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Instrumental-sensory evaluation of texture for fish sausage and its storage stability

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ABSTRACT: Distinct formulations of fish sausage were developed from commercially underutilized fish caught from the coastal regions of the Sultanate of Oman. The storage stability of the products was evaluated microbiologically at –20°C for 12 weeks and once that was deemed to be satisfactory, quality assessment was implemented. The latter focused on the instrumental and sensory attributes of texture. In a first series of experiments, the level of starch in the formulation was varied from 0 to 48% (w/w of raw fish). Results demonstrated that instrumental hardness correlated strongly with the sensory hardness and both attributes increased in magnitude with higher starch additions to the preparation. However, no correlation was observed for firmness, brittleness and adhesiveness, a result indicating a weakness in the customary definition of these instrumental/sensory attributes for valid implementation of the quantitative descriptive analysis. Finally, affective testing argues that textural desirability is achieved in formulations containing 8% starch, and the overall consumer acceptability is improved further with the addition of selected spices to the product.

KEY WORDS: **fish sausage, storage stability, texture profile analysis, texture, underutilized fish.**

INTRODUCTION

Increasingly, seafood is being used as the dish of choice owing to its healthy image and delicious taste. In particular, the fish industry has been developing processed or minced fish products such as fish burgers, fingers and sausages, which add cooking convenience to nutritional benefits. Fish sausage is a product in which fish flesh is mixed with additives, stuffed into suitable casings and heat processed.[1] Although a wide range of fish species can be used, dark muscled fish such as mackerel and tuna are not recommended to be used as raw materials since they produce dark blackish red spots after processing.[2] Furthermore, products are usually prone to deterioration during frozen storage due to protein denaturation and lipid oxidation.[3,4]

The former process is attributed to the toughening up of the major muscle protein, actomyosin, which also leads to loss of water holding capacity and dryness. Protein stability can be assessed through determination of its solubility in a salt solution,[5,6] while peroxide value is employed to determine rancidity.[7,8] It was found that fish could be protected from rancidity to a great extent with decreasing the temperature from –3 to –35°C.[9] Color is another important quality index for fish products but it deteriorates during frozen storage leading to unappealing discolored products.[10,11] Color loss can be minimized at extremely low storage temperatures, i.e. –35°C and below.[12]

Regarding the growth of infectious microorganisms, Ravishankar *et al.*[13] conducted shelf life studies of fish sausage prepared from minced meat using different preservatives such as potassium sorbate (0.2%) or glucono-δ-lactone (0.3%), either singly or in combination. Their results indicated that sausages prepared with the combined use of preservatives had a longer shelf life and remained acceptable for 7 days at room temperature (~26°C), which was extended to 65 days at cooler storage (2°C). Krishnaswany and Patel[14] carried out similar work at room temperature and 37°C on fish

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sausage manufactured on a semi pilot-plant scale. Furyl-furamide in combination with potassium sorbate conferred the longest shelf-life to the product, which extended to 50 days at room temperature. Furyl-furamide alone worked for about 30 days at the same temperature. At 37°C, the shelf-life of fish sausage with the above combination of preservatives was comparatively shorter, i.e. between 20 and 25 days.

Consumer expectations of high eating quality characteristics dictate that processed products are made in the presence of hydrocolloids in order to improve the functionality of fish proteins as structural ingredients. Recent work by Kasapis *et al.*[15] demonstrated the utility of such 'additives' in the organoleptic properties of minced fish embodiments, which utilized milk and soy proteins, citrus pectin, bovine gelatin and κ-carrageenan. Thus the large deformation properties were examined using compression testing, and instrumental textural attributes were related to the overall acceptability of the product on the basis of a hedonic scaling method. Distinctive upper and lower bounds of the values of hardness, firmness, adhesiveness, and the ratio of inflection to maximum stress were defined in relation to optimum sensory acceptability of the preparation.[16]

Gomez-Guillen and Borderias[17] studied the effect of elevated temperature of processing and sodium chloride concentration on the ultrastructure and texture of gels made from giant squid in the presence of starch, carrageenan and egg white. Structural improvements judged *via* rheology were found in hydrocolloid-fortified formulations and sodium chloride addition of 1.5%. This was attributed to carrageenans forming an independent network that does not form conformationally or electrostatically specific enthalpic associations with segments of other polymeric ingredients in the formulation.[18] The continuous carrageenan network assisted the principal structural network of the fish protein to retain water thus providing support to starch and egg white filler domains.

The coastal areas of the Sultanate of Oman are rich in fish resources, however, no attempts have been made to benefit the economy *via* secondary processing of the raw material. The value of marine fish production would be enhanced considerably if it could be converted into a processed material like fish sausage and exported to the lucrative markets of the region and beyond (Al-Musalami SJ, unpubl. data, 2005). To support such an undertaking on a sound technological basis, this work was undertaken with the following aims: (i) assess the storage stability by measuring bacterial load; and chemical composition of the end product; (ii) study the effect of starch on sensory and instrumental textural attributes of fish sausage made from underutilized marine catch; and (iii) compare the sensory perception with the instrumental texture profile analysis.

