EFFECTS OF STARCH PROPERTIES ON TEXTURAL CHARACTERISTICS OF FISH BURGERS: SENSORY AND INSTRUMENTAL APPROACHES

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The objective of this study was to evaluate the effects of starch in the texture of fish burgers (surimi seafood) using starches from different botanical origins by sensory and instrumental analysis and to try to correlate the sensory and instrumental data. Three fish burger samples formulated with different types of starch were evaluated for texture by descriptive analysis and were subjected to instrumental texture profile analysis. On the basis of texture data (instrumental), formulation 3 (modified cassava starch) was categorized into a cluster representing a hard, gummy and chewy product. Sensory evaluation by a panel of eight judges categorized formulations 2 and 3 into a hard and springy product cluster. Hardness (instrumental) was positively correlated to sensory texture attributes such as hardness, springiness, gumminess, chewiness and fracturability. These sensory attributes can be used to describe fish burger that is perceived as hard during mastication.

KEY-WORDS: SURIMI; STARCH; TPA; PCA; SENSORY-INSTRUMENTAL CORRELATION; PLS.

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1 INTRODUCTION

Hake (*Merluccius hubsi*) is a fish species widely processed in Brazil and is commercialized in the form of skinned and boned frozen fillets. In other parts of the world where it is less highly prized, it is used in the manufacture of minced products as the great functionality of its muscle makes it suitable for many industrial preparations (MONTERO, GÓMEZ-GUILLÉN & BORDERÍAS, 1999). Functional properties such as color and texture are the major factors responsible for the final acceptance of surimi-based products by consumers (TABILO-MUNIZAGA & BARBOSA-CÁNOVAS, 2004). Surimi (mechanically deboned, washed, and cryostabilized fish mince) is used as a primary functional ingredient for surimi-based products, like fish burger and crabmeat analogs (YANG & PARK, 1998). To better suit the textural preferences of consumers, ingredients must be added to surimi that modify its textural and water mobility properties (LEE, WU & OKADA, 1992). In a composite food such as surimi seafood, adding both protein and starch can modify the texture (TABILO-MUNIZAGA & BARBOSA-CÁNOVAS, 2004). Searching for alternative starches would be beneficial to the balance of cost and functionality. To evaluate the feasibility of mixing and to select an appropriate formula, the understanding of starch functions is necessary (LI & YEH, 2003). Starch, a natural macro polymer of glucose synthesized by plants, is insoluble in cold water, can be easily dispersed during chopping and renders functionality by heating. Thermal processing causes the granules to swell, absorb water, and impart viscosity (SANDERSON, 1996). When starch is added into surimi seafoods, it modifies texture, improves freeze-thaw stability in the case of modified starches, and decreases the product’s cost with the addition of water (WU, HAMANN & LANIER, 1985a; LEE, WU & OKADA, 1992). The functionality of starch may vary due the differences in botanical origin. Potato starch, for instance, increase the gel strength more than corn starch, due to its ability to bind a large amount of water or swell to a bigger size of the granule (LEE, WU & OKADA 1992). Therefore, gelatinization of starch plays an important role in the formation of the network structure of surimi-starch gels. The ratio of amylose and amylopectin varies among different starches. Amylose and amylopectin behave differently during gelatinization (MORRIS, 1990).

Cassava starch is, among tuberous roots, the most cited in literature. According to MOORTHY (1994), native cassava starch has been largely used in the refrigeration sector, due to presenting higher water binding and lower costs when compared to other types of starch. Some starches derive from hybrid plants, developed for its unique characteristics like the waxy starches, with greater heat stability, higher viscosity, paste clarity and sweet taste (ALEXANDER, 1996). Modification makes the functional properties of starch different from those of the native starch. Modified starches are, in general, obtained by acid or enzymatic hydrolysis, cross-linking or substitution. They work well in high moisture systems such as low-fat spreads and meat emulsions (GIESE, 1996), by binding water and increasing rubberiness (HUGHES, MULLEN & TROY, 1998). Modified cassava starches can improve flavor, increase moisture retention as well as reduce cooking losses (HUGHES, MULLEN & TROY, 1998). Several investigations have been done on profiling the texture of surimi seafoods using texture analyzers (TABILO-MUNIZAGA & BARBOSA-CÁNOVAS, 2004; VENUGOPAL et al., 2002; BARRERA et al., 2002.; YANG & PARK, 1998; PARK, 1994; NOWSAD, KANOH & NIWA, 2000). Besides, researchers have tried to correlate the sensory texture data with instrumental texture data (VENUGOPAL et al., 2002; NOWSAD, KANOH & NIWA, 2000). According to SZCZESNIAK (1986) the main reason for trying to correlate sensory texture with instrumental data is quality control, which essentially means the manufacture of products with consistent quality. Trying to predict consumer preferences or optimizing test conditions for instrumental analysis are the other driving forces of research in the area of sensory-instrumental correlation. The construction of a polynomial equation / function from sensory attributes (dependent variables) and instrumental attributes (independent variables) helps in predicting or estimating sensory profiles from a set of objective instrumental measurements (MOSKOWITZ, 1993).

