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JULLIANE CARVALHO BARROS

ADDITION OF CHIA (*Salvia hispanica* L.) FLOUR TO CHICKEN NUGGETS WITH REDUCED SODIUM CONTENT

"ADIÇÃO DE FARINHA DE CHIA (*Salvia hispanica* L.) EM NUGGETS DE FRANGO COM TEOR DE SÓDIO REDUZIDO"

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"A verdadeira coragem é ir atrás de seu sonho mesmo quando todos dizem que ele é impossível"

Cora Coralina

ABSTRACT

BARROS, J. C. **Addition of chia (S*alvia hispanica* L.) flour to chicken nuggets with reduced sodium content.** 2019. 136 p. Ph.D. Thesis – Faculty of Animal Science and Food Engineering, University of São Paulo, Pirassununga/SP, Brazil, 2019.

The present study aimed to reformulate chicken nuggets to become a healthier meat product, using two different strategies: addition of chia (*Salvia hispanica* L.) flour in replacement of the chicken skin, aiming to improve the fatty acids profile and also fibres enrichment, and reduction of sodium content by replacing sodium chloride with calcium chloride. The chia flour presents high fibres (33.61 g/100 g) and α-linolenic fatty acid (omega-3; 64.97 g/100 g fat) contents. Evaluating the replacement of 0–20% chicken skin by chia flour, it was possible to observe that the addition of chia flour did not compromise the technological characteristics of the meat product. Moreover, the treatments with 5–20% chia flour showed high omega-3 content. The nuggets containing 10% chia flour can be considered a “source of fibre” and the ones containing 15% or more of chia flour, as having “high fibre content”. On the other hand, the dark coloration of the chia flour affected the colour of the chicken nuggets, causing a sensory rejection for the attribute internal appearance. However, although chia flour has influenced the sensory parameters evaluated, it was verified that the addition of up to 10% of the chia flour was considered acceptable by the consumers. The substitution of 0–75% of sodium chloride by calcium chloride with an ionic strength equivalent to 1.5% NaCl in the chicken nuggets showed that the physicochemical characteristics and sensory acceptance were not affected. A reduction of up to 75% NaCl was only able to reduce 34% sodium in chicken nuggets, which can be labelled as "reduced sodium content". The consumption of one portion (130 g) of chicken nuggets with the maximum addition of $CaCl_2$ could provide 16.9% of the recommended daily intake of calcium for adults in Brazil. And finally, the chicken nuggets, reformulate through the substitution of 10% chicken skin with chia flour and 75% sodium chloride per calcium chloride was evaluated. These nuggets showed increased protein content, reduced sodium content and an improvement of the lipid profile, due to the increase of α-linolenic acid. The microbiological analysis showed that the addition of chia flour and $CaCl_2$ did not affect the microbial growth. Regarding the sensory test, addition of chia flour to the different treatments of chicken nuggets caused lower acceptability. However, about 50% of consumers considered samples of chicken nuggets containing chia flour as acceptable. Therefore, it is concluded that the addition of chia flour and $CaCl_2$ together may be considered an even better strategy to obtain healthier chicken nuggets than their addition alone.

Keywords: Breaded meat product, sodium chloride, calcium chloride, omega-3, healthy product.

RESUMO

BARROS, J. C. **Adição de farinha de chia (*Salvia hispanica L.*) em nuggets de frango com teor de sódio reduzido**. 2019. 136 p. Tese de Doutorado – Faculdade de Zootecnina e Engenharia de Alimentos, Universidade de São Paulo, Pirassununga/SP, Brasil, 2019.

O objetivo do presente estudo foi reformular nuggets de frango, para torná-lo mais saudável, usando duas diferentes estratégias: adição da farinha de chia (*Salvia hispanica* L.) em substituição da pele de frango, objetivando melhorar o perfil lipídico e também enriquecer com fibras, e a redução do teor de sódio pela substituição do cloreto de sódio por cloreto de cálcio. A farinha de chia apresentou altos teores de fibras (33,61 g/100 g) e ácido graxo α-linolênico (ômega-3; 64,97 g/100 g lipídeos). Avaliando a substituição de 0–20% da pele de frango por farinha de chia, foi possível observar que esta adição não comprometeu as características tecnológicas do produto cárneo. Além do mais, os tratamentos com 5–20% de farinha de chia apresentaram um aumento no teor de ômega-3. Os nuggets contendo 10% de farinha de chia podem ser considerados como “fonte de fibras” e com 15% ou mais, como “alto teor de fibras”. Por outro lado, a coloração escura da chia afetou a cor dos nuggets de frango, causando rejeição sensorial para o atributo aparência interna. Entretanto, apesar da farinha de chia ter influenciado os parâmetros sensoriais avaliados, verificou-se que a adição de até 10% foi considerada aceitável pelos provadores. Já a substituição de 0–75% do cloreto de sódio por cloreto de cálcio, com uma força iônica equivalente a 1,5% de NaCl nos nuggets de frango, mostrou que as características físico-químicas e sensoriais não foram afetadas. A redução de até 75% do NaCl reduziu 34% do sódio nos nuggets de frango, o qual pode ser rotulado como “teor de sódio reduzido”. Adicionalmente, o consumo de uma porção (130 g) de nuggets de frango com a máxima adição de $CaCl_2$ pode fornecer 16,9% da ingestão diária de cálcio recomendada para adultos no Brasil. E finalmente, avaliou-se os nuggets de frango reformulados com a substituição da pele de frango por farinha de chia e NaCl por $CaCl_2$. Os resultados mostraram aumento no teor de proteínas, redução no teor de sódio e melhoria do perfil lipídico, devido ao aumento do ácido α-linolênico. As análises microbiológicas mostraram que a adição da farinha de chia e $CaCl_2$ não afetou o crescimento microbiano. Em relação ao teste sensorial, a adição de farinha de chia nos diferentes tratamentos de nuggets de frango causou baixa aceitabilidade. No entanto, em torno de 50% dos provadores consideraram as amostras de nuggets de frango contendo farinha de chia aceitáveis. Portanto, conclui-se que a adição da farinha de chia e do $CaCl_2$ em conjunto pode ser considerada uma estratégia adequada para tornar este produto cárneo ainda mais saudável do que quando adicionados isoladamente.

Palavras-chave: Produto cárneo empanado, cloreto de sódio, cloreto de cálcio, ômega-3, produto saudável.

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LIST OF ABBREVIATIONS

SFA	Saturated fatty acid
MUFA	Monounsaturated fatty acid
PUFA	Polyunsaturated fatty acid
aw	Water activity
TPA	Texture profile analysis
FAME	Fatty acid methyl ester
AI*	Acceptance index
d.b.	Dry basis
CF	Chia flour
CS	Chicken skin
NaCl	Sodium chloride
$CaCl_2$	Calcium chloride
KCl	Potassium chloride
$MgCl_2$	Magnesium chloride
NaOH	Sodium hydroxide
Mg^{2+}	Magnesium
Ca^{2+}	Calcium
IS	Ionic strength
C_i	Molary of the ion
Z_i	Net charge of the ion
JAR	Just-about-right
CATA	Check-all-that-apply
n3	Omega 3
n6	Omega 6

pH	Hydrogen potential
CFU	Colony forming unit
AOCS	American Oil Chemists’ Society
AOAC	Association of Official Analytical Chemists
FAO	Food and Agricultural Organisation
WHO	World Health Organisation
SEM	Standard error of mean.
ICP-OES	Inductively-coupled plasma optical emission spectrometers

LIST OF SYMBOLS

%	Percentage
α	Alpha
g	Grams
s	Second
cm	Centimeters
mm	Millimetre
°C	Degrees Celsius
K	Kelvin
min	Minutes
h	Hour
kg	Kilograms
mg	Milligrams
kcal	Kilocalories
M	Mol per liters (mol/L)
µL	Microliter
>	Greater
<	Less
≥	Greater equal
≤	Less equal
C12:0	Lauric acid
C13:0	Tridecanoic acid
C14:0	Myristic acid
C14:1	Miristoleic acid
C15:0	Pentadecanoic acid

C16:0	Palmitic acid
C16:1 n9	7-hexadecenoic acid
C16:1	Palmitoleic acid
C17:0	Margaric acid
C17:1	Heptadecanoic acid
C18:0	Stearic acid
C18:1 n9	Vaccenic acid
C18:1	Oleic acid
C18:2	Linoleic acid
C18:3 n6	γ-linolenic acid
C18:3 n3	α-Linolenicacid
C20:0	Arachidic acid
C20:1	Paullinic acid
C20:4	Arachidonic acid
C23:0	Tricosanoic acid

SUMMARY

1 INTRODUTION

The battered and breaded foods are very popular in high-convenience consumer societies and in developing countries (MUKPRASIRT; HERALD; BOYLE and RAUSCH, 2000). However, a major concern regarding the consumption of breaded products, mainly chicken nuggets, is because they are fried products. It is known that during the frying process of the nuggets the fat most commonly used is palm fat, according to Tan and Nehdi (2012), almost 50% of the fatty acids present in palm fat are saturated. Thus, part of the fat absorbed by the coating system of the nuggets during frying will be saturated. For Barbut (2015), about 10% of the oil will be absorbed into the final product.

One of the alternatives to improve the lipid profile of chicken nuggets would be to replace the usual fat source, i.e., the chicken skin [which presents 32.4 g/100 g of saturated fat in the composition (ALINA; BABJI and AFFANDI (2009)] by chia flour, which is known to be rich in polyunsaturated fat. The chia flour shows a fat content of 32.01 g/100 g (dry base), of which 82.7 g/100 g correspond to polyunsaturated fatty acids and 62.4 g/100 g of this value refers to α-linolenic acid (omega-3) (CONSTANTINI et al., 2014); in addition, it has a dietary fibres content of 35.85 g/100 g (dry base) (SEGURA-CAMPOS et al., 2013). Therefore, the addition of chia flour to chicken nuggets, aiming to improve the lipid profile and incorporate fibres in this meat product, may provide several health benefits to the consumer, as in the reduction of the risk of cancer, diabetes, neurological diseases, among others (SHAHIDI and AMBIGAIPALAN, 2018) and cardiovascular diseases (ROSAMOND, 2002).

Furthermore to the consumption of fat, in recent years there has been a concern about the excess sodium present in processed foods. According to the Food Standards Agency (FSA, 2016), about 75% of the sodium chloride intake is present in processed foods. In study carried out in the United Kingdom, Mhurchu et al. (2011) verified that herbs, spices and salt

(23%), meat products (18%), bread and bakery products (13%), dairy products (12%) and sauces and spreads (11%) were classified as the largest contributors to sodium purchases.

Due to the high sodium content in meat products, the meat industry and consumers became more aware about sodium intake and arterial hypertension, resulting in increased demand for meat products with low sodium content (RUUSUNEN and PUOLANNE, 2005). In Brazil, inspection agencies and meat industries signed a Term of Commitment that established national targets to reduce sodium content in various processed foods, including meat products, like, breaded meats, burgers, mortadellas, sausages, among others (BRASIL, 2013). Therefore, in order to reduce sodium content in meat products, several studies have been carried out with the aim of replacing sodium chloride with different salts, such as calcium chloride, magnesium chloride, potassium chloride, among others (Dos SANTOS et al., 2017; ALMEIDA et al., 2016).

In view of the above, the present study aimed to enrich with fibres and improve the lipid profile of chicken nuggets by replacing chicken skin with chia (*Salvia hispanica* L.) flour and reduce sodium content by substitution of sodium chloride with calcium chloride and assess the physicochemical and sensory qualities of the obtained products.

2 HYPOTHESIS

Chia (*Salvia hispanica* L.) flour can be used in the reformulation of meat products, such as nuggets, aiming at improving the lipid profile by increasing the polyunsaturated fatty acids content, mainly omega-3 and providing fibres enrichment. The replacement of sodium chloride by calcium chloride in chicken nuggets can reduce the sodium content and increase the calcium content of this product without impairing its sensory acceptance.

3 OBJECTIVES

3.1 General objective

The present study aimed to reformulate chicken nuggets to become a healthier meat product, using two different strategies: 1) Addition of chia (*Salvia hispanica* L.) flour in replacement of the chicken skin (commonly used fat source), aiming to improve the fatty acids profile and also fibres enrichment, and 2) Reduction of sodium content by replacing sodium chloride with calcium chloride.

3.2 Specifics objectives

– To evaluate the influence of chia flour when replacing the animal fat (chicken skin) in chicken nuggets, in order to determine the optimum content of chia flour possible to be incorporated with preservation of appropriate technological characteristics and good sensory acceptance;

– To evaluate the influence of calcium chloride when replacing the sodium chloride in chicken nuggets, in order to find the optimum calcium chloride content possible to be incorporated with preservation of adequate technological characteristics and good sensory acceptance;

– To evaluate the physicochemical, microbiological and sensory qualities of chicken nuggets with the optimum content of chia flour and calcium chloride.

4 BIBLIOGRAPHIC REVIEW

4.1 Chia (*Salvia hispanica* L.)

Chia (*Salvia hispanica* L.) is an annual herbaceous plant belonging to the *Labiatae* family (AYERSA and COATES, 2009), which was used by the Aztecs at the beginning of the history of Mesoamerica and was utilized as food, medicine and paints (AYERSA, 1995). But because of religious persecution and can not be cultivated in Europe, chia has disappeared for 500 years (AYERSA and COATES, 2011). However, due to its antioxidant capacity and the high-proteins, fibres and polyunsaturated fatty acids contents, several studies have been carried out with the addition of chia in foods (COELHO and SALAS-MELLADO, 2014).

Comparing the protein, lipids and fibres contents of chia flour with other vegetative sources and different literature, it is possible to verify that the composition of chia flour is superior, as can be observed in Table 1.

Table 1 – Comparison of the protein, lipids and fibre content of chia flour with other sources.

	Protein (g/100 g)	**Lipids (g/100 g)**	**Fibres (g/100 g)**	**Reference**
Chia flour	20.01	30.97	31.51	Pizarro; Almeida; Sammán and Chang, (2013).
Amaranth flour	14.53	6.46	9.37	Bianchini; Beleia and Bianchini, (2014).
Quinoa	13.49	1.42	6.60	Balbi; Oliveira and Chiquito, (2014).
Oat flour	13.4	7.9	4.0	Karam; Grossmann and Silva, (2001).

In relation to the fatty acids profile in chia, Marineli et al. (2014) reported that chia is composed of 11.12 g/100 g saturated fatty acids (SFA), 7.29 g/100 g monounsaturated fatty acids (MUFA) and 81.59 g/100 g polyunsaturated fatty acids (PUFA) and among the PUFAs, the α-linolenic acid (omega-3) is the one present in the highest proportion (62.80 g/100 g). This result of chia PUFA was superior to other sources of omega-3. According to Novello and Pollonio (2012), the brown flaxseed seed has 62.75 g/100 g PUFA (16.61 g/100 g α-linolenic acid) and the golden flaxseed seed 63.26 g/100 g PUFA (16.28 g/100 g α-linolenic acid). The quinoa presents 56.14 g/100 g PUFA, where 7.34 g/100 g corresponds to α-linolênic acid (CALDERELLI; BENASSI; VISENTAINER and MATIOLI, 2010).

Thus, due to the composition of chia, its use can add value to food products. For Mesias; Holgado; Marquez-Ruiz and Morales (2016), the incorporation (5–20%) of chia flour into wheat-based biscuits resulted in a nutritious product with high contents of protein, fibres, polyunsaturated fatty acids and antioxidants. Pizarro; Almeida; Sammán and Chang (2013) verified that pound cake containing 15 g whole chia flour/100 g flour mixture (chia flour and wheat flour) had a decrease in SFA (5%) and MUFA (9%), but there was an increase in PUFA (35%), mainly omega-3 (3238%).

Regarding the incorporation of chia in meat products, Pintado; Herrero; Jiménez-Colmenero and Ruiz-Capillas (2016), studying the incorporation of 10 g/100 g chia flour and different emulsions containing 10 g/100 g chia flour in frankfurters as a substitute for animal fat, found that the formulations containing chia flour were acceptable to the consumers and they were responsible for the increase of fibres and omega-3 contents. Ding et al. (2017) verified that the addition of 0.5–1% chia seed in formulation of restructured ham-like product improved not only physicochemical and sensory properties, but also added nutritional values in the product.