MATERIALS AND METHODS

Fish resource and remaining sausage ingredients

Geelbeck croaker *Atractoscion aequidens* was caught from the Arabian Sea, filleted by Oman Fisheries Company, Ghala, Sultanate of Oman, and supplied to the Sultan Qaboos University (SQU) laboratory in 20 kg boxes for storage at –20°C pending experimentation. Fish sausage formulations consist mainly of filleted fish and corn starch, which was added to enhance the texture of the final product. The formulations for the texture analysis were [concentration for starch (S): kg/100 kg raw fish fillet, water (W): kg/100 kg fish sausage]: A (0, 65.1), B (4, 63.2), C (8, 61.5), D (16, 51.2), E (24, 56.6), F (32, 53.9), G (40, 52.9), H (48, 50.6). Other ingredients in the above formulation are (kg/100 kg fish fillet): table salt 2.5, sugar 0.7, vegetable shortening 10, white pepper 0.2, onion 0.1, nutmeg powder, 0.1, garlic 0.06. Formulations for overall sensory preference were prepared by adding different spices keeping the starch content 8 kg/100 raw fish fillet and water contents around 58 kg/100 kg fish sausage (Table 1).

Sausage processing

Fish were headed, gutted, and the visceral mass was removed. Gutted fish was filleted mechanically or with knives. Fish fillets were first chilled at 2°C usually for 2–3 h and then frozen for a week to imitate a commercial production process. Around 2 kg of fish sausage was developed in the laboratory by mincing in a chopper with crushing and fine cutting. Sausages were formulated by blending appropriate amounts of fish meat with starch and other spices. Fish mince was then inserted into sausage casings using a hand held sausage filling machine (JICA, Japan). Products were stored at –20°C for 12 weeks and analyzed periodically for microbial growth, chemical composition, color, etc. Regarding the organoleptic studies, 14 formulations of fish sausage were stored for one week at –20°C. Thawed samples were analyzed for instrumental and sensory texture after cooking on a hot plate with a thin layer of vegetable oil. Finally, commercially available fish sausages were purchased fresh from a local grocery and processed under the same conditions as for the in-house preparations.

Table 1 Formulations of fish sausage for overall sensory preference assessment

	Formulations of sausage					
Ingredients	I	J	K	L	M	N
Fish fillet (g)	100	100	100	100	100	100
Corn starch†	8	8	8	8	8	8
Milk powder†	2	4	3	3	3	3
Sugar†	0.7	0.7	1.3	1.3	1.3	1.3
Table salt†	2.5	2.5	2.3	2.3	2.3	2.3
Garlic fresh†	0.7	0.7	0.7	0.7	0.7	0.7
Onion fresh†	0.7	0.7	0.7	0.7	0.7	0.7
Nutmeg powder†	0.3	0.3	–	–	0.3	0.3
Ginger fresh†	–	–	0.3	0.3	0.3	0.3
White pepper†	0.2	0.3	0.3	0.3	0.3	0.3
Black pepper†	–	–	–	0.3	0.3	0.3
Bay leaves†	–	–	–	–	0.3	0.3
Chili powder†	–	–	0.1	0.3	0.2	0.2
Turmeric powder†	–	–	–	–	0.3	0.3
Cumin powder†	–	–	–	–	0.3	0.3
Cinnamon powder†	–	–	–	–	0.5	0.4
Cardamon powder†	–	–	–	–	0.3	0.3
Lemon salt powder†	–	–	–	–	0.3	0.2
Vegetable oil†	10	10	10	10	10	10
Ice water†	19	19	19	19	20	20
Color additive†	–	–	–	–	0.05	0.1
Water‡	59.72	58.86	59.07	58.86	58.25	58.31
Overall acceptability	2.74d (1.29)	2.04d (0.84)	4.01c (0.78)	5.48b (1.65)	6.93a (1.35)	6.33ab (0.76)

Onion, garlic and ginger used were freshly crushed; Overall acceptability of commercial sausage: 4.41 (0.60); Values in parentheses are standard deviation; Numbers in a row followed by same letters are not significantly different ($P > 0.05$).
†kg/100 kg of raw fish fillet; ‡kg/100 kg fish sausage.

Microbial analysis

Frozen sausages were thawed under running water at 15–25°C for about 30 min. Immediately after defrosting, samples in triplicate were taken aseptically from each sausage for microbial analysis. The rest of the samples were used for chemical and physical analysis. Total aerobic bacteria were counted by the spread method on Standard Plate Count Agar (Oxoid, Cambridge, UK) and incubated at 27°C for 3 days according to Curran *et al.*[19] Coliform count was assessed by the Most Probable Number (MPN) technique using Lauryl Tryptose Broth (Oxoid), and confirmed with Brilliant Green Bile 2% Broth (Oxoid), at 30°C for 48 h according to Omani Standard no. 627.[20]

Proximate analysis

Proximate composition in terms of water, total lipids, total proteins and ash content was carried out according to AOAC.[21] Moisture was measured using a gravimetric method by drying the sample in an air oven at 105°C until it reached constant weight. Total nitrogen was determined by the Kjeldahl method. Fat was obtained by extracting with light petroleum ether, and the solvent was removed by distillation. Ash was determined from the residue after burning in a muffle furnace at 525°C for around 18 h.