The primary objective of this paper was to evaluate the effects of starch in the texture of fish burgers (surimi seafood) using starches from different botanical origins by sensory and instrumental analysis. The secondary objective was to correlate the sensory texture data with instrumental texture data obtained from the fish burgers formulations investigated.

2 MATERIAL AND METHODS

2.1 MATERIAL

Three kinds of starches were used in this study. Native cassava starch (Bufallo 044003), waxy corn starch (Amisol 4000) and modified cassava starch (snow flake 6800) were obtained from Corn Products Company, Brazil. Hake (*Merluccius hubsi*) surimi was prepared according to methods reported by LANIER & LEE (1992) and PIGGOT & TUCKER (1990). Surimi blocks (of approximately 500 g) were packed in plastic bags, vacuum sealed, frozen in a blast freezer (-35ºC) and stored in a freezer (-18ºC) until used.

2.2 FISH BURGER PREPARATION

Frozen surimi blocks were placed in a cutter machine (MS Suzzano, São Paulo, Brazil). The surimi was then cut into small pieces with an approximate thickness of 1 cm, and then in a mixer (MS Suzzano, São Paulo, Brazil), where others ingredients such as sorbitol (4%), sodium tripolyphosphate (0.3%), sodium chloride (2%), monosodium glutamate (0.5 %), sodium eritorbate (0.1 %) and starch (5%) were added. Three types of starch were added: native cassava starch (formulation 1), waxy corn starch (formulation 2), and modified cassava starch (formulation 3). The mixtures were molded in stainless steel moulds (inner diameter 6 cm; thickness, 0,8 cm) of approximately 50 g. Products were taken into a horizontal blast freezer at -25 ºC for 2 hours and then battered (predust, batter, and breading) and stored at freezing temperatures (-18 ºC) until they were analyzed.

2.3 COMPOSITIONAL ANALYSIS

Moisture, crude protein, lipid, and ash of the hake (*Merluccius hubsi*) fish, hake (*Merluccius hubsi*) surimi and fish burgers (formulations 1, 2 and 3) were determined using AOAC – methods (1998). Percentage carbohydrate values (w/w) were obtained by difference.

2.4 WATER HOLDING CAPACITY (WHC)

Water holding capacity of hake (*Merluccius hubsi*) surimi and fish burgers (formulations 1, 2 and 3) was determined by the AFDF (1987) method.

2.5 SENSORY TEXTURE EVALUATION

Samples were removed from the freezer and deep fat fried in a hand basket fryer for four minutes at 180 °C using a commercial frying corn oil. Immediately after frying in oil, fish burgers were served to each panelist in a pre-heated glass recipient to avoid cooling.

Sensory texture analysis of fried fish burgers was accomplished by a previously selected and trained sensory panel consisting of eight members of the Department of Food Science and Technology of Santa Catarina Federal University, according to ISO guidelines (1985, 1993). The method was modeled after the Texture Profile Method (BRANDT, SKINNER & COLEMANN, 1963), where panels of six to nine technical people are chosen, evaluate selected examples that constitute the points of texture standard rating scales, and draw a profile of the product, evaluating samples independently. The arrangement of samples at each session was made according to a balanced complete block design for three samples. According to this design, each sample was evaluated five times in five sessions. All sessions were conducted in a climate-controlled sensory analysis laboratory. The trained panelists were oriented on the following textural characteristics: hardness, springiness, adhesiveness, fracturability, gumminess, moistness, chewiness, and oily mouth coating. Definitions and evaluation techniques used for each of the eight texture attributes were adapted from CIVILLE & SZCZESNIAK (1973), MUÑOZ (1986), MEILGAARD, CIVILLE & CARR (1999), SZCZESNIAK (1963) and BRAMESCO & SETSER (1990) (Tables 1 and 2). A 9 cm unstructured line scale was used for each descriptor on the sensory ballot and judges were told to place a vertical mark on the scales according to their perception of the sensory attributes (LAWLESS & HEYMANN, 1998). Distilled water was available to judges to rinse residual particulate matter from the mouth.

