffee attrition mill (Dittings, Switzerland). The tempe was moistened to 60% moisture and made into a dough that was blanched for 20 minutes to inactivate the mould and kill any microorganisms present before use.

Preparation of the sausages

Four different types of sausages were made (see table 1): sausages with 0.02% sodium metabisulphite (MCS), sausages with 10% tempe (TCS), sausages with 0.02%

TABLE 1. Recipes for the different types of sausages[a]

Ingredients	SWTM		MCS		MTCS		TCS	
	g	%	g	%	g	%	g	%
Fillet	1,000	100	1,000	100	1,000	100	1,000	100
Starch	100	10	100	10	100	10	100	10
Fat (kimbo)	100	10	100	10	100	10	100	10
Tempe	–	–	–	–	50	5	100	10
NPS[b]	20	2	20	2	20	2	20	2
Sodium tripolyphosphate	–	–	2	0.2	2	0.2	2	0.2
Sodium metabisulphite	–	–	0.2	0.02	0.2	0.02	0.2	0.02
Black pepper	2	0.2	2	0.2	2	0.2	2	0.2
Sage	2	0.2	2	0.2	2	0.2	2	0.2
Nutmeg	2	0.2	2	0.2	2	0.2	2	0.2

Abbreviations: SWTM, sausages without tempe or sodium metabisulphite; MCS, sausages containing 0.02% sodium metabisulphite; MTCS, sausages containing 5% tempe and 0.02% sodium metabisulphite; TCS, sausages containing 10% tempe.

a. Proportions (%) of ingredients shown are based on the weight of the fish fillet.

b. Nitrite pickling salt (99.95% NaCl and 0.05% $NaNO_2$).

sodium metabisulphite and 5% tempe (MTCS), and sausages with neither tempe nor sodium metabisulphite (SWTM).

Increasing the tempe content above 15% decreased the acceptability of the sausages, mainly because the sausages disintegrated instead of holding together. Therefore, no attempt was made to increase the tempe content above 10%. The sausages were processed as follows: 1 kg of fish fillet was cut in a Killia (Zurich) meat cutter three times. Nitrite pickling salt (99.95% sodium chloride and 0.05% sodium nitrite) was added and the mixture was ground two more times. One millilitre of strawberry red colour was added, along with shortening, spices, polyphosphate, and sodium metabisulphite (for MCS and MTCS), and the mixture was ground another three times. Starch was added to all samples, and tempe was added to the MTCS and TCS sausage mixtures, which were ground again to bind them. The sausage mixtures were stuffed into 6-cm, 500-gauge polythene casings. These were then scalded in a Fressman (Zurich) smoking cabinet at 90°C to a core temperature of 75°C for 1 hour. The sausages were cooled with cold water to 20°C.

Storage of the sausages

Each sausage sample was cut in half. One half was stored at 5°C and the other one at 20°C for 7 days for analysis according to the schedules and methods described below.

Microbiological analysis

After 4 days, 11 g of sausage was weighed into 99 ml of saline solution (8.5%) and macerated in a kitchen blender (Croydon, England). Serial dilutions were then made to a dilution of 10^{-6}. Dilutions of 10^{-5} and 10^{-6} were plated in duplicate in plate count agar (PCA) and incubated at 35°C for 48 hours, and the numbers of colonies in plates with visible growth were counted.

Chemical analyses

Determination of pH

A 10-g sample of sausage was weighed out and ground with a mortar and pestle. Boiling water was added to the ground sausage in a 20-ml flat-bottomed flask, which was then shaken at 100 rpm for 30 minutes on a Gerber (Zurich) shaker. Three pH readings were taken with a model 290 MK2 pH meter.

Determination of the extent of production of secondary products of lipid oxidation

A 10-g sample sausage was weighed out in a tared crucible and then dried in an air-circulating oven at 80°C for 6 hours. The sample was crushed with a mortar and pestle and transferred into a 250-ml flat-bottomed flask. One hundred millilitres of light petroleum (40°–60°C) was added, and the contents were agitated on the Gerber shaker at 200 rpm for 1 hour. The extract was filtered through Whatman No. 1 filter paper, and the residue was washed three times with 10 ml of light petroleum. The washings were combined with the extract. The absorbance of the filtrate was then read at 269 nm in a Beckmann spectrophotometer.