Color

The color of raw fish sausages was measured immediately after defrosting using a color meter, Minolta Chroma-meter (Model CR-310, Tokyo, Japan). The equipment was calibrated with the white standard calibration plate as provided by the manufacturer. Sausage was sliced and placed on a flat plate, and the tip of measuring head was pointed on the sample for measurement. At least 10 measurements were recorded from each sample. The results were expressed in hunter L-value, where L is lightness or darkness of the sausage (black $L = 0$; white $L = 100$), $+a$ is the redness, $-a$ is the greenness, $+b$ is the yellowness, $-b$ is the blueness.[22]

Instrumental Texture Profile (TPA) analysis

Frozen sausages were taken out of the domestic freezer and thawed at room temperature for around 30 min. Pan-frying was carried out for 9 and 5 min for laboratory and commercial samples, respectively, with a little spread of oil in the pan and then cooling at room temperature for subsequent analysis. Cooking time was determined based on preliminary experiments for the in-house preparations and the recommendations of the manufacturer for the commercial brand. The cooker was kept at the setting marked 5 in the control knob. The technique of large deformation single compression testing was employed by loading the burgers onto the platen of a TA.XT2 Texture Profile Analyzer (Stable Microsystems, Godalming, UK). Sausages (diameter: 3 cm, height: 1.5 cm) were compressed to 90% of the original height at a compression rate of 0.1 mm/s at room temperature (23°C). Four textural parameters (hardness, brittleness, adhesiveness, and firmness) were estimated from the force-deformation graphs as shown in Figure 1.

Sensory evaluation

Fish sausages were evaluated for sensory scores using nine panelists who were trained in the sensory evaluation laboratory of the Fish Quality Control Center, Ministry of Agriculture and Fisheries, Sultanate of Oman. Fish sausages were first fried and presented to the panelists for the four TPA attributes of hardness, brittleness, adhesiveness, and firmness. The four attributes were described to the panelists as follows.[23]

1. The panelist placed a piece of the cylindrical sausage disk (diameter: 3 cm, height: 1.5 cm) on the molars and then compressed it until rupture occurred. The standards used were soft processed cheese (low) and raw carrot (high).
2. The sample is placed between the molars and pressure is applied until initiation of fracture occurs. The standards used were marshmallow (low) and raw carrot (high).
3. The sample is chewed first and then the mass is pressed against the roof of the mouth with the tongue and assessed. If the sample falls easily then it has low adhesiveness, whereas if it is necessary to apply force by the tongue to the mass in order to remove it this indicates high adhesiveness. The standards used were raw carrot (low) and soft processed cheese (high).
4. Firmness is the change of force with the change in deformation of the sample when it is placed between the molars before the teeth penetrate through it. The standards used were soft processed cheese (low) and raw carrot (high).

Fish sausages were also assessed for flavor, overall texture, moistness, desirability, and overall preference by 13 untrained panel members taken from the Omani students of the department of Food Science and Nutrition, College of Agricultural and Marine Sciences (CAMS), SQU. A graphical scale with low and high marks at the corresponding ends of the scale was used to assess the attributes by the panel.

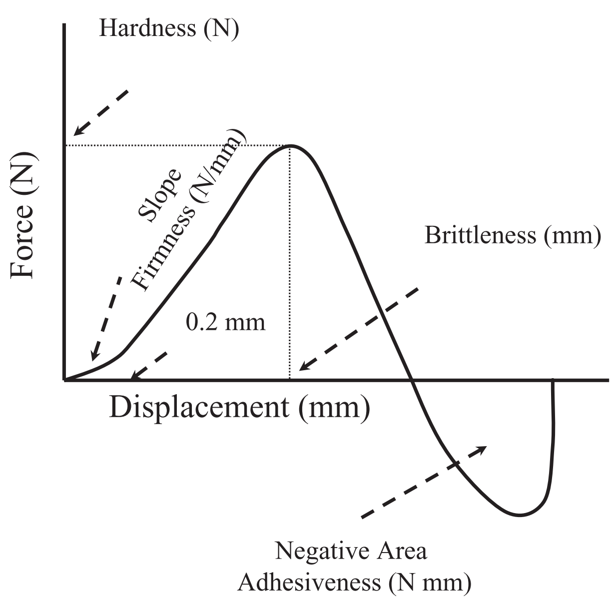

Fig. 1 Force-deformation curves showing the instrumental textural attributes.

Statistical analysis

Data were statistically analyzed using SAS generalized linear model (GLM) procedure and Duncan's Multiple Test to determine any significant effects of the starch on the formulation at 5% significance level.[24] Principal component and factor analyses were conducted using the same software in order to place the attributes into groups and identify their structure.