TABLE 1 - DEFINITIONS, TECHNIQUES, AND REFERENCES USED FOR THE SENSORY ATTRIBUTES EVALUATED (PRIMARY PROPERTIES)

PRIMARY PROPERTIES				
Attribute	**Physical**	**Sensory**	**Technique**	**References and their intensities**
Hardness *	Force necessary to attain a given deformation	Force required to compress a substance between molar teeth	Place the food between molars and bite down evenly through the sample	Cream cheese (1), Egg white (2), Hot dog (3), Yellow cheese (American pasteurized process) (4), Carrot (7)
Springiness * *	Rate at which a deformed material goes back to its undeformed condition after the deforming force is removed	Degree to which a product returns to its original shape, after it has been compressed between the teeth	Compress partially with molar teeth without breaking the sample structure and release	Cream cheese (0), Hot dog (5). Marshmallow (9), Jelly (15)
Adhesiveness * * *	Work necessary to overcome the attractive forces between the surface of the food and the surface of the other materials with which the food comes in contact	Force required to remove the material that adheres to the mouth (generally the palate) during the normal eating process	The product is placed on the tongue, compressed against the palate, then the sample is removed using the tip of the tongue	Hydrogenated vegetable oil (1), Cream cheese (3), Peanut butter (5)

* Definitions were used according to CIVILLE & SZCZESNIAK (1973); Techniques according to MEILGAARD, CIVILLE & CARR, (1999); and references and their intensities according to SZCZESNIAK (1963).
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2.6 INSTRUMENTAL TEXTURE ANALYSIS

A universal testing machine (Stable Micro System, Model TA-XT2, Texture Expert, Surrey, UK), operating *software Texture Expert*, was used for instrumental texture profile analysis. Fish burgers (50 g) were used in a two-bite (two cycles) compressing test. The plunger (50 mm diameter) speed was adjusted to 2.0 mm/s. Samples were prepared as previously described. All the measurements were replicated three times (BOURNE, 1978; BRYANT, USTONOL & STEFFE, 1995).

From the TPA curves, the following texture parameters were obtained: hardness, springiness, cohesiveness, adhesiveness, gumminess and chewiness (Figure1). Hardness was defined by peak force during the first compression cycle. Cohesiveness was calculated as the ratio of the area under the second curve to the area under the first curve. Springiness was defined as a ratio of the time recorded between the start of the second area and the second probe reversal to the time recorded between the start of the first area and the first probe reversal. Chewiness was obtained by multiplying hardness, cohesiveness and springiness. Gumminess was obtained by multiplying hardness and cohesiveness. Adhesiveness was the negative area under the curve obtained between cycles (PONS & FIZSMAN, 1996).

TABLE 2 - DEFINITIONS, TECHNIQUES, AND REFERENCES USED FOR THE SENSORY ATTRIBUTES EVALUATED (SECONDARY PROPERTIES)

SECONDARY PROPERTIES				
Attribute	**Physical**	**Sensory**	**Technique**	**References and their intensities**
Fracturability *	Force with which a material fractures: a product of high degree of hardness and low degree of cohesiveness	Force with which a sample crumbles, cracks, or shatters	Bite evenly through the sample with molars	Angel puffs (2), Graham crackers (3), Peanut brittle (7)
Chewiness *	Energy required to masticate a solid food to a state ready for swallowing: a product of hardness, cohesiveness and springiness	Length of time (in sec) required to masticate the sample, at a constant rate of force application, to reduce it to a consistency suitable for swallowing	Chew the sample at a rate of one chew per second	Rye bread (1), Hot dog (2), Gum (Chuckle) candy (3), Caramels candy (4)
Gumminess *	Energy required to disintegrate a semi-solid food to a state ready for swallowing: a product of a low degree of hardness and a high degree of cohesiveness	Denseness that persists throughout mastication; energy required to disintegrate a semi-solid food to a state ready for swallowing	None	40% Gold Medal (1), 50% Gold Medal (3), 60% Gold Medal (5)
Moistness		Expresses how moist the fish burger is felt in the mouth and how much moisture the product releases in the mouth after chewing	None	Chicken Nuggets, Breaded sliced fish, Breaded fish (surimi)
Residual				
Oily mouth coating		Expresses how oily the product is presented, released, and absorption in the mouth	None	Chicken Nuggets, Breaded slices fish, Breaded fish (surimi)