4.2 Dietary fibres

Dietary fibres are divided into two groups: soluble fibres (e.g. pectins, gums, oat bran and barley meal), whose function is to lower blood cholesterol; and insoluble fibres (e.g. wheat bran), which have less effect on the viscosity of the intestinal contents, increasing the stool size (SLAVIN, 2008; VERMA and BANERJEE, 2010). It is recommended a minimum fibres consumption of 25 g/day on a 2000 kcal diet (BRASIL, 2003), since fibres consumption may reduce obesity, constipation, glucose levels, blood pressure and cardiovascular disease (BERNAUD and RODRIGUES, 2013).

Therefore, the addition of fibres in food products is becoming important for the food industry, as refined flours bakery, beverages, dairy and meat products, because it improves the nutritional value of products and contributes to competitiveness (VERDÚ; BARAT and GRAU, 2017). In addition, fibres have functional properties when incorporated into foods because they increase water and oil retention capacities, prevent syneresis, form emulsions and/or geis, modifie texture, stabilize fat-rich foods and emulsions, and improve the shelf life of the products (ELLEUCH et al., 2011).

Choe et al. (2013), studying the effect of a mixture of pork skin and wheat fibres (40 g/100 g pork skin, 20 g/100 g wheat fibres and 40 g/100 g water) as a substitute for fat in frankfurter-type sausages, found that the addition of up to 15 g/100 g of this blend was able to reduce the cooking loss and increase the emulsion stability and viscosity due to the excellent ability of the fibre to retain water and fat. Verma et al. (2015), when evaluating low-fat chicken nuggets enriched with 8, 10 and 12 g/100 g pea hull flour, found that the nuggets added with fibres presented reduced total cholesterol and glycolipid levels of 8% and 12%, respectively, in function of the addition of the fibres in the formulation.

Verma; Banrjee and Sharma (2012), studying low-fat nuggets made with sodium chloride replacement (with potassium chloride, citric acid, tartaric acid and sucrose) and with addition of different proportions (5, 7.5 and 10 g/100 g) of chickpea hull flour, observed that the presence of chickpea hull flour increased fibre content and reduced cholesterol levels, however, the incorporation of fibres above 5 g/100 g caused low sensory acceptance.

According to Brazilian legislation, for a product to be considered as a "source of fibres", the food must have a minimum of 3 g of fibres/100 g of product or at least 2.5 g/serving and for the "high fibres content" must have at minimum 6 g of fibres/100 g of product or at least 5 g/serving (BRASIL, 2012).

4.3 Omega-3: α-linolenic fatty acid

The α-linolenic acid (belongs to omega-3 family – n3) is a polyunsaturated fatty acid (C18:3) essential in the diet, mainly because it is not synthesized by humans. The adequate consumption of α-linolenic in the diet for men and women over 19 years is 1.6 g/day and 1.1 g/day, respectively (INSTITUTE OF MEDICINE, 2002). The consumption of omega-3 fatty acids is of extreme importance because it can promote several benefits, such as, reducing the incidence of cardiovascular diseases, atherosclerosis, hypertension, obesity, inflammatory diseases, among others (Yashodhara et al., 2009). α-linolenic acid is found in chloroplasts of green leafy vegetables and in flax, chia, rape, walnuts and perilla seeds (SIMOPOULOS, 2016).

In meat and meat products the presence of omega-3 fatty acids is relatively low; therefore, their increase in these products is particularly important (BERNARDI et al., 2016). Pintado et al. (2018) evaluated the use of emulsion gels containing 20% olive oil, 20% chia flour or 20% oat bran as animal fat replacers in low-fat fresh sausage (*longaniza* type) and observed that the formulation containing chia flour presented higher α-linolenic acid content, accounting for approximately 10% of total fatty acids. Pintado et al. (2016) observed an increase in α-linolenic acid content in frankfurters reformulated with 10 g/100 g chia flour.

Novello and Pollonio (2013), when evaluating the addition of 5 g/100 g golden flaxseed in beef patties through different strategies (oil, flour and seed), verified a significant increase in the omega 3 (α-linolenic acid) content. An increase in omega-3 content was also observed by Berasategi et al. (2011) with the addition of 8.75 g/100 g linseed oil in bologna-type sausage stabilized with an aqueous-ethanol extract of *Melissa officinalis*. Heck et al. (2017), studying the effect of the 50% replacement of pork back fat by chia or linseed oil microparticles in beef burger, found an increase >1000% of α-linolenic acid in both raw and cooked products.

4.4 Chicken nuggets

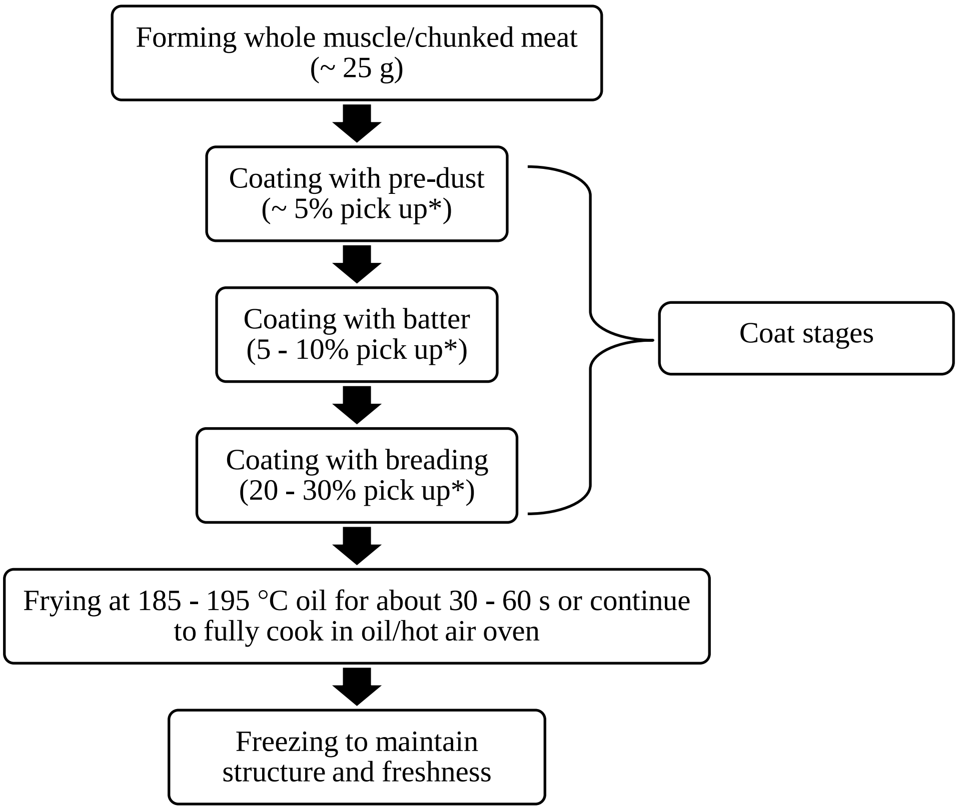
In 1950, Robert C. Baker, a professor of food sciences and poultry science at Cornell University in the United States, helped develop chicken nuggets and also found a way to keep breading linked to nuggets during the frying stage. Today, chicken nuggets are a basic food in supermarkets and fast food restaurants (CORNELL UNIVERSITY, 2006). However, Baker published the formulation of chicken nuggets as non-patented academic work and in 1979 the McDonald's corporation patented its formulation of Chicken McNuggets, beginning to be marketed in 1980 (ANONYMOUS, 2018). Anyway, the introduction of this meat product into fast food restaurants was of great importance for poultry industry (BARBUT, 2012).

In Brazil, in recent years, there has been an increase in the demand for poultry meat products, among of which stand out the chicken nuggets (which belong to the breaded products class) (NUNES; TRINDADE; ORTEGA and CASTILLO, 2009). According to data released by Datamark (2018), in 2017 the consumption of breaded products was 110,114 tons.

According to the Brazilian legislation (BRASIL, 2001), it is understood to be a “breaded product” the industrialized meat product, obtained from meat of different species, added with ingredients, molded or not, and coated with appropriate cover that characterizes it.

The same legislation further specifies that the total carbohydrates content must be at maximum 30 g/100 g and proteins at minimum 10 g/100 g. Figure 1 presents the typical steps involved in the production of chicken nuggets, according to the descriptions of Barbut (2015).

Figure 1 – Steps involved in chicken nuggets production.



Flowchart created from the descriptions of Barbut, S. Battering and breading – Production under HACCP**. In:** The science of poultry and meat processing.Cap.14, p. 14-1 – 14-50, 2015. *pick up – percentage of weight gain in coating.

The coating system (Figure 1) usually comprises three steps: 1) pre-dust – coating the meat with a fine layer of flour before the batter and breading; 2) batter – the meat product is coated with a solution (dry ingredients as corn flour and proteins diluted in water), with the purpose of adhering the breading flour and 3) breading –is used to create appearance, texture and increase the volume and weight of the product (BARBUT, 2015).

According to Dill; Silva and Luvielmo (2009) it is possible to add value and convenience to breaded meat products. Thus, several studies have been developed aiming at improving the nutritional quality of chicken nuggets. Santhi and Kalaikannan (2014), studying the incorporation of 10 g/100 g and 20 g/100 g of oat flour into low fat chicken nuggets, found an increase in fibres content in the formulations containing oat flour and that the addition of up to 10 g/100 g was considered acceptable by the consumers. Alina; Babji and Affandi (2009), evaluating the replacement of chicken fat with palm fat in chicken nuggets, found that this replacement reduced up to 45% of the cholesterol content.

4.5 Reduction of sodium in meat products

Since ancient times, sodium chloride (salt; NaCl) has been used for the preservation of meat products, but currently is one of the ingredients most used with the purpose of enhancing or improving the taste and obtaining desired texture (DESMOND, 2006), by the solubilization of myofibillary proteins, which is capable of increasing adhesion and cohesion in meat products (INGUGLIA et al., 2017), besides to reducing cooking loss and improving yield (RUUSUNEN and PUOLANNE, 2005).

However, sodium chloride is responsible for approximately 90% of sodium in the diet and its consumption contributes to the increase in blood pressure, which is a risk factor for cardiovascular diseases (HE and MACGREGOR, 2010; VERMA and BARNEJEE, 2012). In order to prevent problems caused by excess sodium in foods, the World Health Organization (WHO, 2013) recommends that sodium chloride intake be maximum 5 g/day. One way of reducing the amount of sodium in meat products is the partial or total replacement of sodium chloride by other substances, such as, potassium chloride (KCl), magnesium chloride ($MgCl_2$), calcium chloride ($CaCl_2$), potassium lactate and others (REDDY and MARTH, 1991).

When evaluating the 50% substitution of sodium chloride by potassium chloride in Bologna sausages, Carraro et al. (2012) verified a reduction in sodium content of approximately 31%. Besides its low sodium content (998.15 mg/100 g to 680.19 mg/100 g), the product also presented a high level of potassium (286.98 mg/100 g for 880.92 mg/100 g). However, studying the substitution of the sodium chloride content by potassium chloride and ammonium chloride in chicken pate, Lazic et al. (2015) observed that the overall acceptability of the meat product decreased with the reduction of sodium chloride (5 g to 3.25 and 2.17 g) and that the samples containing (1.1 and 3.25 g) potassium chloride presented bitter taste, which is a characteristic of potassium.

Moreover, Lorenzo et al. (2015), studying the replacement of sodium chloride (100% NaCl; Control) by blends of salts containing 50% NaCl + 50% KCl; 45% NaCl + 25% KCl + 20% $CaCl_2$ + 10% $MgCl_2$ and 30% NaCl + 50% KCl + 15% $CaCl_2$ + 5% $MgCl_2$ in cured and dry lacón, reported that the consumers identified inferior salty taste in relation to the treatment without reduction of sodium and that the bitter taste was perceptible in treatments containing the blends of salt as a substitute for sodium chloride. Armenteros; Aristoy; Barat and Toldrá (2012), evaluating the use of the salts mixtures (50% NaCl + 50% KCl and 55% NaCl + 25% KCl + 15% $CaCl_2$ + 5% $MgCl_2$) as partial substitute of sodium chloride (100% NaCl; Control) in dry-cured hams, verified that the presence of calcium and magnesium salts affected the acceptability of the meat product. The divalent cations, as calcium and magnesium, present bitter taste and metallic or astringent sensations (YANG and LAWLESS, 2005).

Horita; Morgano; Celeghini and Pollonio, (2011) found that calcium chloride negatively influenced the emulsion stability, due to the large amount of liquid released, independent of the presence of other salts in the mortadella composition (1.0% NaCl + 0.5% KCl + 0.5% $CaCl_2$ and 0.5% NaCl + 1% KCl +0.5% $CaCl_2$), which can be explained by the presence of divalent cation ions (Ca^{2+}), which may contribute for the reduction of myofibrillar protein extraction. In another study, Horita et al. (2014) evaluated frankfurter sausages with sodium chloride replacement by blends containing 75% NaCl + 25% KCl; 75% NaCl + 25% $CaCl_2$; 75% NaCl + 12.5% $CaCl_2$ + 12.5% KCl; 50% NaCl + 25% $CaCl_2$ + 25% KCl; 50% NaCl + 50% KCl and 50% NaCl + 50% $CaCl_2$ (with ionic strength equivalent to 2% NaCl). These authors observed that, although calcium chloride has influenced emulsion stability in frankfurter sausages, the use of chloride salt mixtures as partial substitutes for NaCl may favor the balanced ingestion of minerals in the meat product.

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CHAPTER 1

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Omega-3- and fibre-enriched chicken nuggets by replacement of chicken skin with chia (*Salvia hispanica* L.) flour

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Abstract

This study aimed to reformulate chicken nuggets, through the replacement of 0−20% chicken skin by chia flour, to produce a fibre-enriched product with a healthier fatty acid profile. The replacement of chicken skin by chia flour increased polyunsaturated fatty acids (including the omega-3 fatty acid α-linolenic acid) and dietary fibre contents while decreased the contents of moisture, saturated fatty acids and monounsaturated fatty acids, and lowered the water activity. The protein, lipid and ash contents, oil absorption, weight gain of the coating and cooking yield were not affected by the incorporation of chia flour, whereas the objective colour and texture parameters were affected. The chicken nuggets containing 10% chia flour were considered acceptable by the panellists. Moreover, the addition of up to 10% chia flour in chicken nuggets did not compromise the technological characteristics and acceptability of the meat product.

Keywords: α-linolenic acid; acceptance sensory; healthiness; meat product.

1 Introduction

According to Jiménez-Colmenero; Carballo and Cofrades (2001) reformulated meat products can be obtained by reduction of components, such as fat, saturated fatty acids (SFAs), salt and nitrite or by the incorporation of functional ingredients, like fibres, vegetable proteins, monounsaturated fatty acids (MUFAs), polyunsaturated fatty acids (PUFAs) and natural antioxidants. In this context, Pintado; Herrero; Jiménez-Colmenero and Ruiz-Capillas, (2016) and Bernardi; Bertol; Pflanzer; Sgarbieri and Pollonio, (2016) focused on the reformulation of meat products, to improve their healthiness, through the addition of the functional ingredients chia (*Salvia hispanica* L.) and omega-3 (n-3), respectively.

The addition of chia (*S. hispanica* L.) flour, considered a functional food due to its composition (MUÑOZ; COBOS; DIAZ and AGUILERA, 2013), represents an interesting option for reformulated meat products. Chia, an annual herbaceous plant belonging to the *Labiatae* family, is native to southern Mexico and northern Guatemala (ÁLVAREZ-CHÁVEZ; VALDIVIA-LÓPEZ; ABURTO-JUÁREZ and TECANTE, 2008) and has been largely used as a food, oil source and raw material for medicinal compounds (CAPITANI; IXTAINA; NOLASCO and TOMÁS, 2013). In 2009, chia was classified as novel food by the European Food Safety Authority (BREESON et al., 2009). Segura-Campos; Ciau-Solís; Rosado-Rubio; Chel-Guerrero and Betancur-Ancona, (2014) documented that chia flour contains 34.46 g/100 g fibres and 35.13 g/100 g lipids (dry basis), the latter comprising 91.88 g/100 g unsaturated fatty acids, of which, 68.52 g/100 g is α-linolenic fatty acid (n3). A diet rich in n-3, is essential to brain function and has been used in the treatment of cardiovascular disease, cancer and arthritis (PIZARRO et al., 2015). The consumption of fibre improves the functioning of digestive system and also contributes in prevention of colon cancer and constipation (VÁZQUEZ-OVANDO; ROSADO-RUBIO; CHEL-GUERRERO and BETANCUR-ANCONA, 2009).