RESULTS AND DISCUSSION

Proximate composition

The proximate composition of raw fish, freshly formulated sausage and commercial sausage is

Table 2 Composition and formulation of sausages for sensory and instrumental texture profile analyses

	Composition (kg/100 kg sample)			
Product	Moisture†	Protein†	Fat†	Ash†
Raw fish	67.06 (2.28)	21.87 (1.20)	5.16 (2.18)	1.30 (0.02)
Formulated sausage‡	62.26 (1.62)	15.27 (0.15)	9.86 (1.23)	2.61 (0.12)
Commercial sausage	68.34 (0.07)	20.16 (0.79)	5.43 (0.12)	1.86 (0.01)

†Each point is an average of three replicates; ‡For 8% starch sausage.

presented in Table 2. The moisture content of raw croaker fish, formulated sausage and commercial embodiment was about 67.1, 62.3 and 68.3 kg/100 g sample, respectively. The lipid content of the sausage created in this study was higher than the commercial product since vegetable oil was added to improve the mouthfeel. Major varieties of fish made into fish sausage are normally lean and fatty tissue of animal and/or shortening oil are generally mixed into the product.[25] The fish species used in the sausage purchased from the commercial outlet are unknown.

Microbial changes during storage

The initial bacterial load of laboratory sausage was 2.8×10^3 indicating the product was processed under hygienic conditions. After 12 weeks of storage at –20°C, the aerobic plate count was significantly reduced to 18% of the original population ($P > 0.05$). Our results confirm those of Al-Bulushi *et al.*[26] who found that total aerobic bacteria were reduced significantly by 84% and 97% depending on the formulation of fish burgers during 3 months frozen storage at –20°C. The presence of coliforms can be used as an indicator of potential sausage contamination by *Escherichia coli* or other enteric pathogens that pose a safety risk to the consumer. The average population of coliforms in formulated sausage during storage decreased from 2.2 to 0.8 MPN/g (i.e. about 64%), indicating that the product is safe as the number of coliforms is below the standard limit of 100 MPN/g.[27]

Al-Bulushi *et al.*[25] found that coliforms were completely destroyed in formulated fish burgers during frozen storage at –20°C. Digirolamo *et al.*[28] studied the effect of freezing on the survival of *Salmonella* and *E. coli* in Pacific oysters. The former proved to be highly sensitive to various freezing methods thus showing a destruction of 99% or more after 48 h. *E. coli* proved less sensitive, showing a wide and capricious variability of survival during the first week of storage, with destruction rates ranging from 70 to 90%. Iyer and Shrivastava[29] studied the viability of coagulase positive staphylococci in shrimps during freezing. In cooked shrimps, the percentage of destruction during freezing at –40°C was between 8 and 15% and in the subsequent six-month storage at –20°C most of the test strains lost viability. During a similar frozen storage, the rate of microbial destruction was more pronounced in raw shrimps, with the authors pointing out that this may be due to some inherent factor, such as enzymatic action of the cooked and raw shrimp.

Textural Profile Analysis (TPA) and sensory evaluation

The effect of starch content on the instrumental and sensory characteristics of formulated sausage is shown in Table 3. There was an inverse relation between water content and starch since an increase in starch content is compensated by a decrease in water content in formulations from S00 (0% starch) to S48 (48% starch). Starch is considered to be a functional agent for the enhancement of the structural ability of fish muscle.[15] With the exception of instrumental adhesiveness and firmness, the remaining instrumental and sensory attributes showed significant ($P < 0.05$) change with rising levels of starch in the formulation. Furthermore, increasing starch content resulted in a high regression coefficient for the instrumental hardness ($r^2 = 0.84$), as compared to the sensory counterpart ($r^2 = 0.66$), an outcome which emphasizes the distinct response of the human palate from that of the instrumental protocol.

Drawing from data available in the literature, Shehata *et al.*[30] found that wheat flour was a favorable supplement to fish protein concentrate on the basis of a hedonic sensory evaluation. The work of Gomez-Guillen and Borderias[17] emphasized on instrumental techniques and in particular microscopy. Starch was added to squid gels made at 35°C and microscopy images were taken. These suggested that the hydrated starch granules adhered to the matrix formed by the muscle proteins thus contributing to the overall structural cohesion. At

Table 3 Sensory and instrumental texture of formulated sausage

Product	X_w	X_s	Instrumental				Sensory			
			IH (N)	IB (mm)	IA (J) $\times 10^{-4}$	IF (N/mm)	SH	SB	SA	SF
A (S00)	65.4	0	25.7d (9.2)	8.1cd (1.8)	−2.64a (0.84)	0.37b (0.13)	2.51e (0.78)	6.21a (0.53)	2.04e (0.31)	1.79d (0.43)
B (S04)	63.2	4	26.1d (4.8)	10.0ab (0.9)	−1.08a (0.59)	0.37b (0.15)	3.03e (0.59)	3.76b (0.55)	2.78d (0.50)	2.00d (0.35)
C (S08)	61.5	8	29.2cd (5.5)	10.2a (1.0)	−0.81a (0.85)	0.62ab (0.35)	0.19de (0.65)	4.18b (0.50)	3.29c (0.67)	2.20d (0.47)
D (S16)	51.5	16	28.0cd (6.2)	7.5d (0.9)	−2.18a (3.48)	0.88a (0.66)	0.96cd (1.17)	2.72c (0.60)	3.62c (0.51)	3.12c (0.64)
E (S24)	56.6	24	34.7c (5.2)	8.8bcd (0.9)	−4.11a (8.07)	0.48b (0.19)	0.88ab (0.72)	2.28c (0.55)	2.28e (0.55)	3.63bc (0.69)
F (S32)	53.9	32	46.5b (7.5)	9.3abc (0.8)	−2.93a (3.32)	0.56ab (0.29)	0.61bc (0.83)	1.64d (0.32)	4.50b (0.43)	0.92ab (0.58)
G (S40)	52.9	40	56.1a (4.2)	8.4cd (0.9)	−3.12a (2.48)	0.59ab (0.19)	5.41ab (1.16)	0.96e (0.32)	5.22a (0.66)	4.20ab (0.82)
H (S48)	50.6	48	60.9a (6.7)	7.8d (1.1)	−3.37a (1.02)	0.69ab (0.11)	5.71a (0.64)	1.20de (0.34)	5.67a (0.52)	4.50a (0.60)
r^2	0.99	0.99	0.84	0.45	0.09	0.24	0.66	0.93	0.85	0.76
Significance	S	S	S	S	NS	NS	S	S	S	S