* Definitions were used according to CIVILLE & SZCZESNIAK (1973); Techniques according to MEILGAARD, CIVILLE & CARR (1999); and references and their intensities according to SZCZESNIAK (1963).
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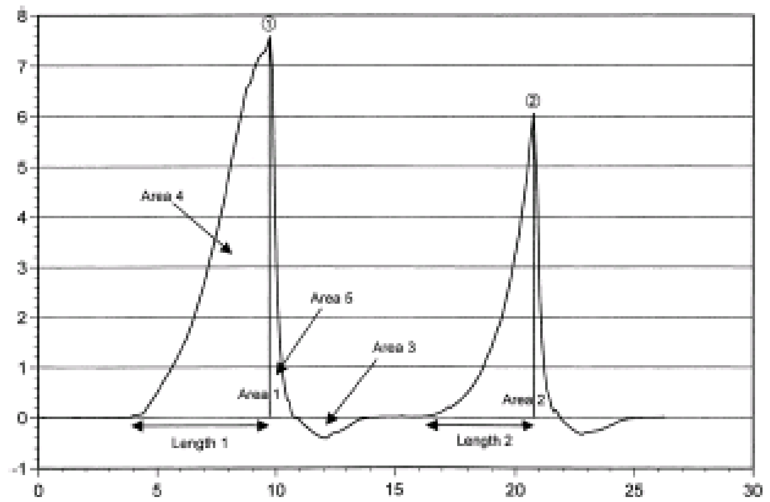
FIGURE 1 - TYPICAL FORCE BY TIME PLOT THROUGH TWO CYCLES OF PENETRATION TO DETERMINE TEXTURE PROFILE ANALYSIS PARAMETERS



PEAK 1 IS FIRMNESS; COHESIVENESS = AREA 2 / AREA 1; SPRINGINESS = LENGTH 2 / LENGTH 1; ADHESIVENESS = AREA 3.

2.7 STATISTICAL ANALYSIS

Analysis of variance (ANOVA) and multivariate analysis of variance (MANOVA) were performed with both the sensory (three-way) and the instrumental (three-way) data. Principal Component Analysis (PCA) was also done to find the differences among fish burgers samples. Sensory data was correlated with instrumental data by partial least square (PLS) regression analysis, with sensory attributes as the *y* variable and instrumental measurement as the *x* variables. PLS is a soft modeling technique used to compare two sets of data by seeking out latent variables common to both data sets (MARTENS, et al. 1986). The data analyses were performed on "Statistica v.6".

3 RESULTS AND DISCUSSION

3.1 COMPOSITIONAL ANALYSIS

Compositional analysis of *in natura* hake, surimi, and fish burger formulations 1, 2 and 3 are showed on Table 3. Analyzing results obtained from the compositional analysis it's possible to observe that there were significant differences between moisture from *in natura* fish and surimi ($p<0.05$), which presented the lower value. This can be explained, as surimi, after being through three washing processes, was centrifuged, which could lower moisture levels. Fish burgers presented significant lower moisture values than surimi, and no significant differences among the three formulations were observed. Moisture results obtained were similar to those from commercial surimi formulations – from 70% to 78% (LEE, 1986), considering that the breading process certainly reduced moisture of the final product. According to the same author, some molded products are frozen before being cooked and are, in general, more susceptible to changes due to the freezing-thawing cycles. This justifies the use of sorbitol as a cryoprotectant in the formulations to reduce moisture levels of raw products which will be stored frozen. According to ADU, BABBIT & CRAWFORD (1983), LEE (1986), SCOTT, PORTER & KUDO (1988) and REPPOND, BABBIT & BERNTSEN (1997) surimi's final moisture levels have great influence on its ability to form a strong and elastic gel and, consequently, on the final product's quality. SCOTT, PORTER & KUDO (1988) and HALL & AHAMAD (1997) reported, for high quality surimi, moisture levels within 75 and 79% limits, after the addition of cryoprotectants.

A significant difference ($p<0.05$) was observed on protein contents of *in natura* fish, surimi and fish burger formulations, the latter presenting the lower levels of protein, due not only to the washing process which removes the sarcoplasmatic proteins of the fish meat (PIGOTT & TUCKER, 1990), but also due to their dilution by the addition of starch and covering flour for the fish burgers' breading. There was a significant reduction on lipid content when fish paste, fish burgers and *in natura* fish were analyzed.