For the processing of breaded meat products, such as chicken nuggets, chicken skin, which contains 30.2 g/100 g saturated fat and 2.37 g/100 g n-3, is normally used (FEDDERN et al., 2010). Thus, the addition of chia flour as chicken skin substitute can improve the lipid profile, by increasing the n-3 content of the product and can also increase fibre content, resulting in several health benefits to the consumer. The present study aimed to reformulate chicken nuggets, by substitution of chicken skin with chia (*S. hispanica* L.) flour, to improve the fatty acids profile and enrich the fibre content.

2 Materials and methods

The study was performed at the College of Animal Science and Food Engineering of the University of São Paulo (FZEA/USP), Brazil. Sensory evaluation of nuggets, was approved by the Ethics Committee for Research at FZEA/USP (Process 49161415.3.0000.5422) (ANNEX B).

2.1 Processing of chicken nuggets

Five formulations of chicken nuggets were prepared, by substituting chicken skin, with chia flour (Table 2). The raw material: chicken breast fillet, chicken skin and chia flour, were obtained from a local market in São Paulo, Brazil.

The total dietary fibre content in chia flour was evaluated by the enzymatic method (985.29), according to the Association of Official Analytical Chemists' (AOAC, 2012). The chia flour and chicken skin were characterized for proximate composition, according to official AOAC method (Cunniff, 1998) and lipid content was evaluated, by the Bligh and Dyer method (1959).

Table 2 – Formulation of control chicken nugget and with various levels of chicken skin substitution by chia (*Salvia hispanica L*) flour.

Ingredients (g/100 g)	Treatments				
	Control	Chia5%	Chia10%	Chia15%	Chia20%
Chicken breast fillet	77.7	77.7	77.7	77.7	77.7
Chicken skin	20	15	10	5	-
Chia flour	-	5	10	15	20
Sodium chloride*	1.5	1.5	1.5	1.5	1.5
Sodium erythorbate**	0.05	0.05	0.05	0.05	0.05
Sodium tripolyphosphate**	0.25	0.25	0.25	0.25	0.25
Onion powder***	0.30	0.30	0.30	0.30	0.30
Garlic powder***	0.15	0.15	0.15	0.15	0.15
White pepper***	0.05	0.05	0.05	0.05	0.05

Reference: Barros et al. (2018). *Cisne (Cabo Frio, Brazil). **Cori Ingredientes (Rio Claro, Brazil). *** New Max (Americana, Brazil).

For the processing of the chicken nuggets, chicken breast fillet was ground in a grinder with an 8 mm diameter disc and chicken skin in a 4 mm diameter disc and then mixed with chia flour and the remaining ingredients (Table 1), until a homogeneous mixture was obtained. The meat batter was shaped in a nuggets format (about 25 g), frozen and then coated as follows: pre-dust (type PDA 66-TC), batter coating (adhesion type BMA 91-TC), and breading (dressing type SA F05). The nugget coating materials were donated by Kerry Company (Campinas, Brazil).

The chicken nuggets were fried in palm fat (type 370F, Agropalma) (Belém, Brazil) at 180 °C until an internal temperature of 72 °C. After frying, the nuggets were packed in polyethylene plastic bags and stored frozen at -18 °C. All analyses of the nuggets were performed after frying step (product ready for consumption). The entire experiment (processing of all formulations) was repeated three times.

2.2 Physicochemical analysis of chicken nuggets

2.2.1 Proximate composition and oil absorption

The proximate composition was carried out according to official AOAC method (Cunniff, 1998) to determine protein (981.10), ash (920.153) and moisture (950.46) contents. Lipid content was evaluated following the Bligh and Dyer method (1959). All analyses were carried out in triplicate. Oil absorption was calculated by difference between the lipid content of the samples, before and after frying.

The fibres content of the chicken nuggets was calculated according to the dietary fibre content present in chia flour and the proportions added to the meat batter of chicken nuggets, considering the weight gain of the coating (pick-up) and the cooking yield of the frying process. The results obtained were expressed as both grams (g) per 100 g and grams (g) per 130 g portion of nuggets, as established by the Brazilian Health and Surveillance Agency (ANVISA) Resolution RDC no. 359 (BRASIL, 2003a).

2.2.2 Objective colour

Samples were cut in half to evaluate the influence of the chia flour on the meat batter colour. The L^* (brightness), a^* (greenness/redness) and b^* (blueness/yellowness) colour parameters of the CIELAB system were recorded using a portable colourimeter (HunterLab®, MiniScan XE, USA), with the D_{65} illuminant, 10º viewing angle and 30-mm cell aperture. A total of eight readings were done.

2.2.3 Water activity

The water activity (aw) of the nuggets was evaluated, using an Aqualab (Decagon Devices, Pullman, WA, USA), with three repetitions per treatment.

2.2.4 Cooking yield

The cooking yield was calculated by difference between fried nuggets weight and the raw nuggets weight (after coating) multiplied by 100 (DEVATKAL; KADAM; NAIK and SAHOO, 2011).

2.2.5 Percentage of weight gain in coating (pick-up)

The difference in weight of nuggets (24 samples per treatment) before and after the three-step coating system (pre-dust, batter and breading) was used to estimate the pick-up (Equation 1):

$$pick-\mathrm{up} = \left(\frac{\text{Nuggets with coating - Nuggets without coating}}{\text{Nuggets with coating}} \right) * 100 \tag{1}$$

2.2.6 Texture profile analysis (TPA)

Instrumental TPA (hardness, cohesiveness, chewiness and springiness parameters) was determined using a TA-XT2i texturometer (Stable Micro Systems, Godalming, UK) equipped with a 30 mm diameter aluminium probe moving at 0.3 mm/s. Six replicates were measured per sample. In order to obtain accurate results, without potential interference by the coating system, the coating system of the nuggets was removed and the meat batter was cut into 2 × 2 cm pieces.

2.2.7 Fatty acid profile

Total fat was extracted from the nuggets, using the Bligh and Dyer method (1959). The fatty acid profile of the meat products was determined by fatty acid methyl ester (FAME) gas chromatography, according to the official AOCS methods Ce 2-66 and Ce 1-62 (AOCS, 1998). A Shimadzu 2010 AF capillary gas chromatograph (Japan), equipped with an automatic injector (AOC 20i, Shimadzu, Japan) and a flame ionisation detector, was used under the following conditions: highly polar capillary bis-cyanopropyl polysiloxane column (100 m × 0.25 mm i.d.; 0.20 µm film thickness) (SP-2560, Supelco, Bellefonte, PA, USA), helium carrier gas at a linear velocity of 19.5 cm/s; injection temperature of 250 ºC, detector temperature of 260 ºC; 1.0 µL injection volume, and 100:1 split ratio. The column temperature was 140 ºC (held for 5 min) after injection and then increased to 240 ºC at 4 K/min (held for 15 min). The FAMEs were identified by comparison with external standards (Supelco, Bellefonte, PA, USA). The quantification was based on comparing the area of each fatty acid with the area of the internal standard methyl tridecanoate (C13:0) (Sigma-Aldrich, Bellefonte, PA, USA) (ZENEBON; PASCUET and TIGLEA, 2008), using the response correction factors of the flame ionisation detector and the conversion of FAMEs to fatty acids.

2.3 Sensory evaluation

The chicken nuggets were sensorially assessed by the acceptance test, using a 9-point hedonic scale, which ranged from “1 – dislike very much” to “9 – like very much”. A total of 113 consumers (aged 17–40 years; 66% female and 34% male) that had interest, availability and a habit of consuming chicken nuggets evaluated the meat products for internal appearance, aroma, texture, flavour and overall quality attributes (Appendix A). Each panellist agreed and signed the Free and Informed Consent Form (Appendix B) before the analysis.

For sensory analysis, the nuggets were heated in an electric oven and kept at 60 °C, until the evaluation. The samples were coded with random three-digit numbers and served monadically to consumers, in a randomised complete block design. Based on the scores attributed by the panellists (hedonic scale), the acceptance index (AI) was calculated by the relation between the average score obtained by the sample and the maximum score of the hedonic scale (9) multiplied by 100 (DUTCOSKY, 1996).

2.4 Statistical analysis

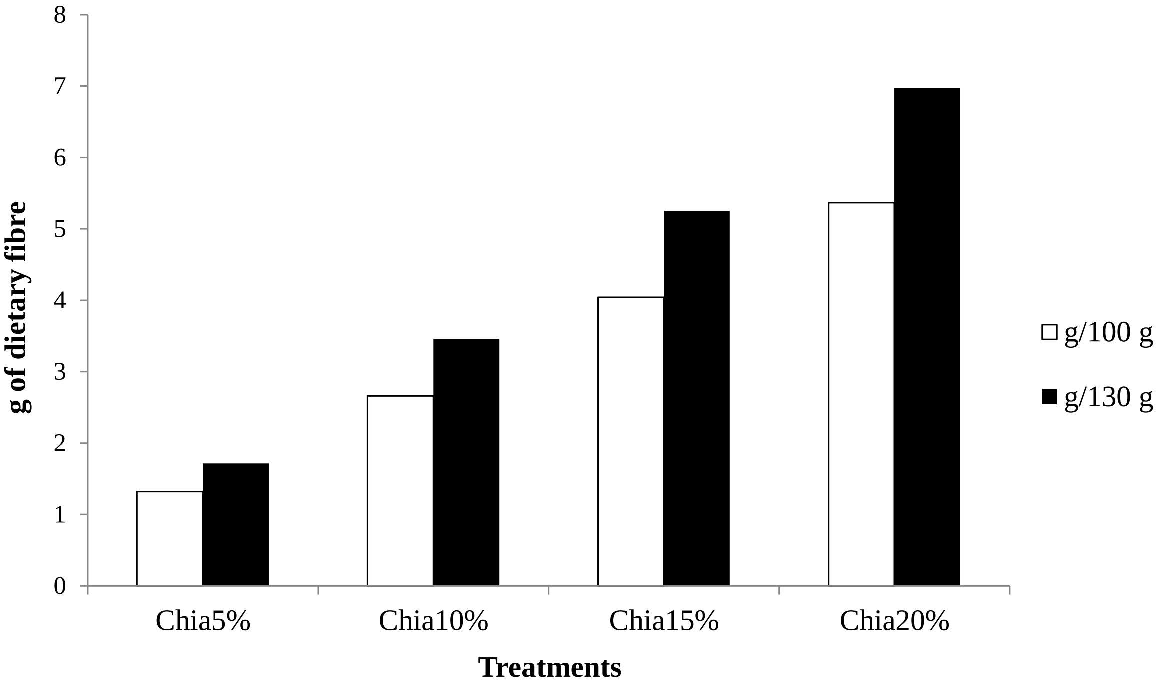
The research was conducted according to a completely randomised design, with five treatments and three repetitions. All data were evaluated by analysis of variance (ANOVA) and the means were compared by Tukey's test, using SISVAR® program, version 5.6 (FERREIRA, 2011), at 5% level of significance.

3 Results and discussion

The chicken skin presented the following proximate composition: 40.42 g/100 g fat, 14.05 g/100 g protein, 49.28 g/100 g moisture and 0.30 g/100 g ash. Chia flour was comprised of 36.26 g/100 g fat, 24.57 g/100 g protein, 33.61 g/100 g fibres, 6.94 g/100 g moisture and 4.55 g/100 g ash. The mean values of the chia flour proximate composition, showed similarity to the results found by Segura-Campos et al. (2014).

Figure 2 shows the increase in fibres content of chicken nuggets due to increasing proportion of chia flour added to substitute chicken skin. The chicken nuggets containing 10% chia flour can be considered a "source of fibre" and above 15% chia flour, as having a "high fibre content", according to Brazilian legislation (BRASIL, 2012). Pintado et al. (2016), studying the addition of 10% chia flour and a chia oil-in-water emulsion gel, in frankfurters (fat reduction), found between 4.90 to 5.80 g/100 g dietary fibre, classifying them as a source of fibre.

Figure 2 – Fibre content (g/100 g product and g/130 g product portion*) in chicken nuggets containing various chia flour concentrations.



Reference: Barros et al. (2018). *A portion of chicken nuggets is equivalent to 130 g (Brasil, 2003a). Chia5% - 15 g/100 g chicken skin + 5 g/100 g chia flour; Chia10% - 10 g/100 g chicken skin + 10 g/100 g chia flour; Chia15% - 5 g/100 g chicken skin + 15 g/100 g chia flour and Chia20% - 20 g/100 g chia flour.

Dietary fibre is an important nutrient in the diet that aids in the functioning of the digestive system and prevention of diabetes, colon cancer and cardiovascular disease, besides satiety sensation and reducing body weight (VERMA and BANERJEE, 2010). Although the daily recommendations of fibre intake differ among some countries, the consumption of 30–40 g/day of fibre is advised (MEHTA; AHLAWAT; SHARMA and DABUR, 2015). The recommended fibre intake is 25–30 g/day, according to the American Dietetic Association while 20 g/day is observed in European guidelines (BORDERÍAS; SÁNCHEZ-ALONSO and

PÉREZ-MATEOS, 2005) and 25 g/day in Brazil, based on a diet of 2000 kcal (BRASIL, 2003b). The present study estimated that the consumption of a portion (130 g) of chicken nuggets containing 10% chia flour (2.66 g dietary fibre/100 g or 3.46 g/130 g), could provide 14% of the recommended daily fibre intake according to Brazilian legislation.

Table 3 presents the proximate composition (dry basis–d.b.), oil absorption, objective colour, aw, cooking yield, pick-up and texture profile results, of chicken nuggets. The protein content did not differ (p>0.05) among all treatments. Conversely, Santhi and Kalaikannan (2014), evaluated the addition of oat flour (0, 10 and 20%) to low-fat chicken nuggets and observed a significant decrease in the protein content. Although the protein contents did not show differences (p>0.05) in the present study, the variations found for the mean protein values (34 to 37 g/100 g), demonstrated that the protein content tended to increase with the increased substitution of chicken skin by chia flour. This was expected given the protein content of the chia flour (24.57 g/100 g). Moreover, the chicken nuggets can be claimed as a product with "high protein content" (BRASIL, 2012).

All treatments presented similar (p>0.05) lipid contents of around 24-28 g/100 g (d.b.), which can be attributed to chia flour (36.26 g/100 g) and chicken skin (40.42 g/100 g), having a similar lipid level. The oil absorption presented no differences (p>0.05), ranging from 6.55−7.72 g/100 g, among all evaluated products. These values were lower than the means values observed by Alina; Babji and Affandi, (2009) who verified, before and after the cooking process, that fat content of chicken nuggets with added palm fat ranged from 12.2−16.5 g/100 g and from 21.3−26.0 g/100 g, respectively.

Table 3 – Proximate composition (dry basis–d.b.), oil absorption, water activity (aw), cooking yield, pick-up, objective colour and texture profile of the chicken nuggets.