Values in the parentheses are standard deviations. Means within the same column followed by the same letter are not significantly different ($P < 0.05$).

IA, instrumental adhesiveness; IB, instrumental brittleness; IF, instrumental firmness; IH, instrumental hardness; SA, Sensory adhesiveness; SB, sensory brittleness; SF, Sensory firmness; SH, sensory hardness; X_s, Starch content (kg/100 kg fish fillet); X_w, Water content (kg/100 kg fish sausage.

S: Significant ($P < 0.05$), NS: Not significant ($P > 0.05$).

temperatures higher than 60°C, starch gelatinized hence producing a planar mesh that spread throughout the material. It is expected that the frying of the fish sausage for 9 min caused starch gelatinization and that would bear an effect on the subsequent rheological and sensory analyses of the present work.

Figure 2 depicts the instrumental and sensory attributes of hardness, brittleness, adhesiveness and firmness as a function of starch content in the formulation. The attributes were transformed into dimensionless ratios by dividing with the corresponding maximum value in order to facilitate comparisons of the two sets of data. Regarding hardness, data increased with the addition of starch indicating that the attribute is sensitive to the functionality of the polysaccharide; however, the instrumental hardness correlates better with the external stimulus. Instrumental brittleness exhibited low sensitivity whereas the sensory counterpart developed a strong and negative correlation as a function of starch content (regression coefficients were 0.45 and 0.93, respectively). A sample deforming before its disintegration indicates low brittleness, whereas sudden disintegration without deformation indicates high brittleness. Similarly, the regression coefficients for instrumental adhesiveness and firmness were low compared to the corresponding sensory attributes hence emphasizing the increased sensitivity of the human palate within the context of this experimentation.

Correlations are used frequently to assess the relationship between instrumental measurement and sensory perception.[31] In Figure 3, the overall textural desirability of the sausage made in-house is marked in the plot of hardness, brittleness, adhesiveness and firmness as a function of changing the starch content in the formulation. Formulation C with 8% starch was the most preferred based on this type of evaluation. Quite closely, Shehata *et al.*[31] found that 6% of added wheat flour to fish protein gave the most favorable sensory scores when the flour content varied from 0 to 8%. Kasapis *et al.*[16] related hardness, firmness, and adhesiveness of fish burger formulations to overall sensory desirability thus being able to identify a range of values for each instrumental attribute that pinpointed the optimum sensory desirability.

Table 4 summarizes important aspects of the correlation matrix of instrumental and sensory attributes. Instrumental hardness correlated with all sensory attributes ($r > 0.656$, absolute value). The remaining instrumental attributes of brittleness, adhesiveness and firmness showed a poor correlation with the sensory attributes ($r < 0.231$). Figure 3 illustrates the relationship of these