TABLE 3 - MOISTURE, CRUDE PROTEIN, LIPID, ASH AND CARBOHYDRATE VALUES % OF HAKE (M*erluccius hubsi*) FISH, HAKE (M*erluccius hubsi*) SURIMI AND FISH BURGER (FORMULATIONS 1, 2 AND 3)

Parameters	Hake	Surimi	Formulation 1	Formulation 2	Formulation 3
Moisture (g/100 g)	80.86 ^{c}	77.20 ^{b}	66.70 ^{a}	66.20 ^{a}	65.70 ^{a}
Crude protein (g/100 g)	17.82 ^{c}	15.94 ^{b}	10.60 ^{a}	11.00 ^{a}	11.80 ^{a}
Carbohydrate (g/100 g)	0.00 ^{c}	3.15 ^{b}	9.82 ^{a}	9.77 ^{a}	9.73 ^{a}
Lipid (g/100 g)	1.02 ^{c}	0.54 ^{a}	0.41 ^{a}	0.34 ^{a}	0.37 ^{a}
Ash (g/100 g)	1.50 ^{c}	0.84 ^{b}	2.57 ^{a}	2.63 ^{a}	2.54 ^{a}

Different letters in the same row indicate that treatments are significantly different at $p<0.05$.

3.2 WATER HOLDING CAPACITY (WHC)

Surimi's water holding capacity results of the three fish burgers formulations are shown on Table 4. Water molecules intimately adsorbed to macromolecules are called "binding water" and reflect the ability of a molecular surface to form weak non covalent bindings with water (RICKARD, ASAOKA & BLANSHARD, 1991). According to the authors the amount of "binding water" associated to starch granules influences their expansion characteristics. There were no significant differences ($p<0.005$) in water holding capacity between fish burger formulations and *surimi*. This may be explained as, in the cold water-starch system, starch granules can reversibly absorb water, swell slightly and become partially hydrated with excessive comminution (WANISKA & GOMEZ, 1992). When dough is first mixed, the damaged starch granules (the damage is an inevitable consequence of flour milling) absorb some cold water (COULTATE, 2002). As they are heated, irreversible swelling of the starch granules occurs. Thermal changes of the starch granule in the surimi-starch system are different from those in the starch-water system. Gelatinization of starch occurs concomitantly with thermal gelation of fish proteins. However, it is delayed by the presence of myofibrillar proteins, salt, sucrose, and sorbitol in the surimi-starch system. Myofibrillar proteins are thermally denatured before the starch is completely gelatinized (WU, HAMANN & LANIER, 1985a). Water is entrapped in the protein-gel network, limiting the availability of water for starch gelatinization and resulting in competition for water between starch and protein (KIM & LEE, 1987). Starch granules absorb water and expand themselves until they are limited by the gel matrix. Even though the starch granules expand in surimi seafood, they cannot expand as much as in the starch-water system because fish proteins take part of the water (OKADA & MIGITA, 1956). When starch is used in *surimi* formulae it acts as a simple "filling" of the myofibrillar protein gel, not directly interacting with the protein matrix nor affecting significantly its formation, as the starch swelling occurs after the protein gelatinization on the cooking cycle (WU, HAMANN & LANIER, 1985b).

TABLE 4 -WATER HOLDING CAPACITY (mg/g) OF HAKE (*Merluccius hubsi*) SURIMI AND FISH BURGERS (FORMULATIONS 1, 2 AND 3)

Surimi	Formulation 1	Formulation 2	Formulation 3
0.4113 [a]	0.5207 [a]	0.5671 [a]	0.5737 [a]

Different letters in the same row indicate that treatments are significantly different at $p<0.05$.