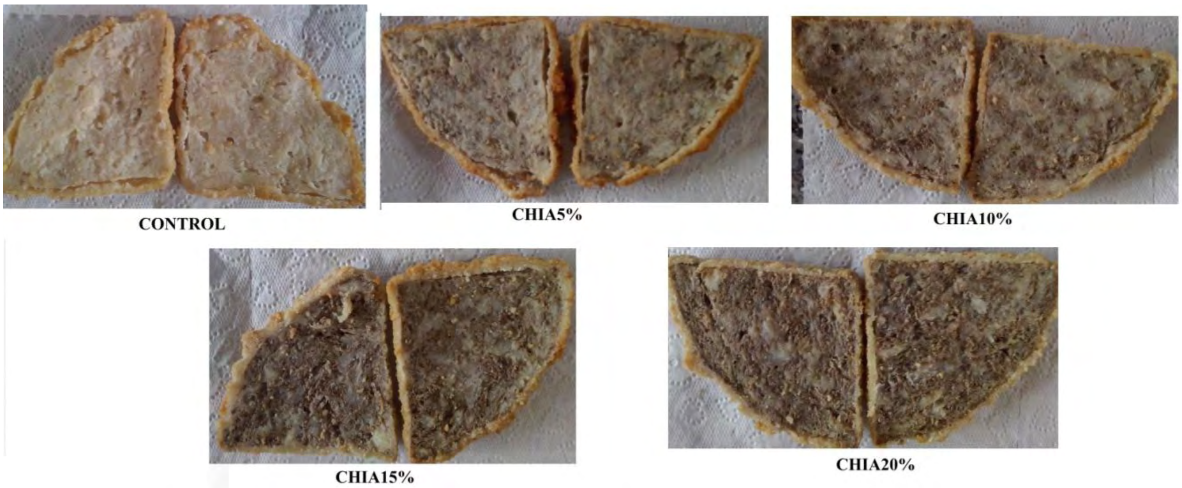
Analysis		Treatments				
		Control	Chia5%	Chia10%	Chia15%	Chia20%
Oil absorption (g/100 g)		6.55±0.36[a]	6.80±0.34[a]	6.50±0.72[a]	7.32±0.05[a]	7.72±1.83[a]
Proximate composition (g/100 g)						
Protein		34.66±1.29[a]	34.91±1.83[a]	36.85±3.15[a]	36.68±1.85[a]	37.33±3.60[a]
Lipid		28.41±3.05[a]	26.77±2.13[a]	26.09±1.14[a]	25.90±1.38[a]	24.89±1.10[a]
Moisture		49.15±1.39[a]	48.71±0.58[a]	47.34±0.96[ab]	45.50±1.11[bc]	43.67±0.67[c]
Ash		3.91±0.29[a]	3.92±0.18[a]	4.30±0.07[a]	4.17±0.06[a]	4.28±0.09[a]
Objective colour	L*	73.74±1.25[a]	61.05±0.75[b]	54.08±1.42[c]	53.01±1.58[c]	48.87±0.84[d]
	a*	2.65±0.53[c]	2.62±0.16[c]	3.58±0.12[b]	4.15±0.25[a]	4.55±0.20[a]
	b*	20.35±0.73[a]	14.86±0.59[c]	15.31±0.39[bc]	15.82±0.33[b]	16.02±0.52[b]
aw		0.97±0.00[a]	0.96±0.00[ab]	0.96± 0.00[ab]	0.96±0.00[bc]	0.95±0.00[c]
Cooking yield (%)		90.54±3.19[a]	95.02±1.73[a]	95.65±1.58[a]	95.04±2.01[a]	95.35±1.85[a]
Pick-up (%)		30.94±3.54[a]	34.04±2.40[a]	32.06±1.28[a]	31.23±2.80[a]	31.37±2.05[a]
Texture profile analysis (TPA)						
Hardness (kg)		4.14±0.41[b]	4.83±0.23[ab]	4.80±0.37[ab]	5.19±0.22[a]	5.32±0.27[a]
Cohesiveness		0.75±0.02[a]	0.65±0.01[ab]	0.58±0.05[bc]	0.54±0.04[c]	0.50±0.07[c]
Chewiness (kg.mm)		2.17±0.37[a]	1.98±0.26[ab]	1.66±0.16[bc]	1.61±0.10[bc]	1.47±0.38[c]
Springiness (mm)		0.69±0.04[a]	0.63±0.05[b]	0.59±0.05[bc]	0.57±0.02[c]	0.54±0.04[c]

Reference: Barros et al. (2018). [a, b, c, d] Means with different letters in a row are significantly different ($p<0.05$). Means ± standard deviation. Control – 20 g/100 g chicken skin; Chia5% - 15 g/100 g chicken skin + 5 g/100 g chia flour; Chia10% - 10 g/100 g chicken skin + 10 g/100 g chia flour; Chia15% - 5 g/100 g chicken skin + 15 g/100 g chia flour and Chia20% - 20 g/100 g chia flour.

The addition of 5 and 10% chia flour in chicken nuggets, did not cause any significant difference ($p>0.05$) in the moisture content, compared to the control treatment. However, a decrease ($p<0.05$) in this parameter occurred in the 15 and 20% chia flour treatments. This moisture loss was indicated by Verma; Banerjee and Sharma (2015) in low-fat chicken nuggets with salt substitute (potassium chloride, citric acid, tartaric acid and sucrose) and enriched with 8, 10 and 12 g/100 g pea hull flour. The moisture reduction in the present research can be explained by the low moisture content of chia flour (6.94 g/100 g) compared to the chicken skin (49.28 g/100 g). The ash content (minerals) in chicken nuggets did not differ ($p>0.05$) among all treatments. Similarly, Pintado; Herrero; Jiménez-Colmenero; Cavalheiro and Ruiz-Capillas (2018), also observed no differences in ash content when studying the addition of chia emulsion gel in fresh sausages.

All the objective colour parameters evaluated differed ($p<0.05$) among the various chicken nuggets. The brightness (L^*) parameter decreased with the increase in chia flour addition ($p<0.05$). This decrease was caused by the dark colour of the chia flour, as illustrated in Figure 3. Coelho and Salas-Mellado (2015) also verified this trend in the L^* value, in the crumb of bread with added chia flour.

Figure 3 – Internal appearance of chicken nuggets treatments.



Reference: Barros et al. (2018). Control – 20 g/100 g chicken skin; Chia5% - 15 g/100 g chicken skin + 5 g/100 g chia flour; Chia10% - 10 g/100 g chicken skin + 10 g/100 g chia flour; Chia15% - 5 g/100 g chicken skin + 15 g/100 g chia flour and Chia20% - 20 g/100 g chia flour.

The 5% chia addition was similar to the control formulation for parameter *a** (redness) ($p>0.05$) whereas at 10% chia flour addition the mean *a** values increased ($p<0.05$) in comparison to control nuggets. However, a decrease in yellowness (*b**), was observed between the treatments containing chia flour and the control ($p<0.05$). Pintado et al. (2016) studied frankfurters reformulated with 10% chia flour and identified a decrease in *L** and *a**, and an increase in *b**. The difference between the current colour parameter values (Table 3) and other literature sources that added chia flour to food products, can be attributed to the variable composition of the products studied such as raw materials used in the processing which can result in a product with different characteristics.

Regarding the aw results (Table 3), the nuggets with up to 10% chia flour addition did not differ from the control treatment ($p>0.05$) but the mean aw values decreased in nuggets with 15% chia flour or more ($p<0.05$). An aw reduction was also observed by Mesías; Holgado; Márquez-Ruiz and Morales (2016), in biscuits with various proportions of chia flour added (0–20%). In the present study, the aw correlated positively with the moisture content of the chicken nuggets ($r = 0.3593$, $p<0.05$, $n = 45$) indicating that aw reduction was a function of the chicken skin substitution by chia flour, which had a relatively lower moisture content (6.94 g/100 g) than the chicken skin (49.32 g/100 g).

A replacement of up to 20% chicken skin by chia flour in chicken nuggets did not affect the cooking yield ($p>0.05$, Table 3). However, the observed cooking yields (control: 90%; samples with chia flour: 95%), showed that the yield tended to increase with chia flour addition, probably due to the improved water retention and absorption capacity displayed by chia flour (CAPITANI; SPOTORNO; NOLASCO and TOMÁS, 2012), as a consequence of its high fibres content (33.61 g/100 g).

The mean pick-up values did not differ ($p>0.05$) among the chicken nugget treatments which was expected because the formulation changes were carried out only in the meat batter and not in the coating system. The pick-up was around 31%, which was very close to the 30%, suggested by the coating system manufacturer.

Regarding the hardness values (Table 3), the nuggets with up to 10% chia flour did not differ from the control treatment ($p>0.05$). The hardness increase, observed for the 15 and 20% chia flour treatments compared to the control treatment, was due to the low moisture content and high fibres content found in chicken nuggets with high chia flour content. The increase of chia flour in the meat batter, leaded to a decrease of cohesiveness, springiness and chewiness ($p<0.05$). These results agreed with Pintado et al. (2016), who observed a decrease in the cohesiveness, springiness and chewiness parameters of frankfurters with 10% chia flour addition, compared to the control. In the present study, the variations in the texture parameters were due to the presence of the chia flour that has high protein and fibres contents and low moisture content which resulted in a meat product with a crumbly texture.

The fatty acids profiles of the different chicken nuggets and it ingredients chicken skin and the chia flour are presented in Table 4. The fatty acids identified in chicken nuggets differed significantly ($p<0.05$) among the different treatments, except for stearic and linoleic (omega-6 [n-6]) fatty acids ($p>0.05$). The substitution of chicken skin by chia flour in chicken nuggets decreased the total contents of SFA (36.22 g/100 g vs. 25.24 g/100 g; control vs. 20% chia flour addition, respectively; $p<0.05$) and MUFAs (41.38 g/100 g vs. 23.92 g/100 g; control vs. 20% chia flour addition, respectively, $p<0.05$). The decrease in SFA and MUFA was due to the presence of the chia flour which has lower contents of SFA (9.36 g/100 g) and MUFA (6.95 g/100 g) than chicken skin (28.12 and 45.78 g/100 g, respectively).

Table 4 – Fatty acid profiles of the chicken nuggets and raw materials, chicken skin and chia flour.

g/100 g Fatty acids	Treatments Control	Chia5%	Chia10%	Chia15%	Chia20%	CS*	CF**
Saturated (SFA)							
Palmitic (C16:0)	31.88±1.94[a]	29.17±1.05[b]	26.65±1.25[c]	25.38±1.32[c]	23.09±1.44[d]	22.49	6.70
Stearic (C18:0)	4.35±0.27[a]	4.06±0.26[a]	3.85±0.11[a]	2.93±0.95[a]	2.15±1.87[a]	5.63	2.66
Monounsaturated (MUFA)							
Palmitoleic (C16:1)	2.46±0.90[a]	1.72±0.43[ab]	1.26±0.40[bc]	0.59±0.05[cd]	0.06±0.11[d]	5.81	-
Oleic (C18:1)	38.92±1.32[a]	35.43±2.14[b]	31.49±1.00[c]	27.57±0.53[d]	23.86±0.94[e]	39.97	6.95
Polyunsaturated (PUFA)							
Linoleic (C18:2 n6)	21.51±3.32[a]	21.02±2.65[a]	20.23±2.16[a]	19.19±0.89[a]	18.68±0.50[a]	24.73	18.72
Linolenic (C18:3 n3)	0.89±0.78[e]	8.60±1.01[d]	16.52±0.75[c]	24.35±0.21[b]	32.16±1.67[a]	1.38	64.97
ΣSFA	36.22±1.92[a]	33.24±1.13[b]	30.50±1.26[bc]	28.31±0.42[c]	25.24±0.75[d]	28.12	9.36
ΣMUFA	41.38±2.18[a]	37.15±2.56[b]	32.75±1.41[c]	28.16±0.49[d]	23.92±0.85[e]	45.78	6.95
ΣPUFA	22.40±4.09[e]	29.62±3.59[d]	36.75±2.54[c]	43.54±0.87[b]	50.84±1.52[a]	26.11	83.69
PUFA:SFA	0.62±0.14[d]	0.89±0.14[d]	1.21±0.13[c]	1.54±0.05[b]	2.02±0.12[a]	0.93	8.94
n6:n3	24.2:1	2.4:1	1.2:1	0.8:1	0.3:1	17.9:1	0.1:1

Reference: Barros et al. (2018). [a, b, c, d, e] Means with different letters in a row are significantly different ($p<0.05$). Means ± standard deviation. *CS – chicken skin. **CF – chia flour. Control – 20 g/100 g chicken skin; Chia5% - 15 g/100 g chicken skin + 5 g/100 g chia flour; Chia10% - 10 g/100 g chicken skin + 10 g/100 g chia flour; Chia15% - 5 g/100 g chicken skin + 15 g/100 g chia flour and Chia20% - 20 g/100 g chia flour.

In contrast to the SFA and MUFA, PUFA increased in the chicken nuggets containing chia flour ($p<0.05$). The 20% chia flour treatment (50.84 g/100 g) resulted in a PUFA content two-fold greater than the control treatment (22.40 g/100 g, $p<0.05$) which can be attributed to the high α-linolenic fatty acid content (n3, 64.97 g/100 g) in chia flour. Pizarro et al. (2015) used chia flour in several food products and found similar results to the present study and noted a reduction in the SFA and MUFA and an increase in the PUFA that was due to the high n-3 content of chia flour.

The addition of chia flour in chicken nuggets increased the PUFA:SFA ratio ($p<0.05$, Table 4). A diet rich in SFAs can elevate the risk of coronary heart disease (HU et al., 1997). Moreover, the joint Food and Agricultural Organisation/World Health Organisation (FAO/WHO, 2008) recommends that the consumption of SFAs must be <10% and PUFAs between 6–11%. Therefore, it is possible to infer that the PUFA:SFA ratio in the diet should be higher than 1. In the present study, the replacement of 10% or more of the chicken skin by chia flour increased the PUFA:SFA ratio to >1.2, deeming the chicken nuggets healthier according to the FAO/WHO recommendation. Pintado et al (2018), also observed that addition of chia emulsion gel improved PUFA:SFA ratio in fresh sausages.

Substitution of the chicken skin by chia flour in chicken nuggets resulted in a decrease of the n-6:n-3 ratio from 24.2:1 (control) to 0.3:1 (20% chia flour treatment). The addition of 5–20% chia flour in the present study are in accordance with the recommended n-6:n-3 value of ≤5:1 (WHO/FAO, 1994). This reduction in the n-6:n-3 ratio was due to the presence of the chia flour that has high n-3 content (64.97 g/100 g) and low n-6 content (18.72 g/100 g). According to Simopoulos (2010), several diseases such as cardiovascular, cancer as well as inflammatory processes are caused by an excessive ingestion of n-6 fatty acids and, consequently, a high n-6:n-3 ratio in the diet. Therefore, the increased n-3 content in nuggets with added chia flour can provide valuable health benefits, contributing to the prevention of diseases caused by excess dietary intake of n-6 fatty acids. In view of the obtained results, it is possible to affirm that the treatments with 5–20% chia flour can be considered as products with “high n-3 content” (COMMISSION REGULATION (EU) No. 116/2010).

Regarding the sensory analysis of the chicken nuggets, 91% of the 113 panellists reported that they sought to consume healthier foods, 84% knew or had heard of chia seed or flour, and 52% already consumed some product containing chia. Table 5 presents the results of the sensory acceptance test and AI of the chicken nuggets.

Table 5 – Results of sensory analysis and acceptance index (AI) of the chicken nuggets.

Parameters	Treatments				
	Control	**Chia5%**	**Chia10%**	**Chia15%**	**Chia20%**
Internal appearance	8.04±1.03^{a}	6.17±1.65^{b}	5.55±1.72^{c}	4.95±1.72^{d}	4.86±1.86^{d}
Aroma	7.60±1.40^{a}	7.45±1.16^{a}	7.01±1.31^{b}	6.52±1.37^{c}	6.34±1.42^{c}
Texture	7.73±1.30^{a}	7.58±1.32^{a}	7.40±1.26^{a}	6.56±1.56^{b}	6.50±1.63^{b}
Flavour	7.99±1.13^{a}	7.68±1.23^{a}	7.04±1.58^{b}	6.03±1.71^{c}	5.55±2.15^{c}
Overall quality	7.97±1.01^{a}	7.48±1.19^{b}	6.98±1.43^{c}	6.06±1.58^{d}	5.81±1.81^{d}
AI (%)	87.39	80.81	75.52	66.92	64.58

Reference: Barros et al. (2018). $^{a, b, c, d}$ Means with different letters in a row are significantly different ($p<0.05$). Means ± standard deviation. Control – 20 g/100 g chicken skin; Chia5% - 15 g/100 g chicken skin + 5 g/100 g chia flour; Chia10% - 10 g/100 g chicken skin + 10 g/100 g chia flour; Chia15% - 5 g/100 g chicken skin + 15 g/100 g chia flour and Chia20% - 20 g/100 g chia flour.