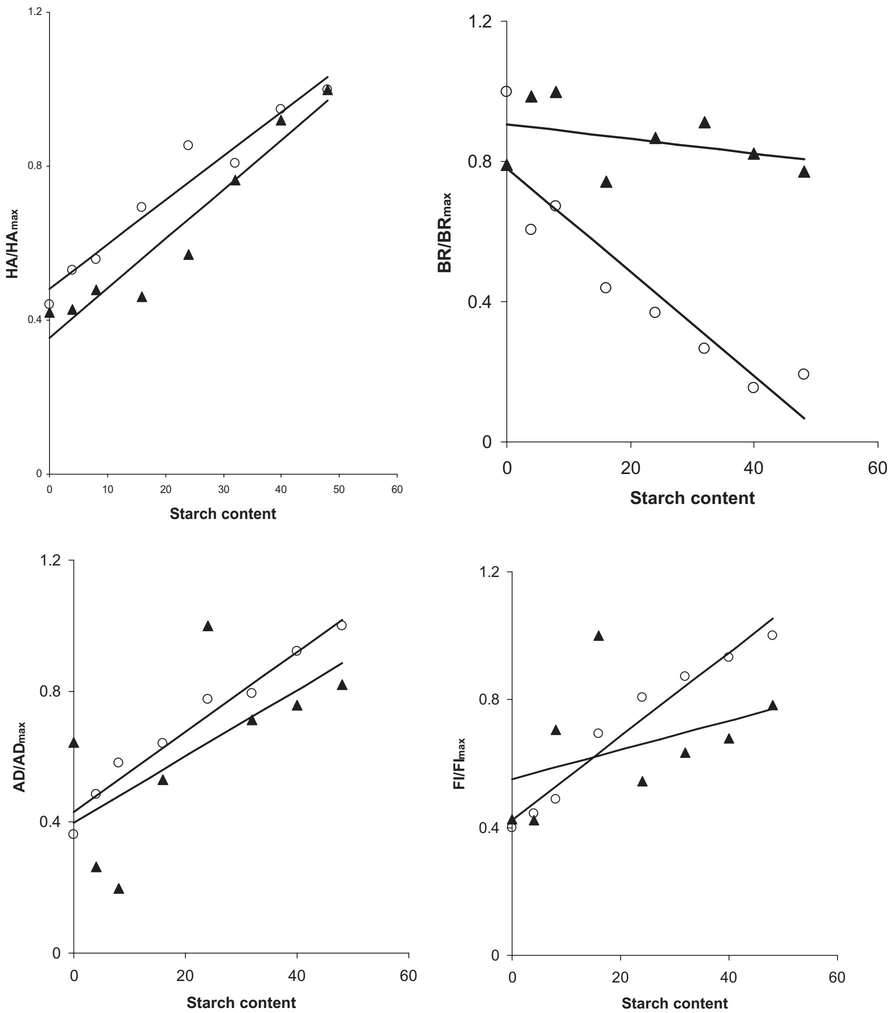

Fig. 2 Instrumental (▲) and sensory (○)) hardness, adhesiveness, brittleness and firmness of formulated fish sausage as a function of starch content. HA, hardness; HA_{max}, maximum hardness; AD, adhesiveness; AD_{max}, maximum adhesiveness; BR, brittleness; BR_{max}, maximum brittleness; F, firmness; F_{max}, maximum firmness.

instrumental and sensory attributes, where the higher the gradient the higher the correlation. Thus, instrumental hardness was highly correlated with sensory hardness followed by adhesiveness and firmness. The near horizontal line in the case of brittleness indicated negligible correlation.

In a review article, Szczesniak[32] argued that properly conducted evaluation tests should yield reliable correlations between instrumental and sensory measurements, especially, for hardness. Andersson *et al.*[33] confirmed such a high correlation ($r = 0.87$) for hardness judgements obtained by squeezing crisp breads between the fingers, biting and chewing on the samples. Meullenet *et al.*[31] studied quality aspects of texture for 21 foodstuffs using sensory and instrumental protocols in an effort to define a generic pattern of behavior connecting these two types of tests. They did find very acceptable linear correlations between the sensory and instrumental parameters of hardness ($r = 0.76$) and springiness ($r = 0.83$). However, no such relationships could be drawn for the corresponding factors of cohesiveness and chewiness. Based on the above and other results, Bourne[34] conceded that there is still much ambiguity regarding the fundamental principles and approaches that govern the instrumental-sensory relationship in edible biomaterials. The results presented here constitute further testimony of the care that should be taken in designing and drawing quality-control conclusions on the basis of such protocols in sausage formulations.

Principal component analysis

This was conducted to reduce the number of variables required to evaluate the quality of a processed food product thus making inroads upon the structures governing the relationship between attributes and formulation. Different tests, such as the Kaiser criterion, scree test, proportion of variance, and existing knowledge or common sense are applied to determine the manner whereby