3.3 SENSORY ANALYSIS

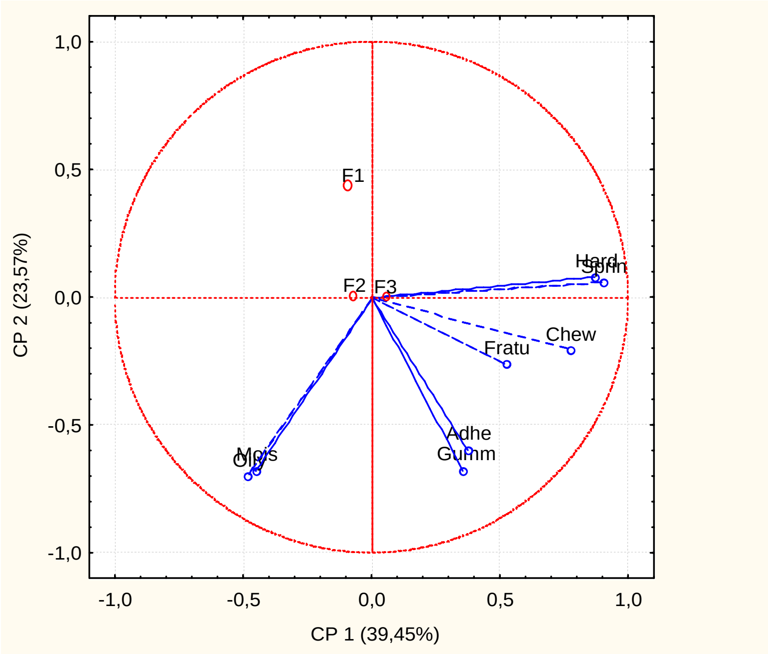
Results from the analysis of variance (ANOVA) of 8 sensory attributes (hardness, springiness, fracturability, gumminess, chewiness, adhesiveness, moisture, and oily mouth coating) ratings are summarized in Table 5. The results indicated that the fish burgers samples were not significantly different ($p<0.05$), for all the sensory attributes. The biplot of PC1 vs. PC2 from the PCA of the matrix of significant sensory attributes across the fish burgers samples is shown in Figure 2. PC1 and PC2 explained 39.45 and 23.57 % of the total variance, respectively. The PCA biplot (Figure 2) shows that hardness, springiness, chewiness and fracturability were the main attributes explaining PC1. On PC2 adhesiveness, gumminess, moisture and oily mouth coating were the main contributors. Samples from formulations 2 and 3 were distinct for being closer to hardness and springiness attributes and somewhat distant from formulation 1. The 'F2' and 'F3' fish burgers were indistinguishable on the PCA biplot (Figure 2), showing that they presented similar sensory data. Further sensory analysis might be necessary within each group ('F2' or 'F3') to get discriminatory results.

TABLE 5 - RESULTS OF THE AVERAGE TEXTURE PROFILE ANALYSES (TPA) OF THREE FORMULATIONS DE FISH BURGERS

Formulation	Hard	Sprin	Fratu	Gumm	Chewi	Adhe	Mois	Oily
F1	2.6575 [a]	2.5475 [a]	2.3325 [a]	2.3225 [a]	2.6500 [a]	1.8995 [a]	2.1500 [a]	1.800 [a]
F2	2.4850 [a]	2.4050 [a]	2.1225 [a]	2.1675 [a]	2.4800 [a]	2.0550 [a]	2.2400 [a]	1.8250 [a]
F3	2.5475 [a]	2.4825 [a]	2.2425 [a]	2.2850 [a]	2.6075 [a]	2.0225 [a]	2.0400 [a]	1.9300 [a]

Means in columns followed by different letters are statistically different ($p<0.05$).
Sensory parameters; Hard = hardness, Sprin = springiness, Fratu = Fracturability, Gumm = gumminess, Chewi = chewiness, Adhe = adhesiveness, Mois = moisture, Oily = oily mouth coating.

FIGURE 2 - CPA BIPLOT SHOWING THE FISH BURGERS IN RELATION TO THE ATTRIBUTES



(Hard = hardness, Sprin = springiness, Fratu = Fracturability, Gumm = gumminess, Chewi = chewiness, Adhe = adhesiveness, Mois = moisture, Oily = oily mouth coating), based on the sensory texture analysis.