The addition of chia flour at high levels (>10%) impaired the acceptance of all evaluated attributes. The internal appearance and overall quality scores decreased with the addition of chia flour in the chicken nuggets ($p<0.05$). The 15 and 20% chia flour treatments did not differ ($p>0.05$) in these attributes and the acceptance of the internal appearance of these treatments achieved the range of rejection (scores <5) for nuggets with ≥15% of chia flour. This rejection can be related to the darker colour of the products, compared to the control treatment (Figure 3).

The 5% chia flour treatment was similar to the control treatment for the aroma and flavour attributes ($p>0.05$) whereas treatments with ≥10% chia flour yielded a decrease in these attributes ($p<0.05$). The acceptance of the texture attribute did not differ ($p>0.05$) for nuggets with up to 10% chia flour addition. Pintado et al. (2016) mentioned that addition of 10 g/100 g chia flour to frankfurters generated lower scores for the colour, flavour, texture and general acceptability attributes compared to the control with no added chia flour. However, all the samples were judged acceptable by the consumers. According to Dutcosky (1996), for a product to be considered “well accepted”, it must show an AI ≥70%. Considering this target value, the nuggets with up to 10% chicken skin substitution by chia flour can be considered well-accepted (AI = 75.52%).

4 Conclusion

The addition of up to 10% chia flour as a substitute of the chicken skin in chicken nuggets can be recommended. At these levels, most of the technological characteristics of the product were not compromised and the nuggets could be considered to have a good balance between the nutritional gains and the sensory impairment of the meat product. The chicken nuggets containing 10% chia flour can provide valuable health benefits to the consumer and being considered a source of fibre and presenting a high n-3 content.

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CHAPTER 2

Article submitted to Journal of Food Science and Technology: BARROS, J. C., GOIS, T. S., PIRES, M. A., RODRIGUES, I., TRINDADE, M. A. Sodium reduction in enrobed restructured chicken nuggets through replacement of NaCl with $CaCl_2$.

Sodium reduction in enrobed restructured chicken nuggets through replacement of NaCl with $CaCl_2$

Abstract

The present study aimed to reformulate chicken nuggets with reduced sodium content, replacing the NaCl with $CaCl_2$ and assessing the physicochemical and sensory properties of the obtained products. Four treatments of chicken nuggets were processed: a Control formulation (1.5 g NaCl/100 g) and three treatments containing $CaCl_2$ substituting 25, 50 and 75% of the NaCl, considering an ionic strength equivalent to 1.5% NaCl. The four different chicken nuggets were similar ($p>0.05$) for the variables oil absorption, lipid, protein and moisture contents, water activity, cooking yield, pick-up and texture profile analysis. However, a decrease in ash content (2.21 to 1.75 g/100 g) was observed. The replacement of 75% NaCl could reduce 34% sodium in chicken nuggets with a concomitant increase in the calcium content (10 to 130 mg/100 g). For objective colour, the brightness (L*) increased from 74.43 to 78.28 as $CaCl_2$ contents increased in the chicken nuggets, but the a* and b* parameters did not show differences ($p>0.05$) among all treatments. Sensory acceptance (texture, flavour and overall quality attributes) did not differ between Control and the 75% sodium reduction treatments (all values around 7.5 in the 9-point hedonic scale), despite the decrease in the salty taste observed in the just about right scale test. Thus, the maximum tested replacement of 75% NaCl by $CaCl_2$ produced healthier chicken nuggets, for having provided a reduction in sodium content and increase in calcium content, besides maintaining sensory quality and most of the technological characteristics.

Keywords: Consumer study; healthiness; ionic strength; meat product; salt substitute; physicochemical analysis.

1 Introduction

The development of value added meat products, such as chicken nuggets, has been identified as the best way to increase poultry meat consumption (Yogesh et al., 2013). Nowadays, it has been observed an increase in the consumption of chicken nuggets, mainly due to its convenience (easy-to-prepare, ready for consumption) and to be consumed by all ages and income ranges. Furthermore, chicken nuggets can be a good source of proteins. According to Devatkal et al. (2011) the protein content of chicken nuggets in traditional formulations (control) was 20.29 g/100 g and Barros et al. (2018) found 34.66 (dry basis) g/100 g.

However, according to the Scientific Advisory Committee on Nutrition (SACN, 2003) and the Food Safety Authority of Ireland (FSAI, 2016), meat and meat products provide 21.0 and 27.4% of the sodium in the diet, respectively. For the processing of poultry meat products 1.0–1.6 g/100 g sodium chloride (NaCl) is typically used (PETRACCI, RIMINI, MULDER and CAVANI, 2013). In traditional formulations of chicken nuggets, the NaCl content can range from 2 g/100 g (VERMA, BANERJEE and SHARMA, 2012a) up to 2.5 g/100 g (YOGESH et al. 2013).

Hereditary predisposition to arterial hypertension is influenced by obesity and excessive sodium ingestion from food (JIMÉNEZ-COLMENERO, CARBALLO and COFRADES, 2001). The joint World Health Organisation and Food Agricultural Organisation of the United Nations (WHO/FAO, 2003) recommend NaCl (salt) consumption should be maximum 5 g/day, which is equivalent to a maximum sodium intake of 2 g/day. However, in Europe, the salt intake ranges from 8–11 g/day (European Food Safety Authority [EFSA], 2005) and 11.38 g/day in Brazil (Brazilian Association of Food Industries [ABIA], 2013).

Several studies aimed to reduce the sodium content in meat products, by partial replacement of NaCl with chloride salts of calcium, potassium and magnesium (Dos SANTOS et al. 2015a; HORITA, MORGANO, CELEGHINI and POLLONIO, 2011). However, the reformulation of meat products with reduced sodium content is not a simple task, as salt reduction not only affects the salty taste but the product intensity regarding the characteristic flavour (RUUSUNEN and PUOLANNE, 2005). According to Lawless et al. (2003), the calcium chloride is known primarily for contributing a bitter taste and resulting metallic, astringent and irritative sensations. Furthermore, the reduction of NaCl in the meat batter requires other ionic compounds to restore the meat functionality that is lost with the salt reduction, such as the water-holding, protein-binding and fat-binding capacities (DOYLE and GLASS, 2010).

One of the alternatives to reduce the undesirable effects of the NaCl substitution in meat products is the use of salt substitutes at concentrations which maintain the same ionic strength (IS) (ZANARDI, GHIDINI, CONTER and IANIERI, 2010). Horita et al. (2014), evaluated reduced-sodium frankfurter sausages produced with blends of chloride salts (75% NaCl + 25% KCl; 75% NaCl + 25% $CaCl_2$; 75% NaCl + 12.5% $CaCl_2$ + 12.5% KCl; 50% NaCl + 25% $CaCl_2$ + 25% KCl; 50% NaCl + 50% KCl and 50% NaCl + 50% $CaCl_2$) with ionic strength equivalent to 2% NaCl and containing high levels of mechanically deboned poultry meat. They found that the partial substitution of NaCl by mixtures of potassium and calcium chloride represented a viable strategy in reducing the sodium content.

In an approach to substitute NaCl in chicken nuggets, some studies have added mixtures containing potassium chloride (KCl), citric acid, tartaric acid and sucrose (VERMA, BANERJEE and SHARMA, 2012a; VERMA, SHARMA and BANERJEE, 2012b). However, no studies of chicken nuggets with NaCl substitutes, particularly calcium chloride ($CaCl_2$), have yet been published. Thus, the present study reformulated chicken nuggets, by using

$CaCl_2$ as NaCl replacer, with IS equivalent to 1.5% NaCl, and assessed the physicochemical and sensory attributes of the obtained products.

2 Material and methods

2.1 Reformulation and processing

The present study was performed at the College of Animal Science and Food Engineering of University of São Paulo (FZEA/USP), Brazil. Four treatments of chicken nuggets were processed: a control formulation (1.5 g/100 g NaCl) and three treatments containing $CaCl_2$ by NaCl substitution (25, 50 and 75% NaCl), with IS equivalent to 1.5% NaCl (described in Table 6). The ISs of the different salt concentrations were calculated according to Segel (1976):

$$\mathrm{IS} = \frac{1}{2}\sum_{\mathrm{i}=1}^{\mathrm{n}} C_i Z_i^2 \tag{1}$$

where IS=ionic strength, C_i=molarity of the ion (M, mol/L), and Z_i=the net charge of the ion.

Table 6 – Various $CaCl_2$ concentrations in chicken nuggets with ionic strength equivalent to 1.5% NaCl.

Treatments	NaCl		$CaCl_2$	
	g/100 g	**IS***	**g/100 g**	**IS***
Control	1.5	0.256	-	-
NaCl 75%	1.125	0.192	0.237	0.064
NaCl 50%	0.75	0.128	0.474	0.128
NaCl 25%	0.375	0.064	0.712	0.192

*IS = ionic strength.

The salts, NaCl (Umari Salineira, Macau, Brazil) and $CaCl_2$ (Asher Produtos Químicos, Ribeirão Preto, Brazil), used in the processing of the chicken nuggets were food grade. The other ingredients and proportions used in all treatments were: 77.7 g/100 g chicken breast fillet, 20 g/100 g chicken skin, 0.05 g/100 g sodium erythorbate (Cori Ingredientes, Rio Claro, Brazil), 0.25 g/100 g sodium tripolyphosphate (Cori Ingredientes), 0.30 g/100 g onion powder (New Max, Americana, Brazil), 0.15 g/100 g garlic powder (New Max) and 0.05 g/100 g white pepper (New Max). The chicken breast fillet and skin were obtained from local commerce in the city.

The processing of the chicken nuggets followed the one described by Barros et al. (2018). Summarizing, the chicken breast and skin were ground (8 and 4 mm diameter disc, respectively) and homogenised together with the different percentages of salts (Table 6) and other ingredients and shaped in a chicken nuggets format. The chicken nuggets were coated in a three steps system as follows: 1) Pre-dust (type PDA 66-TC; Kerry Company [Campinas, Brazil]): the formatted chicken nuggets were passed in a fine flour whose function is adhere the batter coating, 2) Batter coating (adhesion type BMA91-TC; Kerry Company): the meat products were immersed in a liquid solution prepared in a 1:2 ratio (powder:water), aiming an improvement in the adhesion of the breading flour and 3) Breading (dressing type SA F05; Kerry Company): is a flour (bread crumb) with larger particle size that has as characteristic to provide the crispness of the chicken nuggets.

After pre-dusting, battering and breading, the chicken nuggets were fried in an eletric deep fat fryer with two vats, and with capacity of 2.5 liters each. In this stage the chicken nuggets were fried in palm fat (type 370F, Agropalma, Belém, Brazil) at 180 °C until an internal temperature of 72 °C, being that for the verification of the internal temperature of the chicken nuggets a digital thermometer type skewer was used. The amount of palm fat added in the fryer was about 2 kg in each vat (enough to completely cover the chicken nuggets). A total of 12 chicken nuggets were fried at a time in each vat. The fat exchange was performed between each different treatment. The chicken nuggets were packed in polyethylene plastic, frozen and stored at –18 °C. All analyses of the chicken nuggets were undertaken after the frying (product ready for consumption), and the experiment (processing) was repeated twice (n=2). A total of 5 kg of meat mix were processed, resulting in about 200 chicken nuggets in each treatment and each repetition.

2.2 Physicochemical analysis

In order to simulate the conditions that the product is usually marketed in Brazil, the preparation of the chicken nuggets samples for physicochemical analysis were performed according to Barros et al. (2018), that is, before performing all physicochemical analyzes, the fried and frozen chicken nuggets were thawed overnight at 2 °C.

2.2.1 Proximate composition and oil absorption

The proximate composition was evaluated according to the Association of Official Analytical Chemists (AOAC, 1998) methods, for determination of protein (981.10), moisture (950.46) and ash (920.153) contents. The lipid contents were determined by the Bligh and Dyer method (1959). The oil absorption was calculated as the difference between the lipid content of the samples before and after frying. All analyses were conducted in triplicate.

2.2.2 Mineral analysis: sodium and calcium contents

The sodium content was determined by following the AOAC 956.01 method (1996), using a flame spectrophotometer (Micronal, B462, Brazil). The calcium content was established by inductively coupled plasma atomic emission spectrometry (Sindirações 2013). In order to carry out these analyzes, 5 grams of each treatment were incinerated in muffle 550 ºC until obtaining white ash. The ash obtained was added 20 ml of 50% HCl. After standing for 20 minutes, the volume was transferred to a 100 ml volumetric flask and the volume adjusted with distilled water. All analyzes of minerals were carried out in aliquots of this solution. The analysis was performed in duplicate, and the results were expressed in mg/100 g.

2.2.3 Objective colour

The thawed samples of chicken nuggets were cut in half for instrumental colour assessment in the internal part of the meat products, i.e., only the pre-cooked meat mix of each different treatment was evaluated, not the enrobing (breading) material. A portable colorimeter (HunterLab®, MiniScan XE model, USA) was used to record the L^* (brightness), a^* (greenness/redness) and b^* (blueness/yellowness) parameters of the CIELAB system, with the D_{65} illuminant, 10° viewing angle and 30 mm cell aperture. The instrument was calibrated using a black and white reference standard. Readings were carried out in the two halves of each sample, in four different chicken nuggets, totalling eight readings in each treatment.

2.2.4 Determination of water activity (aw)

The aw was ascertained using AquaLab equipment (Decagon Devices, Pullman, WA, USA). Triplicates were evaluated per treatment.

2.2.5 Cooking yield and percentage of weight gain by coating (pick-up)

The cooking yield was calculated from the weight relationship between the fried and raw chicken nuggets (with coating) multiplied by 100 (DEVATKAL, KADAM, NAIK and SAHOO, 2011). The chicken nuggets were weighed before and after the three-step coating system (pre-dust, batter and breading), and the pick-up was calculated by:

$$Pick - \mathrm{up} = \left(\frac{\text{Nuggets with coating - Nuggets without coating}}{\text{Nuggets with coating}} \right) \mathrm{x}\,100 \qquad (2)$$

In total, 24 samples of chicken nuggets per treatment were used for each analysis.

2.2.6 Texture profile analysis (TPA)

The TPA was carried out in a texturometer (TA-XT2i Stable Micro Systems, Godalming, UK) and evaluated for hardness, cohesiveness, chewiness and springiness, using an aluminium probe with 30 mm diameter, operating at a velocity of 0.3 mm/s. Six chicken nuggets were measured per treatment. The coating system of the chicken nuggets was removed to obtain results without the interference of the coating system, and the samples were cut into 2 × 2 cm pieces.

2.3 Consumer study

The research was approved by the Research Ethics Committee of the FZEA/USP (Process 49161415.3.0000.5422). Sensory tests were performed in the sensory laboratory of the FZEA/USP in only one session and during the morning and afternoon periods. A total of 115 consumers (aged from 17–52 years) that had interest, availability and a habit of consuming chicken nuggets participated in the analysis. The consumers evaluated the chicken nuggets with various sodium contents, by the acceptance test. A nine-point hedonic scale, ranging from "1 = disliked very much" to "9 = liked very much" was used for texture, flavour and overall quality attributes. The fried and frozen chicken nuggets were reheated in an electric oven at 200 °C and kept at 60 °C in an electric greenhouse (used to maintain food temperature), until the analysis. For sensory analysis, approximately 60 chicken nuggets per treatment were used, being that, one unit of chicken nuggets served two consumers. All samples were coded with three-digit random numbers and served monadically to the consumers, in a randomised complete block design.

Together with the acceptance test, the chicken nuggets were evaluated for the salty taste, using a just-about-right (JAR) scale ranging from “1 = taste extremely less salty than the ideal” to “9 = taste extremely saltier than the ideal” (Appendix C). Consumers also assessed the chicken nuggets by the check-all-that-apply (CATA) questionnaire containing 29 sensory descriptors (described in Table 7) (Appendix C). The descriptive terms used in the CATA test were based on the study about sensory descriptors of low-sodium meat products (GALVÃO, MOURA, BARRETTO and POLLONIO, 2014).

2.4 Statistical analysis

All the physicochemical and acceptance test results were evaluated by analysis of variance (ANOVA), using Sisvar® program, version 5.6 (FERREIRA, 2011), and the means were compared by Tukey’s test, at 5% significance. The JAR results for the salty taste were analysed by penalty analysis (Dos SANTOS et al. 2015b). The correspondence analysis was used to interpret data from the CATA terms, considering the chi-square distance (VIDAL et al. 2015). Both analyses were evaluated using XLSTAT® software (version 2016, Addinsoft, Paris, France).