Sensory analysis

The sausages that had been held at 5°C for 4 days were evaluated three times at 2-week intervals by a panel of 18 for appearance, odour, flavour, texture, and overall acceptability on a 7-point hedonic scale (7 = liked very much, 6 = liked moderately, 5 = liked slightly, 4 = neither liked nor disliked, 3 = disliked slightly, 2 = disliked moderately, and 1 = disliked very much) according to Larmond [13]. The data were subjected to analysis of variance, also as described by Larmond.

Results and discussion

Microbiological quality

TCS had the lowest total microbial count at both 5° and 20°C after 7 days (table 2). At 5°C, the total count (5.0×10^6 cfu/g) was about 20 times lower than that of SWTM, which had the highest count (2.4×10^7 cfu/g). This indicates that tempe has strong antimicrobial effects. This is also clear from the observation that its incorporation in sodium metabisulphite-containing sausages (MCS) decreased the total count by about 53% (from 1.6×10^7 to 7.0×10^6 cfu/g), as shown by the results for MTCS, whereas incorporation of sodium metabisulphite reduced the total count of SWTM by about 33% (from 2.4×10^7 to 1.6×10^7 cfu/g) in comparison with MCS. The total count for sausages containing 10% tempe (TCS) was in fact 31.3% of the total count for sausages containing sodium metabisulphite only (MCS) and about 11% that of MTCS, which had 5% tempe and 0.02% sodium metabisulphite. This indicates that at the acceptable and allowed levels, sodium metabisulphite has a weaker antimicrobial effect than tempe. These results may have been partly due to the high pH of the sausages (table 3). High pH conditions cause dissociation of metabisulphite, which is otherwise most active in the form of undissociated sulphurous acid (H_2SO_3) [5].

That tempe had a very strong antimicrobial effect may be attributed to the presence of an antimicrobial substance produced by *Rhizopus* mould [11]. This compound is a glycopeptide that is very effective against gram-positive bacteria, which include the food-poisoning *Staphylococcus aureus* and *Clostridium* species.

At ambient temperature (20°C), the pattern was similar to that at 5°C. The counts in all the samples reached the slime limit of 10^8 [4], which is the limit indicative of microbial spoilage. At 20°C TCS containing 10% tempe had a microbial count (8.0×10^8) which was 20% of that of SWTM (a reduction of 80.8%). The reduction when 5% tempe and 0.020% sodium metabisulphite were added (50%) was much lower than that observed in TCS. When sodium metabisulphite alone was added, there was practically no reduction (table 2). This could be because sodium metabisulphite is broken down to release sulfur dioxide, which may be bound to carbonyl compounds of oxidized fat. The odour of the sausages suggested that indeed sulphur dioxide was being released. The antimicrobial effect shown by MTCS (containing 5% tempe) is, therefore, mainly due to tempe, which has superior antimicrobial activity.

TABLE 2. Total microbial count (cfu/g) of different types of sausages stored at 5°C and 20°C for 4 days[a]

Sausage type	5°C	20°C
SWTM	2.4×10^7	4.0×10^9
MCS	1.6×10^7	3.0×10^9
MTCS	7.0×10^6	2.0×10^9
TCS	5.0×10^6	8.0×10^8

Abbreviations: SWTM, sausages without tempe or sodium metabisulphite; MCS, sausages containing 0.02% sodium metabisulphite; MTCS, sausages containing 5% tempe and 0.02% sodium metabisulphite; TCS, sausages containing 10% tempe.
a. The values are averages of two readings.

TABLE 3. pH changes of different types of sausages stored at 20°C for 7 days[a]

Sausage type	Day 0	Day 1	Day 4	Day 7
SWTM	6.9	6.8	7.2	6.7
MCS	6.9	7.2	7.1	7.1
MTCS	6.7	6.9	6.7	7.1
TCS	6.7	6.8	6.7	6.8

Abbreviations: SWTM, sausages without tempe or sodium metabisulphite; MCS, sausages containing 0.02% sodium metabisulphite; MTCS, sausages containing 5% tempe and 0.02% sodium metabisulphite; TCS, sausages containing 10% tempe.
a. The values are averages of three determinations.