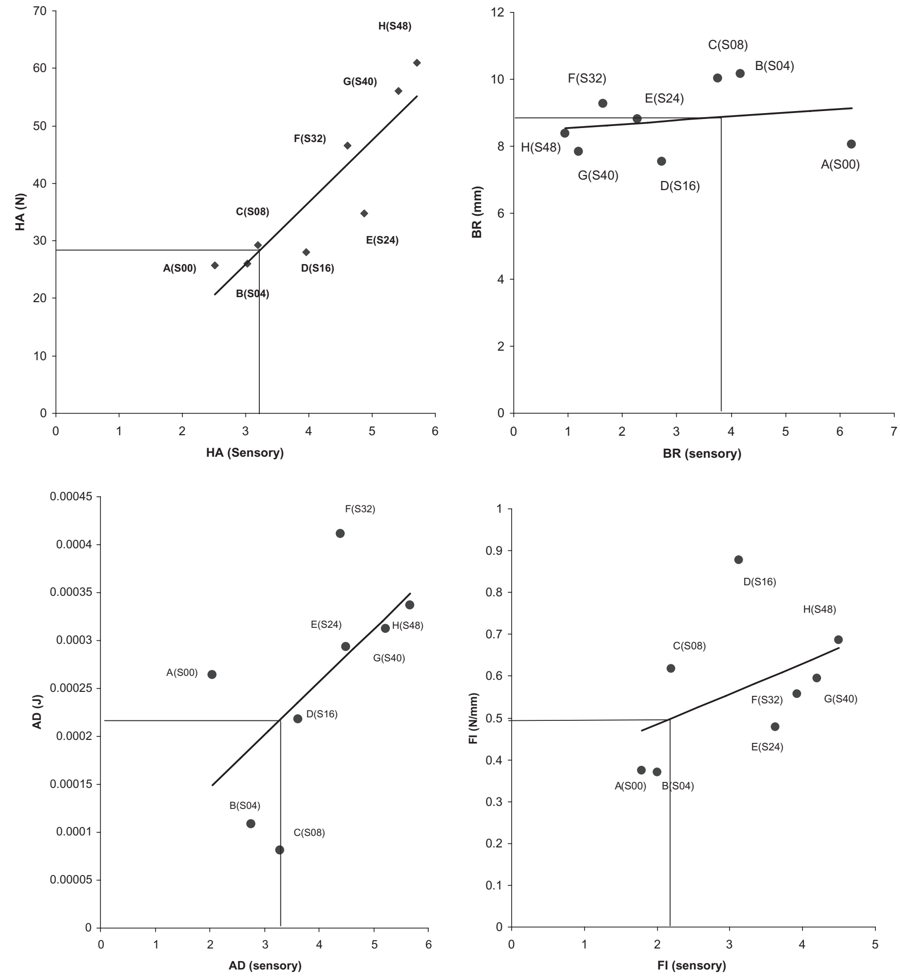

Fig. 3 Relationship of instrumental hardness, adhesiveness, brittleness and firmness with sensory hardness considering all sausage formulations. Abbreviations are the same as in Figure 2.

Table 4 Correlation matrix between instrumental and sensory textural attributes

	Correlation matrix between instrumental and sensory textural attributes										Factor loading or pattern	
	W	S	IH	IB	IA	IF	SH	SB	SA	SF	Factor 1	Factor 2
W	**1.000**										–0.911	0.202
S	–0.866	**1.000**									0.980	0.015
IH	–0.672	0.879	**1.000**								0.857	0.215
IB	0.320	–0.228	–0.021	**1.000**							–0.215	0.742
IA	0.147	–0.184	–0.210	–0.022	**1.000**						–0.206	–0.403
IF	–0.386	0.222	0.100	–0.356	0.111	**1.000**					0.265	–0.766
SH	–0.683	0.768	0.656	–0.147	–0.116	0.132	**1.000**				0.818	0.054
SB	0.858	–0.892	–0.748	0.059	0.185	–0.213	–0.675	**1.000**			–0.921	–0.085
SA	–0.807	0.917	0.765	–0.116	–0.145	0.179	0.746	–0.885	**1.000**		0.928	0.073
SF	–0.783	0.860	0.762	–0.157	–0.156	0.120	0.708	–0.779	0.773	**1.000**	0.890	0.084

IA, instrumental adhesiveness; IB, instrumental brittleness; IF, instrumental firmness; IH, instrumental hardness; S, starch content; SA, sensory adhesiveness; SB, sensory brittleness; SF, sensory firmness; SH, sensory hardness; W, water content.
Variance explained by factor 1: 80.6%.
Variance explained by factor 2: 19.4%.

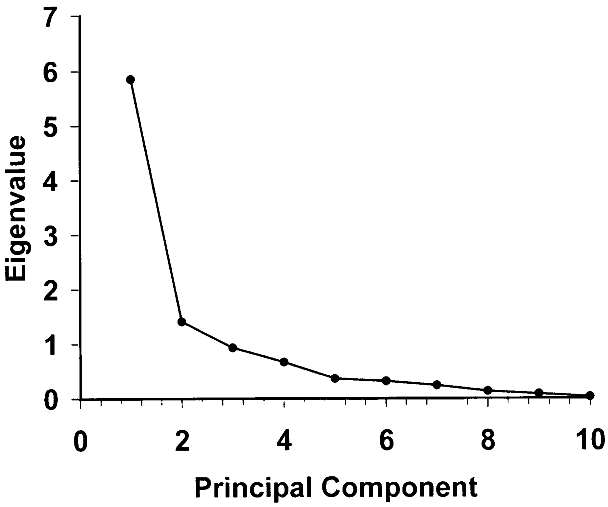

Fig. 4 Scree test depiction of eigenvalue as a function of an array of principle components derived from our work on formulated fish sausage.

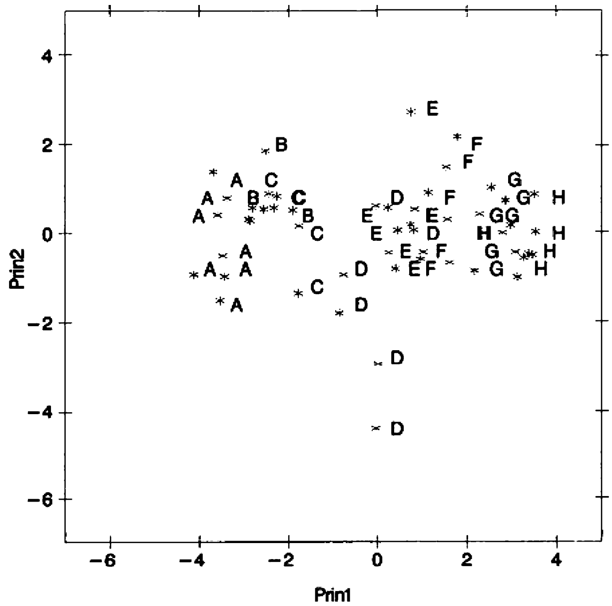

Fig. 5 Formulated products based on sensory and instrumental TPA attributes are shown in the principal components 1 and 2. (Prin1: principal component 1, Prin2: principal component 2).