3.4 INSTRUMENTAL ANALYSIS

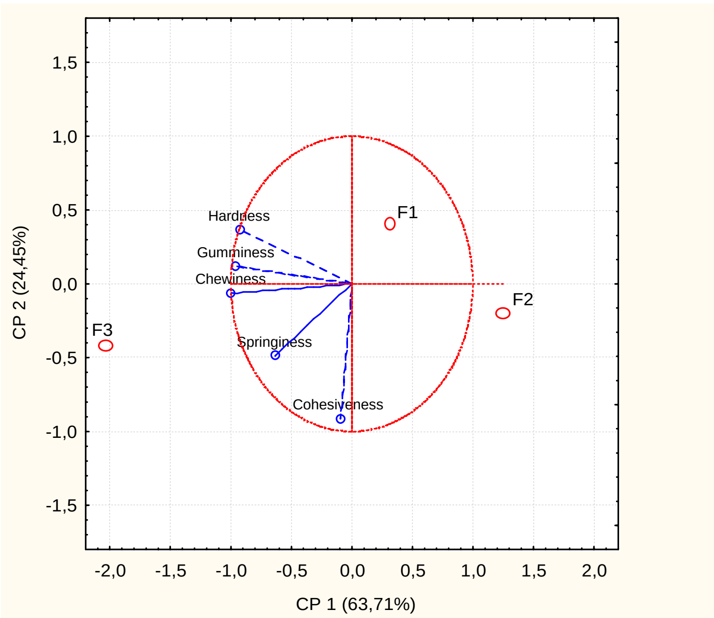
Table 6 presents the average results of the texture profile of the three fish burger formulations prepared with native cassava starch (1), corn starch (2) and modified cassava starch (3). Five parameters were obtained: hardness, springiness, cohesiveness, chewiness and gumminess. The MANOVA results for the texture data showed that fish burgers samples were significantly different ($p<0.05$), the ANOVA results indicated that the fish burgers differed significantly ($p<0.05$) for all attributes, with the exception of springiness and cohesiveness parameters, validating the MANOVA results. The three fish burger formulations did not show the cohesiveness parameter on instrumental evaluation. Formulation 3, prepared with modified cassava starch, presented the higher values for hardness, chewiness and gumminess. The two dimensions of PCA (Principal Component Analysis) explained 87.62 % of the variation in the data set, and were significant ($p<0.05$). The variation explained by the first two dimensions was 63.71 and 24.45%, respectively. The PCA biplot (Figure 3) shows that hardness, gumminess and chewiness were the main attributes explaining PC1 (principal component 1). On PC2 (principal component 2), springiness and cohesiveness were the main contributors. It can be seen that hardness was correlated with gumminess and chewiness, consistent with the findings from the correlation analysis. Formulation 3 was characterized by hardness, gumminess and chewiness parameter, thus demonstrated on the left quadrant, and differs from the other two samples analyzed by being apart from each other, on the right quadrant (Figure 3). Similar results were presented by YANG & PARK (1998), who analyzed the effects of different types of starches on texture of surimi gel, among them native potato starch, native corn starch, modified potato starch and modified waxy maize starch. The authors affirmed that modified starch caused the granules to swell easily and resulted in increased gel strength. Effects of starch on the texture of surimi-starch gels depend on its concentration, modification, and the ratio of amylose and amylopectin. The amylopectin component (present in modified starch) made the granule swell and greatly increased gel strength and the larger size starch granules also produced the stronger gel. The effect of modified cassava starch in the surimi gels may be explained by the following theory: the starch granules embedded in protein gel absorb water from the matrix and push the matrix as they swell during cooking. At the same time, the protein matrix loses moisture and becomes firmer (KIM & LEE, 1987). According to YOON & LEE (1990), the use of modified starch in surimi-based products results in a gummy and less humid texture. VENUGOPAL, DOKES & KAKATKAL (2002) reported preparation, storage characteristics and properties of restructured steaks from shark meat making use of weak acid-induced gelation of the fish structural proteins and observed that the hardness of the product, measured in terms of shear force, was essentially due to gelation of the myofibrillar proteins, particularly myosin. Vegetable oil frying of the salted steaks further enhanced its hardness. Other authors reported the same results using meat/starch complexes. HUGHES, MULEN & TROY (1998) evaluated the effect of *tapioca* starch on the textural characteristics of frankfurters and observed that the *tapioca* starch significantly increased hardness, gumminess, and chewiness, but had no effect on springiness or cohesiveness. YANG & FRONING (1992) also reported a significant increase in gel strength and a decrease in cohesiveness of the mechanically deboned and washed chicken meat cooked paste when compared to the non-washed meat.

TABLE 6 - AVERAGE RESULTS OF THE INSTRUMENTAL TEXTURE PROFILE ANALYSIS (TPA) OF THREE FORMULATIONS OF FISH BURGER

Formulations	Hardness	Springiness	Cohesiveness	Gumminess	Chewiness
F1	6830.00 ^{ab}	0.71 ^{a}	0.53 ^{a}	3613.17 ^{b}	2561.79 ^{b}
F2	5816.13 ^{b}	0.71 ^{a}	0.54 ^{a}	3107.05 ^{b}	2210.740 ^{b}
F3	8143.51 ^{a}	0.76 ^{a}	0.56 ^{a}	4520.96 ^{a}	3463.65 ^{a}

Means in columns followed by different letters are statistically different ($p<0.05$).
(F1- Formulation 1, F2 - Formulation 2, F3 - Formulation 3).

FIGURE 3 - CPA BIPLOT SHOWING THE FISH BURGERS IN RELATION TO THE ATTRIBUTES (HARDNESS, SPRINGINESS, COHESIVENESS, CHEWINESS AND GUMMINESS), BASED ON THE INSTRUMENTAL TEXTURE ANALYSIS