Change in pH

There were no marked changes in the pH of the sausages over the whole storage period (table 3). The pH remained above 6.7 for all the samples at both 5°C and 20°C. However, the incorporation of tempe in both MTCS and TCS resulted in lower pH values than in MCS and SWTM. The pH of all four samples was, however, above the pH for acidic foods and would thus have little inhibitory effect on the growth of microorganisms, which indicates that the lower total microbial count in tempe-containing sausages was due mainly to its antimicrobial effects. The high pH observed is further supported by Eskin's observation that the pH of fish hardly ever falls below 6.0, even at full rigour [14].

Production of secondary lipid oxidation products

The extent of formation of secondary lipid oxidation products, as shown by absorbance at 269 nm, which is indicative of the degree of development of rancidity, is shown in tables 4 and 5. All the sausage types showed a similar pattern during storage both at 5°C and at 20°C. At 20°C, the highest degree of rancidity development was shown by TCS, as indicated by its absorbance (1.23) after 7 days of storage. The next highest absorbance (1.13) was shown by SWTM, which was 92% of that

TABLE 4. Ultraviolet absorption by secondary products of lipid oxidation of sausages stored at 20°C for 7 days[a]

Sausage type	Day		
	1	4	7
SWTM	0.04	0.17	1.13
MCS	0.04	0.11	0.32
MTCS	0.13	0.24	0.57
TCS	0.26	0.49	1.23

Abbreviations: SWTM, sausages without tempe or sodium metabisulphite; MCS, sausages containing 0.02% sodium metabisulphite; MTCS, sausages containing 5% tempe and 0.02% sodium metabisulphite; TCS, sausages containing 10% tempe.
a. The values are averages of three readings.

TABLE 5. Ultraviolet absorption by secondary products of lipid oxidation of sausages stored at 5°C for 7 days[a]

Sausage type	Day		
	1	4	7
SWTM	0.13	0.17	0.27
MCS	0.04	0.15	0.19
MTCS	0.12	0.23	0.39
TCS	0.23	0.43	0.52

Abbreviations: SWTM, sausages without tempe or sodium metabisulphite; MCS, sausages containing 0.02% sodium metabisulphite; MTCS, sausages containing 5% tempe and 0.02% sodium metabisulphite; TCS, sausages containing 10% tempe.
a. The values are averages of three readings.

of TCS. This clearly shows that tempe did not have antioxidant effects in the sausages. In fact, it appeared to increase the rancidity. The next highest level of secondary products of lipid oxidation was shown by MTCS, whose absorbance was 0.57, 46% of that of TCS and 50% of that of SWTM. The observation that MTCS (containing 5% tempe) had lower absorbance than TCS (containing more tempe) or SWTM, which was expected to have the highest absorbance, clearly shows that sodium metabisulphite not only reduced lipid oxidation in tempe-containing sausages but also inhibited their oxidation in SWTM.

The sausage containing sodium metabisulphite only (MCS) had the lowest absorbance (0.32), which was 26% of that of TCS, 36% of that of SWTM, and 56% of that of MTCS. These results further confirm that sodium metabisulphite had antioxidative effects or that it reduced the development of rancidity, whereas tempe increased rancidity or susceptibility to rancidity. This observation may be due to reactions between sulphurous acid ions and carbonyl groups of the secondary oxidation reaction.

Similarly, at 5°C the degree of rancidity increased with time during storage (table 5). The sausages containing 10% tempe (TCS) also had the highest degree of rancidity (as indicated by their absorbance of 0.52) over the storage period. The sausages with 5% tempe (MTCS) had the second highest degree of rancidity, as shown by the absorption by their secondary oxidation products, which was 0.39 (75% of that of TCS). The sausages with neither tempe nor metabisulphite (SWTM), which at 20°C had the second highest absorbance, had the third highest degree of rancidity at 5°C, with an absorbance of 0.27, 52% of that of TCS. The least rancid sausages were those with metabisulphite only, as was the case at 20°C. These had an absorbance of 0.19, which was only 36.5% of that of TCS.

The above results suggest that metabisulphite strongly reduced the development of rancidity, had strong antioxidative action, or both. The fact that MTCS ranked second after TCS clearly shows that tempe enhanced the rancidity in proportion to the amount added to the recipe. The higher absorbance of SWTM than MTCS at 20°C may have been due to the binding of practically all the SO_2 to the carbonyl compounds and at the same time an increase in the amount of carbonyl compounds due to the presence of tempe (which, as shown above, appears to increase the amount of oxidized lipids).