Table 7 – List of 29 sensory descriptors used for check-all-that-apply (CATA) questionnaire.

Appearance	**Odour**	**Texture**	**Flavour**
Bright internal appearance	Weak chicken odour	Dry	Weak chicken meat flavour
Dark internal appearance	Strong chicken odour	Juiciness	Strong chicken meat flavour
Low fatty	Nugget odour	Soft texture	Without seasonings
Fatty		Hard texture	Weak seasonings
		Crispy	Ideal seasonings
		Little crispy	Strong seasonings
			Tasty
			Without flavour
			Strong flavour
			Weak flavour
			Bad flavour
			Strange flavour
			Bitter flavour
			Metallic flavour
			Rancid
			Little rancid

3 Results and discussion

Table 8 presents the physicochemical data for the chicken nuggets formulated using $CaCl_2$ as NaCl substitute. The different treatments of chicken nuggets were similar ($p>0.05$) for the variables oil absorption, lipid, protein and moisture contents. The same outcomes were observed in the work by Horita, Morgano, Celeghini and Pollonio (2011), who found that the replacement of 50–75% NaCl by salt blends (NaCl, KCl and $CaCl_2$) did not cause differences in the moisture, lipid and protein levels of reduced-fat mortadella. In the present study, the reformulated chicken nuggets would expect to yield comparable results to the control for these evaluated parameters, given the same proportions of raw meat materials (chicken breast and skin) were used. However, there was a decrease in ash content ($p<0.05$) with the increase in replacement level of NaCl by $CaCl_2$. This trend could be explained because $CaCl_2$ is a divalent salt and to maintain the same IS (0.256), less $CaCl_2$ addition than NaCl removal was required in the substitution.

It was verified that the substitution of NaCl by $CaCl_2$, at an ionic strength (IS) equivalent to 1.5% NaCl, decreased ($p<0.05$) the sodium content (Table 8). A reduction of up to 75% NaCl was only able to reduce 34% sodium in chicken nuggets. Although the same proportions of sodium tripolyphosphate and erythorbate have been used in all formulations, the use of these additives and other sources of sodium, such as the meat raw material and the coating system, may have contributed to the non-proportional reduction of the sodium content, i.e, reductions not corresponding to the sodium chloride reduction percentages (25, 50 and 75%) in the different treatments. Similarly, Horita et al. (2014) observed that a 50% reduction in NaCl in frankfurter sausages was responsible for reducing only 35% sodium. Although these authors have used the same proportions of sodium erythorbate, tripolyphosphate and nitrite and meat raw material in all formulations, they reported that the presence of these ingredients contributed to the sodium content in the formulations. According to Maurer (1983), sodium tripolyphosphate and sodium erythorbate contribute to 31.24 and 11.61% of the increased sodium in meat products, respectively.

Table 8 – Physicochemical data for the NaCl-reduced chicken nugget.

Analysis		Treatments				SEM	P – Value
		Control	NaCl 75%	NaCl 50%	NaCl 25%		
Oil absorption (g/100 g)		6.11[a]	5.59[a]	6.17[a]	6.06[a]	0.52	0.8467
Proximate composition (g/100 g)							
Lipids		13.68[a]	12.91[a]	13.56[a]	13.21[a]	0.35	0.5070
Proteins		18.21[a]	17.32[a]	17.72[a]	17.46[a]	0.34	0.3989
Moisture		52.60[a]	52.77[a]	51.86[a]	51.74[a]	0.26	0.1457
Ash		2.21[a]	2.06[ab]	1.89[bc]	1.75[c]	0.03	0.0035
Mineral analysis (mg/100 g)							
Sodium content		530[a]	460[ab]	400[bc]	350[c]	0.01	0.0083
Calcium content		10[c]	50[bc]	90[ab]	130[a]	0.01	0.0108
	L*	74.43[b]	76.44[ab]	76.65[ab]	78.28[a]	0.55	0.0573
Objective colour	a*	1.99[a]	1.75[a]	1.84[a]	1.97[a]	0.09	0.3756
	b*	17.97[a]	17.79[a]	17.79[a]	17.75[a]	0.12	0.6222
aw		0.96[a]	0.96[a]	0.96[a]	0.96[a]	0.00	0.6244
Cooking yield (%)		94.02[a]	94.57[a]	91.80[a]	92.22[a]	1.17	0.4110
Pick-up (%)		29.66[a]	30.49[a]	31.46[a]	31.92[a]	0.56	0.1829
Texture profile analysis (TPA)							
Hardness (kg)		3.32[a]	3.48[a]	3.99[a]	4.07[a]	0.19	0.1526
Cohesiveness		0.67[a]	0.63[a]	0.65[a]	0.63[a]	0.02	0.4453
Chewiness (kg.mm)		1.61[a]	1.47[a]	1.73[a]	1.77[a]	0.10	0.3221
Springiness (mm)		0.70[a]	0.66[a]	0.67[a]	0.68[a]	0.02	0.4385

[a, b, c,] Means with different letters in a row are significantly different (P<0.05). SEM - standard error of mean. Control: 1.5 g/100 g NaCl; NaCl 75%: 1.125 g/100 g NaCl + 0.237 g/100 g $CaCl_2$; NaCl 50%: 0.75 g/100 g NaCl + 0.474 g/100 g $CaCl_2$, and NaCl 25%: 0.375 g/100 g NaCl + 0.712 g/100 g $CaCl_2$.

The commitment term signed by government agencies and food industries (BRASIL, 2013) aimed to reduce the sodium content in processed foods to a maximum 650 mg/100 g for breaded meat products, in 2017. In the present study, all chicken nuggets agree with this recommendation, with sodium contents between 350 (NaCl 25%) and 530 mg/100 g (control). Moreover, the Brazilian (BRASIL, 2012) legislation state that if a product presents 25% or more of sodium reduction, like the NaCl 50% and 25% formulation in the current study, it can be labelled as "reduced sodium content".

For the calcium content, an increase (from 10 to 130 mg/100 g; $p<0.05$) was observed, as a function of the added $CaCl_2$ in the chicken nuggets formulation. It is verified that the consumption of one portion (130 g; established by Brazilian legislation [BRASIL, 2003]) of chicken nuggets with the maximum addition of $CaCl_2$ (NaCl 25% treatment) could provide 169 mg calcium/130 g. This calcium content corresponds to 16.9% of the recommended daily intake for adults in Brazil, which is equivalent to 1000 mg/day (BRASIL, 2005). Thus, the replacement of NaCl by $CaCl_2$ in chicken nuggets is an alternative to increasing calcium intake. Furthermore, as specified by Brazilian legislation (BRASIL, 2012), the NaCl 25% chicken nuggets could present the claim “source of calcium”.

Along with the increase in the calcium content, an increase in the brightness (L*; $p=0.0573$) of the meat products was apparent, but the parameters a* and b* were comparable ($p>0.05$), among the treatments (Table 8). These results corroborated the colour variables in sodium-reduced frankfurter sausages, investigated by Horita et al. (2014). In that study, the authors hypothesised that the presence of calcium tends to increase the brightness parameter.

As expected, the variable aw (Table 8), was similar ($p>0.05$) irrespective of the nugget formulations. Zanardi, Ghidini, Conter and Ianieri (2010), studying Cacciatore salami (typical Italian dry fermented sausage) with partial NaCl replacement by salt mixture containing 13.5

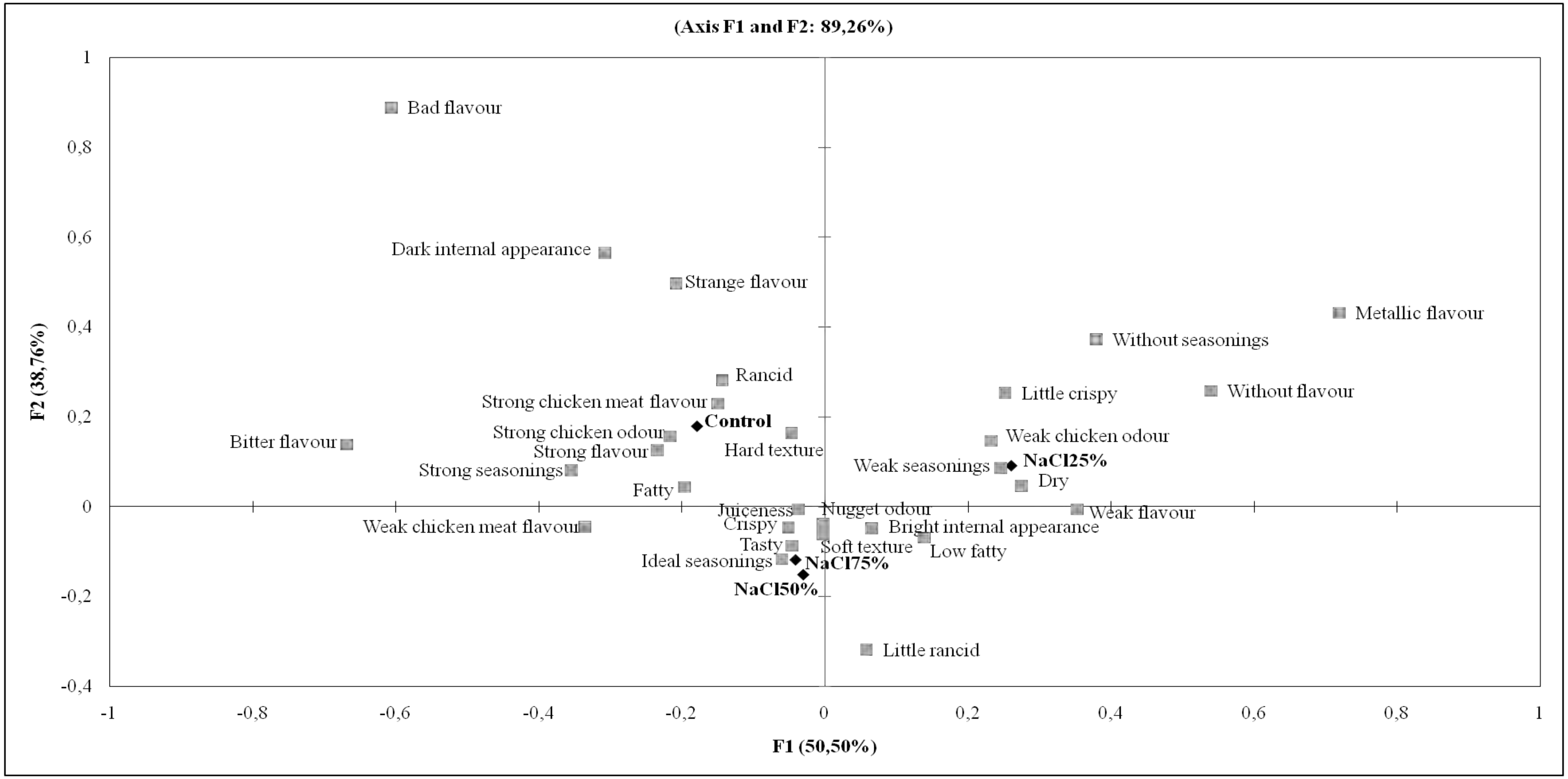
g/kg NaCl, 4.2 g/kg KCl, 2.4 g/kg $CaCl_2$, and 2.4 g/kg $MgCl_2$ (with the same IS), also did not find differences in the aw relative to the control formulation (2.7 g/100 g pure NaCl).

All the chicken nuggets showed analogous cooking yields to each other ($p>0.05$; Table 8). Hamm (1986) noted that divalent cations, such as Mg^{2+} and Ca^{2+}, could decrease the water-holding capacity of meat because the binding of cations reduces electrostatic repulsion between amino acids with negatively charged groups; therefore, the protein structure is tightened, and shrinkage occurs, adversely affecting the cooking yield of meat products. However, this behaviour was not observed in the current study, probably because the lower amount of $CaCl_2$ needed to replace NaCl (to maintain an equivalent IS) was insufficient to affect yield. These results indicate that the substitution of NaCl by divalent salts, such as $CaCl_2$, with the same IS, is an alternative in reducing sodium content and maintaining the product yield, which is an important parameter for the food industry. Contrary to our results, Verma, Sharma and Banerjee (2012b) noticed the cooking yield reduced in chicken nuggets reformulated with 40% NaCl replacement by salts mixture (potassium chloride, citric acid, tartaric acid and sucrose) and with addition of bottle gourd (5, 7.5 and 10 g/100 g).

As expected regarding the pick-up (weight gain by coating), no differences were observed ($p>0.05$; Table 8) among the treatments because the changes were only performed in the proportions of salts (NaCl and $CaCl_2$) added to the meat mix and not the coating system. It can also be seen in Table 3 that the substitution of NaCl by $CaCl_2$ did not affect the TPA ($p>0.05$) parameters. Similar behaviour was demonstrated by Dos Santos et al. (2015b), who did not observe significant differences in the texture parameters of dry fermented sausage with 50% NaCl replacement by $CaCl_2$ when compared with the control formulation (NaCl only). It is known that the use of high calcium concentrations can increase the hardness of the products (CÁCERES, GARCÍA and SELGAS, 2006). However, in the current study, the addition of calcium chloride did not affect the texture of the chicken nuggets. This may have occurred due to the same ionic strength (0.256) used in all formulations, that is, to replace 75% of NaCl, a lower amount of $CaCl_2$ was used to maintain the same ionic strength equivalent to 1.5% NaCl.

Figure 4 presents the results of the correspondence analysis used to evaluate the CATA questionnaire of the chicken nuggets having a reduced NaCl content (25, 50 and 75%) with IS equivalent to 1.5% NaCl. The results explained 89.26% of the total variance, with 50.50 and 38.76% in the first (F1) and second (F2) dimensions, respectively. Figure 4 suggests that the different formulations of chicken nuggets could be separated into three groups. The first group, composed by the control treatment, was characterised by the sensory attributes, bad flavour, dark internal appearance, strange flavour, rancid, strong chicken meat flavour, bitter flavour, strong chicken odour, hard texture, strong flavour, strong seasonings and fatty. In the second group, NaCl 25% treatment was associated with a metallic flavour, without seasonings, without flavour, little crispy, weak chicken odour, weak seasonings and dry, probably due to the greatest NaCl reduction in this treatment. Both the NaCl 75% and NaCl 50% treatments formed the third group and were identified as possessing positive sensory attributes, being assigned the terms, juiciness, crispy, tasty, ideal seasonings, weak chicken meat flavour, nuggets odour and soft texture by the consumers. Based on these results, it can be stated that the substitution of up to 50% NaCl by $CaCl_2$ (IS = 0.256) did not negatively affect the sensory quality of chicken nuggets. In contrast, Dos Santos et al. (2015a) found that consumers considered reformulated dry fermented sausages containing $CaCl_2$ as a NaCl substitute as having low sensory quality. In that study, the sausages formulated with 50% $CaCl_2$ were linked to the terms, bitter taste and fattiness, and the sausages comprising a blend of 25% KCl and 25% $CaCl_2$ were described as possessing an acid taste and fattiness.

Figure 4 – Representation of the sample and terms in the first and second dimensions of the correspondence analysis performed on the check-all-that-apply (CATA) questionnaire on the NaCl-reduced chicken nuggets.