3.5 RELATIONSHIP BETWEEN SENSORY ATTRIBUTES AND INSTRUMENTAL PARAMETERS

The regression coefficients in Table 7 denote the strength of correlations between individual sensory attributes and instrumental parameters while developing polynomial functions for predicting sensory profile from instrumental data (MOSKOWITZ, 1993). Hardness (instrumental) was positively correlated to hardness, springiness, gumminess, chewiness and fracturability (sensory). All these sensory attributes might contribute to the perception of hardness during chewing of food products like fish burgers (Table 7; shown in bold). On the other hand, springiness and cohesiveness (instrumental) were negatively correlated to hardness, springiness, gumminess, chewiness and fracturability (sensory). Correlating sensory with instrumental TPA has recently become of renewed interest (MEULLENET et al., 1997, 1998). Most researches indicate that the quality of correlations varies significantly, depending on the parameter. Hardness has consistently been demonstrated to correlate very well. Springiness and cohesiveness, as a rule, give low degrees of correlation (MEULLENET et al., 1998). This could be due to difficulties in quantifying those parameters in sensory profiling, or to the need for improved methods of quantifying them in instrumental profile. Such methods have been suggested by PELEG (1976) for cohesiveness and by MEULLENET et al. (1998) and FISZMAN, PONS & DAMÁSIO (1998) for springiness. Different authors reported the same results in other types of products such as mechanically deboned smoked chicken sausage. Sensory and instrumental properties were correlated and a positively correlation was found for the hardness (instrumental) parameter, but springiness and cohesiveness (both instrumental) were not well correlated with sensory parameters (LI, CARPENTER & CHENEY, 1998). Poor correlations between cohesiveness (instrumental) was also reported by DRAKE et al. (1999), who contended that a single parameter like 'cohesiveness' is not enough to explain the sensory perception of cohesiveness in the mouth.

TABLE 7 - REGRESSION COEFFICIENTS FROM PLS ANALYSIS BETWEEN SENSORY TEXTURE DATA (Y-MATRIX) AND INSTRUMENTAL TEXTURE DATA (X-MATRIX)

Dependent variables (sensory)	Independent variables (instrumental)				
	Hard * *	Sprin * *	Gummi * *	Chewi * *	Cohes * *
Hard *	**0.73 *****	-0.41	0.51	0.29	-1.23
Sprin*	**0.76 *****	-0.36	0.54	0.33	-1.16
Gummi*	**0.75 *****	-0.28	0.55	0.35	-1.03
Chewi*	**0.75 *****	-0.28	0.55	0.35	-1.03
Fratu*	**0.76 *****	-0.35	0.55	0.33	-1.15

* Sensory parameters; Hard = hardness, Sprin = springiness, Gummi = gumminess, Chewi = chewiness, Fratu = fracturability.
** Instrumental parameters; Hard = hardness, Sprin = springiness, Gummi = gumminess, Chewi = chewiness, Cohes = cohesiveness.
*** Bold: shows correlations that are consistent.

4 CONCLUSION

Based on texture data, formulation 3 (modified cassava starch) was categorized into a cluster representing a hard, gummy and chewy product. Based on the results from the texture profile data (sensory), formulations 2 (waxy corn starch) and 3 were categorized into a cluster representing hardness and springiness. From the PLS analysis it was seen that there was a correlation between the sensory texture and the instrumental texture data sets. 'Hardness' (instrumental) was positively correlated to

sensory texture attributes such as hardness, springiness, gumminess, chewiness and fracturability. These sensory attributes can be used to describe fish burger that is perceived as hard during mastication. The addition of modified cassava starch caused the granules to swell easily and resulted in increased gel strength.

RESUMO

EFEITO DO AMIDO SOBRE AS CARACTERÍSTICAS TEXTURIAIS DE HAMBÚRGUER DE PEIXE: ANÁLISE SENSORIAL E INSTRUMENTAL

O objetivo deste estudo foi avaliar o efeito do amido de diferentes origens botânicas na textura de hambúrguer de peixe (a base de surimi), mediante análises sensorial e instrumental, e correlacionar a informação sensorial com a instrumental. Três amostras de hambúrguer de peixe elaboradas com diferentes tipos de amido foram avaliadas por análise sensorial descritiva e análise instrumental. Em relação aos resultados de textura (instrumental), a formulação 3 (amido de mandioca modificado) foi caracterizada pelos atributos dureza, gomosidade e mastigabilidade. A análise sensorial realizada por equipe de 8 julgadores caracterizou as formulações 2 e 3 pelos atributos dureza e elasticidade. Verificou-se correlação positiva entre dureza (instrumental) e atributos sensoriais de textura, como dureza, elasticidade, gomosidade, mastigabilidade e fraturabilidade, contribuindo para a percepção da dureza durante a mastigação do hambúrguer de peixe.

PALAVRAS-CHAVE: SURIMI; AMIDO; ANÁLISE DE PERFIL DE TEXTURA; ACP; CORRELAÇÃO SENSORIAL-INSTRUMENTAL; PLS.

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