The degree to which the formation of secondary oxidation products was reduced when the temperature was lowered from 20° to 5°C varied according to the type of sausage. After seven days of storage, SWTM showed the highest reduction factor (4.19). This shows that the reduction was due purely to a low-temperature effect. The next highest reduction factor was observed for TCS (2.37). This was followed by 1.68 and 1.46 for MCS and MTCS, respectively, which were not significantly different. The fact that the sausages with metabisulphite had lower reduction factors suggests strong antioxidative action, inhibitory effects, or both on the development of rancidity by sodium metabisulphite. The similarity of the two reductions indicates that the decrease in temperature had little influence.

The higher level of rancidity in sausages containing tempe may have been due to the failure of the antioxidant 6,7,4-trihydroxyisoflavone [12] to be effective in fat, since it would be in the polar phase.

The observed high absorbance in sausages containing tempe supports observations made by others showing that although tempe is resistant to oxidation [9], it has little antioxidant activity in food systems or when mixed with flours.

Sensory quality

Sausages with 10% tempe (TCS) were significantly different from the rest in terms of taste ($p < .05$) and had the highest score (5.57) (table 6). Although MTCS was not significantly different from MCS and SWTM, it had a higher score for taste (5.26). This shows that the presence of tempe in the sausages enhanced taste. SWTM

TABLE 6. Sensory evaluation of different types of sausages

Sausage type	Taste	Appearance	Odour	Texture	Acceptability
SWTM	5.05^a	5.72^a	5.20^a	5.72^a	5.60^a
MCS	4.47^a	4.78^b	4.30^a	4.78^a	4.70^b
MTCS	5.26^a	4.56^b	4.50^a	5.33^a	5.06^b
TCS	5.57^b	5.44^{ab}	5.40^a	5.72^a	5.40^{ab}

Figures in the same column followed by the same letters are not significantly different from each other at $p = .05$. Each score is the average of 54 observations.

had the third highest taste score (5.05) and MCS had the lowest (4.47). From this observation, it is clear that sodium metabisulphite decreased taste scores.

There were no significant differences in odour scores among any of the samples ($p > .05$). As was the case with taste, TCS had the most acceptable odour (with a score of 5.40), followed by SWTM, which had a score of 5.20. The odour scores for MTCS and MCS were generally very low (4.50 and 4.30, respectively) and bordered on rejection. This could be attributed to a faint sulphurous odour, which was noticed in these sausages.

Three trained panelists noticed a weak fish odour in SWTM, but none of them noticed this odour in any of the other sausages. The relatively high preference for the odour score of SWTM indicates that the fish odour and taste are weak in the Nile perch fillet.

It is important to note that tempe appeared to improve the odour of the sausages, since sausages with tempe (TCS and MTCS) had higher scores than those without tempe (MCS).

There were also no significant differences in appearance among MCS, MTCS, and TCS ($p > .05$). The sausages with neither tempe nor sodium metabisulphite (SWTM) had the highest score (5.72) and were significantly different from sodium metabisulphite-containing sausages (MTCS and MCS) ($p < .05$) but had a score which was not significantly different from that of TCS (5.44), with 10% tempe but no sodium metabisulphite. A relatively intense colour was noticed in SWTM, whereas that of TCS was very light. It is important to note that the cost of sausages would be decreased by about 6% by adding tempe at the rate of 10% (7.5% based on the weight of the sausage mass).

The metabisulphite-containing MCS and MTCS (containing 5% tempe) were less preferred and had lower appearance scores (4.78 and 4.56, respectively). These did not have any trace of strawberry red colour. Thus, it appears that sodium metabisulphite bleached the colour, whereas tempe reduced the rate of bleaching, probably by producing reducing conditions. Sulphurous acid is known to reduce pigments. The residual red colour in MTCS is due to the presence of tempe. It is possible that the creation of reducing conditions decreased the destruction of the colour. Absorption of the colour by tempe could also have accounted for decreased colour destruction.

There were no significant differences in texture among the samples ($p > .05$). The texture scores of SWTM and TCS (5.72 in both cases) were the highest. The next highest texture score was that of MTCS (5.33). The sausages containing sodium metabisulphite only had the lowest score (4.78). Incorporation of tempe to a level not exceeding 10% improved the texture of the sausages.