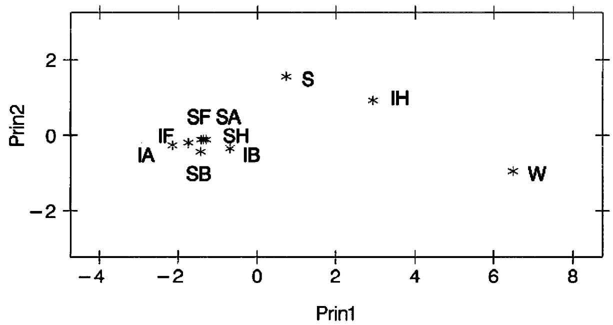

Fig. 6 Sensory and instrumental TPA attributes in the plot of principal components 1 and 2 (attribute legends are shown in Table 4, Prin1: principal component 1, Prin2: principal component 2).

principal components need to be retained.[35] Two principal components exist in the data set according to Kaiser criterion, which considers that principal components with eigenvalues greater than 1 are retained and interpreted.

Figure 4 summarizes results of the scree test (it is a plot of each principal component versus its associated eigenvalue) for this work based on the eigenvalue and a number of principle components thus showing that the eigenvalues nearly level off once the analysis incorporates two principal components. This indicates that the attributes considered presently could be lumped into two groups in order to measure adequately the quality characteristics of the product. Figures 5 and 6 illustrate the outcome of such grouping for the formulated products in principal components axes 1 and 2. Each formulation possesses a distinct location within the cluster and this product location is shifted clearly to the right of the *x*-axis with increasing starch content. Nevertheless, there is a concurrent vertical shift of the replicates of each formulation indicating a certain variability when all attributes are taken into consideration.

Figure 5 reproduces the attributes in the principal components axes 1 and 2. The pictorial outcome argues that the starch content has a higher loading on the principal component 2 (close to the *y* axis). The remaining sensory and instrumental attributes of hardness, firmness, brittleness and adhesiveness, and the water content exhibit a higher loading on the principal component 1 (close to the *x* axis). In addition, the factors of starch content, instrumental hardness and water content occupy a distinct position from the other attributes, which are lumped close to each other. In Figure 6 there is further confirmation that all attributes are correlated strongly to the principal component 1 (close to the *x* axis) making sufficient the two principal-component analysis for the evaluation of the quality control factors engaged in the engineering of these novel fish sausage formulations.

Table 4 reproduces the outcome of factor analysis which indicates the manner by which the various attributes are shared in relation to each other within the same set. Two factors are retained based on the mineigen criterion.[24] The first and second factors explain 80.6 and 19.4% of the variance, respectively, i.e. 100% of the variance in the original 10-dimensional space is retained in the two-dimensional space. Based on correlation, attributes with a large contribution to the first factor are the water and starch contents, instrumental and sensory hardness, and sensory firmness, brittleness and adhesiveness, whereas attributes with a large contribution to the second factor are instrumental brittleness and firmness.

In a recent paper, Rahman and Al-Farsi[22] reported on the instrumental TPA of mature date as a function of moisture content. Based on the factorial analysis, it was identified that the first factor relates to the elastic nature of the material hence incorporating the attributes of deformation in the first compression cycle (i.e. hardness, adhesiveness, and chewiness). The second factor correlated better with the fight back of the dried date to regain its original shape or, in other words, with the plastic nature of the sample. The latter includes the characteristics of cohesiveness, resilience and springiness derived by the second compression cycle. It appears therefore that the first factor encompasses the attributes of applied force whereas the second factor describes the manner by which the material deforms. However, the experimental design did not address issues of sensory TPA, which sheds light on the analytical characteristics of mouthfeel seen in the present work.

Overall acceptability

The overall acceptability of the formulated and commercial sausages containing 8% corn starch is given in Table 1. This range of products was developed using a variation of herbs and spices but keeping the textural attributes unaffected. Formulations M and N were the most acceptable compared to the remaining preparations ($P < 0.05$), an outcome attributed to the selective addition of spices. Within this context, optimum formulations of in-house sausages fared better than the commercial counterparts. Standard deviations of the means for each product are related to the day-to-day composition of the sensory panel that varied in gender, past experience, socio-cultural background, etc.

CONCLUSION

Distinct formulations of fish sausage were developed by varying primarily the starch content and these were assessed for organoleptic quality using sensory and instrumental texture profile analysis. Based on current definitions for quantitative measurement of food characteristics, the important attributes of hardness and brittleness increased and decreased, respectively, with increasing starch content. Furthermore, hardness could be measured and correlated well with several sensory attributes. Acceptable textural desirability was obtained in the presence of 8% starch in the formulation and this was further improved with the addition of selected spices. Principal component analysis was carried out in order to reduce the number of variables required to describe the organoleptic quality of the novel formulations. It was found that on a two dimensional matrix the attributes of instrumental hardness and brittleness featured mostly in the first and second factor, respectively.

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