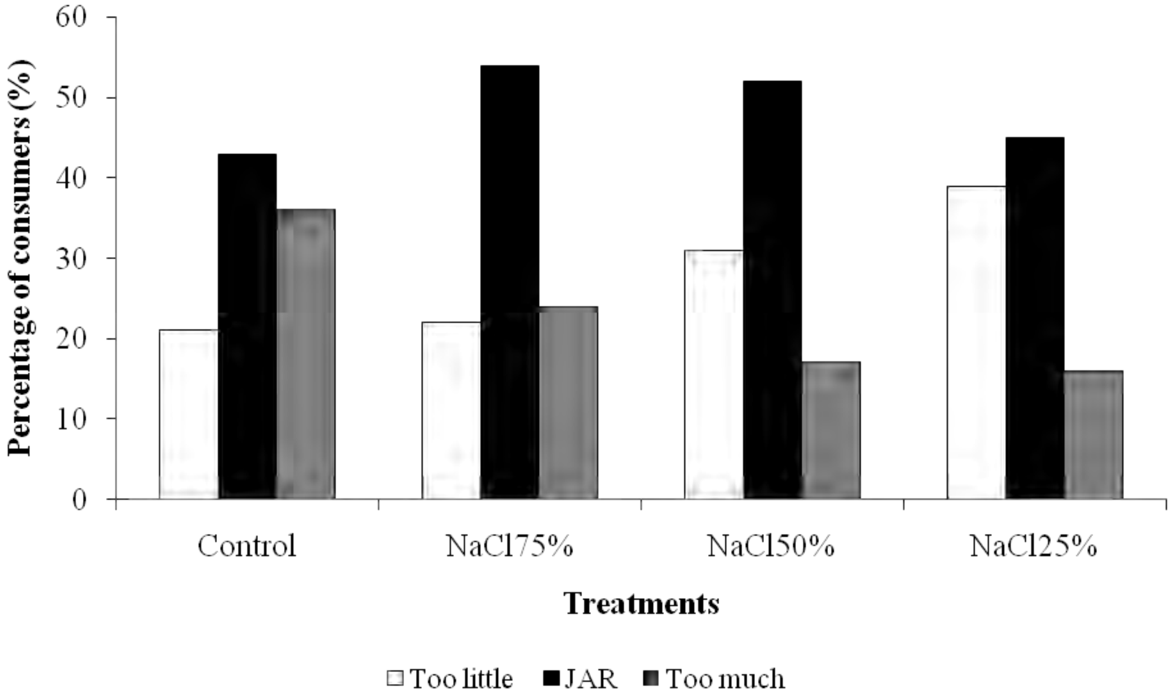


Control: 1.5 g/100 g NaCl; NaCl 75%: 1.125 g/100 g NaCl + 0.237 g/100 g $CaCl_2$; NaCl 50%: 0.75 g/100 g NaCl + 0.474 g/100 g $CaCl_2$, and NaCl 25%: 0.375 g/100 g NaCl + 0.712 g/100 g $CaCl_2$.

Figure 5 presents the percentage of the frequency of the JAR scale by consumers for the salty taste of the chicken nuggets. As mentioned by Meullenet, Xiong and Findlay (2007), for an attribute at its optimum level, a minimum of 70% of the answers should be considered ideal (JAR). Thus, among the evaluated chicken nuggets, none were deemed optimal (JAR) for the salty taste attribute. However, the NaCl 75% and NaCl 50% treatments received higher percentages of JAR score (54 and 52%, respectively) for the salty taste in comparison to the other treatments (control and NaCl 25%). The percentages of JAR score of the control and NaCl 25% treatments were similar. These results imply that the use of $CaCl_2$ as a substitute for NaCl did not interfere in the consumer's perceptions of the salty taste and a reduction of up to 50% NaCl in chicken nuggets was considered acceptable by consumers for this attribute. Thus, this similarity can be explained by the presence of $CaCl_2$ that contributed to the saltiness. In the sensory study performed by Lawless et al. (2003), where they verified whether NaCl, citric acid and sucrose would mask the bitter taste of $CaCl_2$, an increase in saltiness as a function of concentration of calcium chloride (without addition of NaCl) was observed. Horita et al. (2014) reported that the substitution of 25 and 50% NaCl by $CaCl_2$ indicated an alternative to reduce sodium in frankfurter sausages since they were similar to the control for the flavour parameter. Differently, Dos Santos et al. (2015b) showed that the addition of 25 and 50% $CaCl_2$ in dry fermented sausages caused lower responses on the JAR scale for the perception of the salty taste than the control product.

Additionally, for the NaCl 25% treatment, 39% of consumers affirmed that chicken nuggets were less salty than ideal and 36% of the consumers considered the control formulation had a salty taste above the ideal (Fig. 5). As a result, the high and low amounts of salt present in control and NaCl 25% samples, respectively, may adversely affect consumer's perceptions for salty taste in chicken nuggets.

Figure 5 – Percentages of the frequency of the just-about-right (JAR) scale by consumers for the salty taste of NaCl-reduced chicken nuggets.



JAR values are shown as percentages of the frequency of consumers ratings from options: 1–4 = too little, 5 = JAR and 6–9 = too much. Control: 1.5 g/100 g NaCl; NaCl 75%: 1.125 g/100 g NaCl + 0.237 g/100 g $CaCl_2$; NaCl 50%: 0.75 g/100 g NaCl + 0.474 g/100 g $CaCl_2$, and NaCl 25%: 0.375 g/100 g NaCl + 0.712 g/100 g $CaCl_2$.

The sensory acceptance test results (Table 9) identified the texture attribute of the NaCl 50% treatment did not differ (p>0.05) from the NaCl 75% and NaCl 25% treatments but was better (p<0.05) accepted than the control formulation. However, it is possible to affirm that all the treatments presented a well-accepted texture, receiving scores of "7 = liked moderately" and "8 = liked much", which parallel the TPA results, where no differences were found among all treatments. Likewise, Verma, Banerjee and Sharma (2012a) revealed that 40% replacement of NaCl by mixtures of substitute salts (potassium chloride, citric acid, tartaric acid and sucrose) in chicken nuggets did not affect the sensory texture parameter.

Table 9 – Acceptance test results of NaCl-reduced chicken nuggets.

Acceptance test	Treatments				SEM	P-value
	Control	NaCl 75%	NaCl 50%	NaCl 25%		
Texture	7.48^{b}	7.80^{ab}	7.94^{a}	7.57^{ab}	0.12	0.0078
Flavour	7.26^{b}	7.73^{a}	7.85^{a}	7.50^{ab}	0.12	0.0007
Overall quality	7.30^{b}	7.73^{a}	7.86^{a}	7.59^{ab}	0.12	0.0006

$^{(a, b)}$ Means with different letters in a row are significantly different ($P<0.05$) by the acceptance test (nine-point hedonic scale). SEM - standard error of mean. Control: 1.5 g/100 g NaCl; NaCl 75%: 1.125 g/100 g NaCl + 0.237 g/100 g $CaCl_2$; NaCl 50%: 0.75 g/100 g NaCl + 0.474 g/100 g $CaCl_2$, and NaCl 25%: 0.375 g/100 g NaCl + 0.712 g/100 g $CaCl_2$.

For the flavour parameter, the NaCl 75% and NaCl 50% treatments presented higher sensory scores ($p<0.05$) than the Control treatment, but neither formulation differed ($p>0.05$) from the NaCl 25% treatment. These results indicate that the addition of $CaCl_2$ did not contribute to the bitter taste in chicken nuggets, which could be explained by the lower amount of $CaCl_2$ as a substitute for NaCl, to maintain the same ionic strength (IS = 0.256). In addition, the type of meat product tested, which is breaded (enrobed) and fried, thus presenting strong flavour, may have helped to mask any undesirable sensory parameters of $CaCl_2$. According to Lawless et al. (2003), the bitter and metallic taste of $CaCl_2$ decreased with the presence of NaCl. In support of these findings, Horita, Morgano, Celeghini and Pollonio (2011) verified that reduced-fat mortadella reformulated with 1% NaCl, 0.5% KCl and 0.5% $CaCl_2$ were considered accepted by consumers for the flavour parameter. Verma et al. (2012b) noticed that 40% replacement of NaCl by mixtures of salt substitutes (KCl, citric acid, tartaric acid and sucrose) in chicken nuggets did not affect flavour.

Regarding the overall quality attribute, the NaCl 25% and NaCl 50% treatments received better scores ($p<0.05$) than the Control treatment. However, the NaCl 25% treatment was similar ($p>0.05$) to all formulations. Horita et al. (2014) were also unable to identify differences in overall acceptance among the control treatment and the formulations containing 25 and 50% $CaCl_2$ as a NaCl substitute (at an IS equivalent to 2% NaCl) in frankfurter sausages. The current study alludes to one of the possible reasons for the decrease in the overall quality consumer acceptance of the control versus NaCl 75% and NaCl 50% treatments is its higher sodium content (Table 8), which consumers considered above the ideal for salty taste (Fig. 5).

Therefore, in view of the all sensorial results obtained (CATA, JAR and acceptance test), the substitution of 50% NaCl by $CaCl_2$ was considered to be acceptable by the consumers, obtaining positive sensory parameters and making the chicken nuggets healthy by reducing the sodium content and increasing the calcium content.

4 Conclusions

The replacement of up to 50% of the NaCl with $CaCl_2$ (with an ionic strength equivalent to 1.5% NaCl) did not affect most of the physicochemical characteristics and sensory acceptance of chicken nuggets. Given the obtained results, one can recommend this level of replacement (reduction of 50% of the sodium chloride) as a good strategy to reduce the sodium content and increase the calcium content in chicken nuggets, producing a healthier meat product.

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CHAPTER 3

Healthier chicken nuggets can be produced through the addition of chia flour and partial replacement of sodium chloride with calcium chloride

Abstract

The aim of the present study was to evaluate the quality of chicken nuggets reformulated through the concurrent substitution of chicken skin with chia flour and NaCl per $CaCl_2$. Four treatments of chicken nuggets were processed: 1) Control – 1.5 g/100 g NaCl and without addition of the chia flour, 2) $CaCl_2$ – 75% substitution of NaCl by $CaCl_2$, without addition of the chia flour, 3) Chia – 50% replacement of chicken skin by chia flour, 1.5 g/100 g NaCl and 4) Chia+$CaCl_2$ – 75% replacement of NaCl by $CaCl_2$ and 50% substitution of chicken skin by chia flour. The different treatments presented variations in the proximate composition, objective colour, cooking yield and texture profile. The protein content increased with the incorporation of chia flour (17.21 to 18.61 g/100 g). The $CaCl_2$ and Chia+$CaCl_2$ treatments presented 40 and 43% sodium content reduction, respectively. The chicken nuggets containing chia flour showed an increase of α-linolenic fatty acid (omega-3) (1.21 to 9.83 g/100 g; $P < 0.05$) and can be labeled as "high omega-3 content". The sodium reduction and addition of chia flour did not affect the microbial growth. The Chia and Chia+$CaCl_2$ formulations presented lower sensory acceptance, while the Control and $CaCl_2$ treatments had higher scores on all attributes evaluated. However, around 50% of consumers considered the treatments containing chia flour acceptable. In view of the results obtained, the Chia+$CaCl_2$ formulation can be recommended to consumers seeking for a healthier meat product, due to its high omega-3 and reduced sodium contents.

Keywords: Omega-3; sodium reduction; breaded meat product; acceptance sensory.

1 Introduction

Meat and meat products are important sources of protein, vitamins and minerals; however, they may contain high levels of fat, cholesterol, saturated fatty acids, salt (NaCl) and nitrite, which can cause a negative effect on human health (JIMENEZ-COLMENERO, CARBALLO and COFRADES, 2001). Excessive consumption of fat and sodium can cause various health problems, such as obesity (BRAY and POPKIN, 1998), cardiovascular disease (WILLETT, 2012) and hypertension (HE, CAMPBELL, GRAHAM and MacGREGOR, 2012). In order to obtain healthier meat products, they can be modified by adding healthy ingredients (as fibres and vegetables) or by the elimination or reduction of components (as fat and additives) considered as harmful to health (FERNÁNDEZ-GINÉS, FERNÁNDEZ-LÓPEZ, SAYAS-BARBERÁ and PÉREZ-ALVAREZ, 2005).

Therefore, chia (*Salvia hispanica* L.) flour may be added into meat products as an alternative to turn them healthier, through the improvement of the lipid profile (omega-3) and addition of fibres. Chia is an annual herbaceous plant belonging to the *Labiatae* family (COATES and AYERZA, 1996), and presents 30.9 g/100 g total dietary fibre and high proportion of α-linolenic acid (63.4 g omega-3/100 g)(MESÍAS, HOLGADO, MÁRQUEZ-RUIZ and MORALES, 2016). Barros et al. (2018), studying the incorporation of 5–20 g/100 g chia flour in chicken nuggets as substitute for chicken skin, verified that the addition of up to 10 g/100 g chia flour can be recommended, as the obtained products can be considered as source of fibres and presented high α-linolenic acid content. Similarly, Pintado, Herrero, Jiménez-Colmenero and Ruiz-Capillas (2016), when evaluating the effect of different strategies (10 g/100 g chia flour and chia oil-in-water emulsion gels) for the use of chia flour as substitute of animal fat in frankfurters, reported that the addition of chia in this meat product was adequate for labeling with certain nutritional and health claims, due to the increase in fibres and omega-3 content.

In relation to the high sodium content in meat products, several studies have been carried out with the aim of decrease sodium content through the reduction and/or substitution of the NaCl with other chloride salts, such as KCl, $CaCl_2$, $MgCl_2$ (ALIÑO, GRAU, TOLDRÁ and BARAT, 2010; LAZIC et al., 2015; Dos SANTOS et al., 2017). However, the replacement of the NaCl by other salts in meat products may negatively affect the flavour of the products, causing a rejection by consumers (HORITA et al., 2011; Dos SANTOS et al., 2015). This is mainly due to the use of divalent salts that causes bitter taste (Yang and Lewless, 2005). Almeida et al. (2016) reported that the replacement of NaCl by KCl and $CaCl_2$ in salami was able to reduce sodium content by 64%. However, they observed that the sensory flavour parameter was negatively affected by the substitution of NaCl with these salts. Differently, Zanardi, Ghidini, Conter and Ianieri (2010) evaluating the partial substitution of NaCl by a salt mixture containing 1.35% NaCl + 0.42% KCl + 0.24% $CaCl_2$ + 0.24% $MgCl_2$, at the equivalent ionic strength of 2.7 g/100 g NaCl in Italian salami, verified that the bitterness parameter were unaffected by NaCl partial replacement.

In this context, aiming to improve the lipid profile and reduced sodium content in chicken nuggets, the present study evaluated chicken nuggets reformulated by the substitution of chicken skin with chia (*Salvia hispanica* L.) flour and sodium chloride per calcium chloride at an equivalent ionic strength to 1.5% NaCl.

2 Materials and methods

The study was performed at the College of Animal Science and Food Engineering of the University of São Paulo (FZEA/USP), Brazil. Sensory evaluation of chicken nuggets was approved by the Ethics Committee for Research at FZEA/USP (Process 49161415.3.0000.5422) (Annex B).

2.1 Reformulation and processing of chicken nuggets

Four treatments of chicken nuggets were prepared according to Table 10, being: Control treatment – chicken nuggets with 1.5 g/100 g NaCl and without addition of the chia flour, $CaCl_2$ treatment – chicken nuggets with 75% substitution of sodium chloride (NaCl) by calcium chloride ($CaCl_2$) at an equivalent ionic strength to 1.5% NaCl, Chia treatment – chicken nuggets with 50% replacement of chicken skin by chia flour and Chia+$CaCl_2$ treatment – chicken nuggets with 75% replacement of NaCl by $CaCl_2$ at an equivalent ionic strength to 1.5% NaCl and with 50% de substitution of chicken skin by chia flour. All salts used were of food grade.

Table 10 – Formulations of chicken nuggets with/without added of chia (*Salvia hispanica L*) flour and different salts.

Treatments	**Ingredients**					
	Chicken skin (g/100 g)	**Chia flour (g/100 g)**	**NaCl***		**$CaCl_2$****	
			g/100 g	**IS*****	**g/100 g**	**IS*****
Control	20	_	1.5	0.256	_	_
$CaCl_2$	20	_	0.375	0.064	0.712	0.192
Chia	10	10	1.5	0.256	_	_
Chia+$CaCl_2$	10	10	0.375	0.064	0.712	0.192

*Sodium chloride – Refimosal (Mossoró, Brazil). **Calcium chloride – ASHER Produtos químicos (Ribeirão Preto, Brazil). ***IS – ionic strength.

The proportion of chia flour (10 g/100 g) used in the reformulation of chicken nuggets was based on the study carried out by Barros et al. (2018). These authors reported that the replacement of chicken skin with up to 10 g/100 g of chia flour in chicken nuggets produced sensory acceptable products which can be considered as source of fibre and presented high α-linolenic content (omega-3).