There was no significant difference in acceptability between SWTM and TCS ($p > .05$). However, SWTM had the highest acceptability score (5.60). TCS, which had a score of 5.40, was not significantly different from MCS and MTCS, which scored 4.70 and 5.06, respectively. The least acceptable sausage (MCS) had the lowest scores for the other four attributes: taste, odour, appearance, and texture. It is important to note that with respect to nearly all the attributes except taste, the ranking was similar to that of acceptability. Taste, a factor expected to influence acceptability, had, therefore, little influence on acceptability.

The observation that sausages containing neither tempe nor sodium metabisulphite (SWTM) had the highest acceptability was unexpected. It is possible that a long period of storage, even at low temperature, resulting in increased rancidity could make these sausages less acceptable than those containing sodium metabisulphite (MCS).

Since the sausage did not have a fish flavour, which is disliked by most people of the non-fish-eating communities in Kenya, especially those in the Central and Eastern Provinces, other products, such as "meat loaf," may be consumed in the future. The tempe-containing sausages would be particularly attractive to workers and schoolchildren, for whom sausages and chips are the most popular lunch meal, mainly because of their palatability and their relatively low cost compared with sausages prepared from other meats.

Conclusions

Acceptable sausages can be made from Nile perch (*Lates niloticus*) fillets without the addition of either tempe or sodium metabisulphite. However, the addition of tempe to decrease microbial activity and hence increase keeping quality is recommended. Tempe, apart from having strong antimicrobial effects, enhances the overall eating quality through improved taste and texture when incorporated at a rate of 10% (based on the fish fillet, i.e., 7.5% of the sausage mass). It has, however, little antioxidative effect in fish sausages and lowers their cost. Sodium metabisulphite is recommended to decrease the rate of development of rancidity arising from the accumulation of secondary products of lipid oxidation.

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References

1. Ogunja JC. Recent development in the Nile perch (*Lates niloticus)* and sardine/omena *(Rastrineobola argentea)* processing in Kenya. In: Proceedings of the FAO expert consultation on fish technology in Africa held in Accra, Ghana, on 22–25 October 1991. FAO Fisheries Report No. 467. Rome: Food and Agriculture Organization, 1991: 175–85.
2. Suzuki T. Fish and krill protein processing technology. London: Applied Science Publishers, 1981.
3. Borgstrom G. Fish as food. Vol. 1. New York and London: Academic Press, 1961:242–7.
4. Muroki NM. Meat science and technology lectures. Nairobi, Kenya: Department of Food Technology and Nutrition, University of Nairobi, 1996.
5. Allen JC, Hamilton RJ. Rancidity in foods. 2nd ed. London and New York: Elsevier Applied Sciences, 1989.
6. Seow CC. Food preservation by moisture control. London and New York: Elsevier Applied Sciences, 1988.
7. Oliele TK. Quality of fish in Kenya and existing problems. In: Proceedings of the FAO expert consultation on fish technology in Africa held in Lusaka, Zambia, on 21–25 January. FAO Fisheries Report No. 329. Rome: Food and Agriculture Organization, 1985:430–2.
8. International Commission on International Foods. Microbial ecology of food. Vol. 1. Factors affecting the life and death of microorganisms. London and New York: Academic Press, 1980.
9. Bannen AL, Davidson PM. Antimicrobials in foods. New York and Basel: Marcel Dekker, 1983.
10. Packett LV, Chen H, Liu JT. Antioxidant potential of tempe as compared to tocopherol. J Food Sci 1971;36:798–9.
11. Wang HL, Ruttle DI, Hesseltine CW. Antimicrobial compound from soybeans fermented by *Rhizopus oligosporus* (33930). Proc Soc Exp Biol Med 1969;131:579–83.
12. Prawirharsono S, Sregar E, Matondang TH. Investigation of isoflavones and microorganisms in tempe. In: Hermana, Mahmud MKMS, Karyadi D, eds. Second Asean Symposium on non-salted soybean fermentation held in Jakarta, Indonesia, on 13–15 February 1990. Bogor, Indonesia: Nutrition Research and Development Centre, Ministry of Health, 1990:77–82.
13. Larmond E. Laboratory methods for sensory evaluation of food. Ottawa: Food Research Institute, 1977.
14. Eskin NAM, Henderson HM, Townsend RJ. Biochemistry of foods. New York and London: Academic Press, 1971.