The other ingredients and proportions used in the present study in all treatments were: 77.7 g/100 g of chicken breast fillet, 0.25 g/100 g of sodium tripolyphosphate (Cori Ingredientes, Rio Claro, Brazil), 0.05 g/100 g of sodium erythorbate (Cori Ingredientes), 0.30 g/100 g of onion powder (New Max, Americana, Brazil), 0.05 g/100 g of white pepper (New Max) and 0.15 g/100 g of garlic powder (New Max). The raw material: chicken breast fillet, chicken skin and chia flour, were obtained from a local market in Pirassununga – São Paulo, Brazil.

For the processing of the chicken nuggets, chicken breast fillet was ground in a grinder with an 8 mm diameter disc and chicken skin in a 4 mm diameter disc and then mixed with the other ingredients, until a homogeneous mixture was obtained. Pieces with approximately 25 g of this mixture was shaped into nuggets format and then coated as follows: pre-dust (type Liganex Gourmet), batter coating (type Liganex Gourmet), and breading (type Empanex extra crocante). The nugget coating materials used were obtained from Baptistella Alimentos (Itatiba, Brazil). The pick up values, i.e., the percentage of weight gain after coating, were around 36% for all treatments. The chicken nuggets were fried in palm fat (Doratta Fry, Agropalma, Belém, Brazil) at 180 °C until a minimum internal temperature of 72 °C.

After frying, the nuggets were packed in polyethylene plastic bags and stored frozen at -18 °C until the completion of the analyses. All analyses of the nuggets were performed after frying step (product ready for consumption). The entire experiment (processing of all formulations) was repeated three times.

2.2 Physicochemical characterization of chicken nuggets

2.2.1 Proximate composition and oil absorption

The proximate composition was carried out according to official AOAC method (Cunniff, 1998) to determine protein (981.10), ash (920.153) and moisture (950.46) contents. Lipid content was evaluated following the Bligh & Dyer method (1959). Oil absorption was calculated by difference between the lipid content of the samples, before and after frying. All analyses were carried out in triplicate.

2.2.2 Sodium content

To determine the sodium content, the chicken nuggets samples were prepared according to the methodology of Krung and Rocha (2016). The reading was performed in the inductively-coupled plasma optical emission spectrometers (ICP OES, Radial) (Spectro brand, Arcos model). The analysis was performed in duplicate, and the results were expressed in mg/100 g

2.2.3 Objective colour

Samples were cut in half to evaluate the influence of the chia flour on the meat batter colour. The L^* (brightness), a^* (greenness/redness) and b^* (blueness/yellowness) colour parameters of the CIELAB system were recorded using a portable colourimeter (HunterLab®, MiniScan XE, USA), with the D_{65} illuminant, 10º viewing angle and 30 mm cell aperture. A total of eight readings were done.

2.2.4 Water activity and pH

The water activity (*aw)* of the nuggets was evaluated, using an Aqualab (Decagon Devices, Pullman, WA, USA), with three repetitions per treatment. The pH values of the chicken nuggets were measured with a portable pH meter (HANNA®, HI 9916 model). Four readings by repetition were realized.

2.2.5 Cooking yield

The cooking yield was calculated by difference between fried nuggets weight and the raw nuggets weight (after coating) multiplied by 100 (DEVATKAL, KADAM, NAIK and SAHOO, 2011).

2.2.6 Texture profile analysis (TPA)

Instrumental TPA (hardness, cohesiveness, chewiness and springiness parameters) was determined using a TA-XT2i texturometer (Stable Micro Systems, Godalming, UK) equipped with a 30 mm diameter aluminium probe moving at 0.3 mm/s. Six replicates were measured per treatment. In order to obtain accurate results, without potential interference by the coating system, the coating system of the nuggets was removed and the meat mixture was cut into 2 × 2 cm pieces before analysis.

2.3 Fatty acid profile

Lipids from each treatment of chicken nuggets were extracted by the method proposed by Bligh & Dyer (1959). Oil extracted from the samples was esterified as described by Shirai, Suzuki and Wada (2005). Oil samples were added in tubes containing 1 mg of IS (Tricosanoic Acid Methyl Ester (C23:0), 50 μL 0.5% BHT and 1 mL 0.5 M methanolic NaOH. The solution was vortexed by 15 sec and heated in water bath at 100 °C/5 min. After cooling, samples were mixed with 2 mL 14% BF_3 in methanol, vortexed, and heated in water bath at 100 °C for 5 min more. After cooling, 1 mL isooctane was added. The tubes were vigorously shaken for 30 sec, 5 mL of saturated solution of NaCl were added and the tubes were gently homogenized.

After centrifugation at 13,000 x g/5 min, the organic phase was transferred to a new vessel and dried under nitrogen stream. The recovered lipids were reconstituted in 0.5 mL isooctane. Fatty acids quantification was determined by gas chromatograph GC equipped with a G3243A MS detector (Agilent 7890 A GC System, Agilent technologies Inc., Santa Clara, USA). A fused silica capillary column (J&W DB-23 Agilent 122-236; 60 m x 250 mm inner diameter) was used for injection of 1 μL of sample. High-purity helium was used as the carrier gas at a flow rate of 1.3 ml/min with a split injection of 50:1. The oven temperature was programmed from 80 °C to 175 °C at a rate of 5 °C/min, followed by another gradient of 3 °C/min to 230 °C, and kept at this temperature for 5 min. The temperature of GC inlet and transfer line were 250°C and 280 °C, respectively. GC-MS was performed using 70 eV EI in scan acquisition and quantified by TIC.

The fatty acids were identified by NIST11 comparing the retention times with those of four purified standard mixture of fatty acid methyl esters (Sigma Chemical Co.: 4-7801; 47085-U; 49453-U and 47885-U). All mass spectra were acquired over the m/z range of 40-500. Results were expressed as g fatty acids/100 g oil extracted from the samples.

2.4 Microbiological analyzes

In order to assurance the microbiological safety of chicken nuggets, the counting of pathogenic microorganisms was evalueted: *Salmonella* sp (using BAX® System) according to Kushida (2005), counts of total Coliforms (incubated at 35 ± 1 °C/24 h) and *Escherischia Coli* (incubated at 35 ± 1°C/48 h) using EC 6404 Petrifilm™ (3M® Health Care,St. Paul, MN, USA, Brazil), *Staphylococus aureus* (incubated at 35 ± 1°C/24 h) using STX 6490 Petrifilm™ (3M® Health Care,St. Paul, MN, USA, Brazil). It was also determined the counts of aerobic psychotrophic microorganisms (incubated at 7 ± 1 ºC/10 days) according to AOAC official method (990.12) (2000). The microbiological results were expressed in colony-forming units per g (CFU/g) sample.

2.5 Sensory evaluation

The chicken nuggets were sensorially assessed by the acceptance test, using a 9-point hedonic scale, which ranged from "1 – dislike very much" to "9 – like very much". A total of 122 consumers (aged 18–38 years; 71% female and 29% male) that had interest, availability and habit of consuming chicken nuggets evaluated the meat products for internal appearance, aroma, texture, flavour and overall quality (Appendix A) attributes. Each panellist agreed and signed the Free and Informed Consent Form (Appendix B) before the analysis. For sensory analysis, the nuggets were heated in an electric oven and kept at 60 °C, until the evaluation. The samples were coded with random three-digit numbers and served monadically to consumers, in a randomised complete block design.

2.6 Statistical analysis

Statistical analyses were carried out using the Statistical Analysis System (SAS version 9.4). Normal distribution and variance homogeneity were previously tested (Shapiro-Wilk). Data from physicochemical analyses were submitted to ANOVA (treatments were considered fixed effect and the replicates as random effect, the MIXED procedure was used), followed by the Tukey´s test when the ANOVA showed significant effect ($P<0.05$). As a complement to the sensory results it was determined, according to Galvão, Moura, Barretto and Pollonio (2014), the frequencies of acceptance (values assigned from 6 to 9), indifference (value assigned to 5) and rejection (values assigned from1 to 4) of the different treatments of chicken nuggets, which was based on the overall quality attribute.

3 Results and discussion

3.1 Physicochemical characterization

Table 11 presents the physicochemical results of the different treatments of chicken nuggets, with or without addition of chia flour and different salts. For oil absorption the different treatments of chicken nuggets did not present differences ($P > 0.05$), ranging from 9.46–10.30 g/100 g, among all evaluated products. The $CaCl_2$ treatment differed ($P < 0.05$) from the Control and Chia treatments for lipid content, but was similar ($P > 0.05$) to Chia+$CaCl_2$ treatments. Differently of the present study, Verma, Banerjee and Sharma (2015) did not found significant difference in fat content in the nuggets reformulated with salt substitute blend (potassium chloride, citric acid, tartaric acid and sucrose) and addition of 8, 10 and 12 g/100 g pea hull flour. It was possible to observe (Table 11) the lipid content of the nuggets containing chia flour was similar ($P > 0.05$) to the Control formulation, due to the similar lipid level of chia flour (36.26 g/100 g) and chicken skin (40.42 g/100 g) (BARROS et al., 2018).

The addition of the chia flour in the chicken nuggets increased ($P < 0.05$; Chia and Chia+$CaCl_2$) the protein content in relation to the Control formulation. The increase in the protein content found in chicken nuggets is due to the addition of chia flour that has higher protein content (19.8 g/100 g according to MESÍAS, HOLGADO, MARQUEZ-RUIZ and MORALES, 2016) than chicken skin (14.05 g/100 g according to BARROS et al., 2018). However, all evaluated formulations of chicken nuggets can be claimed as “high protein content” according to Brazilian legislation, which recommends the minimum of 12 g of protein/100 g of product (BRASIL, 2012). The same was observed by Pintado, Herrero, Jiménez-Colmenero and Ruiz-Capillas (2016), in frankfurter containing 10 g/100 g chia flour, regardless of the reformulation process.

Table 11 – Physicochemical results of the different treatments of chicken nuggets, with or without added of chia flour and different salts.

Analysis	Treatments				
	Control	$CaCl_2$	Chia	Chia+$CaCl_2$	SEM
Oil absorption	9.46^{a}	10.30^{a}	9.54^{a}	10.20^{a}	0.30
Proximate composition (g/100 g)					
Lipids	16.27^{b}	17.26^{a}	15.95^{b}	16.68^{ab}	0.31
Protein	17.21^{b}	18.03^{ab}	18.61^{a}	18.53^{a}	0.32
Moisture	46.22^{a}	44.31^{b}	42.86^{c}	42.20^{c}	0.30
Ash	2.39^{b}	2.00^{d}	2.72^{a}	2.30^{c}	0.01
Sodium (mg/100 g)	764.83^{a}	457.67^{b}	759.33^{a}	436.00^{c}	33.02
Objective colour					
L*	75.03^{b}	77.04^{a}	54.42^{d}	63.44^{c}	0.78
a*	2.42^{c}	2.48^{c}	3.86^{a}	3.22^{b}	0.09
b*	20.68^{a}	19.91^{b}	16.16^{c}	16.76^{c}	0.09
Cooking yield (%)	88.52^{ab}	87.01^{b}	90.51^{a}	89.51^{a}	0.61
pH	5.15^{a}	5.34^{a}	5.35^{a}	5.28^{a}	0.12
aw	0.953^{a}	0.954^{a}	0.946^{b}	0.953^{a}	0.00
TPA - Texture profile analysis					
Hardness (kg)	4.67^{ab}	4.16^{b}	5.30^{a}	4.31^{b}	0.13
Cohesiveness	0.63^{a}	0.60^{a}	0.55^{b}	0.54^{b}	0.01
Chewiness (kg.mm)	2.01^{a}	1.65^{ab}	1.80^{a}	1.34^{b}	0.06
Springiness (mm)	0.68^{a}	0.65^{ab}	0.60^{bc}	0.58^{c}	0.01

[a, b, c] Equal letters on the same row indicate that there is no significant difference at 5%. SEM: Standard error of mean. Control – 1.5 g/100 g NaCl + 20 g/100 g chicken skin; $CaCl_2$ – 0.375 g/100 g NaCl + 0.712 g/100 g $CaCl_2$; Chia – 10 g/100 g chicken skin + 10 g/100 g chia flour and Chia+$CaCl_2$ – 0.375 g/100 g NaCl + 0.712 g/100 g $CaCl_2$+10 g/100 g chia flour.

It was observed (Table 11) that both replacement of NaCl by $CaCl_2$ and chicken skin by chia flour decreased ($P < 0.05$) the moisture content of chicken nuggets ($CaCl_2$, Chia and Chia+$CaCl_2$ treatments). This reduction can be explained: 1) by the presence of $CaCl_2$ and the low amount of NaCl used in the formulation. For Schut (1976), the use of the divalent salts, as $CaCl_2$, decrease the water-holding capacity and the opposite (increased water-holding capacity) occurs with the presence of high amounts of NaCl (PUOLANNE and PELTONEN, 2013) and 2) lower moisture content of chia flour when compared to the chicken skin. According to Barros et al. (2018), chia flour presents 6.94 g/100 g moisture, while the chicken skin 49.28 g/100 g. Verma, Banerjee and Sharma (2012a) assessing low-fat chicken nuggets with salt substitute (potassium chloride, citric acid, tartaric acid and sucrose) and enriched with 5, 7.5 and 10 g/100 g chickpea hull flour, also verified that the moisture content was reduced by both replacement NaCl per salt mixtures and incorporation the chickpea hull flour.

Ash content in chicken nuggets was affected ($P < 0.05$) by both substitutions (NaCl by $CaCl_2$ and chicken skin by chia flour). The $CaCl_2$ and Chia+$CaCl_2$ treatments showed lower ($P< 0.05$) ash content due to the lower amount of $CaCl_2$ needed to replace NaCl (to maintain an equivalent IS). Verma, Sharma and Banerjee (2012b) studying low-fat chicken nuggets with salt replacement (potassium chloride, citric acid, tartaric acid and sucrose) and added bottle gourd (5, 7.5 and 10 g/100 g), found that the formulation containing only NaCl substitution by salt mixtures (KCl, citric acid, tartaric acid and sucrose) had reduced ash content in comparison to the control treatment. Gimeno, Astiasarán and Bello (1999), also observed a decrease in ash content in the reformulated dry fermented sausages with partial replacement of NaCl by KCl and $CaCl_2$ (1% NaCl + 0.552% KCl + 0.738% $CaCl_2$; IS=2.6% NaCl). The increase ($P < 0.05$) in ash content of the Chia formulation was due to the high mineral content of chia flour (4.26 g/100 g according to CONSTANTINI et al., 2014). Pintado, Herrero, Jiménez-Colmenero and Ruiz-Capillas (2016), also observed an increase in the ash content in frankfurters containing 10 g/100 g of chia flour in comparison with the Control (no chia flour) formulation.

The sodium content of the $CaCl_2$ and Chia+$CaCl_2$ treatments was significantly reduced ($P < 0.05$; Table 11) in comparison to Control formulation. However, the reduction of 75% NaCl in these formulations was only able to reduce 40% and 43% sodium content, respectively. This reduction lower than expected can be attributed to other sources of sodium in the formulation, as sodium tripolyphosphate, sodium erythorbate, the raw meat material and the coating system. Differently, Campagnol, Santos, Lorenzo and Cichoski (2017), evaluating the replacement of 50% NaCl by disodium inosinate/disodium guanylate and transglutaminase in low-fat bologna-type sausages enriched with fructooligosaccharides, found a 55% reduction in sodium content. In addition, the chicken nuggets with 75% replacement of NaCl by $CaCl_2$ could be claimed as "reduced sodium" (BRASIL, 2012; EUROPEAN COMMISSION, 2006). The $CaCl_2$ and Chia+$CaCl_2$ treatments are in agree with the recommendation established by the government agencies and food industries (BRASIL, 2013) for the maximum sodium content of 650 mg/100 g in breaded meat products.

It is possible to observe (Table 11) that the different treatments of chicken nuggets influenced ($P < 0.05$) the brightness parameter (L*). These differences verified in the L* can be explained by the addition of chia flour that has a dark colour and $CaCl_2$ whitish colour. Pintado et al (2016) also observed a decrease in L* values in frankfurters containing 10 g/100 g chia flour, irrespective of the incorporation strategy. Gimeno, Astiasarán and Bello (1999), evaluating the influence of partial replacement of NaCl with KCl and $CaCl_2$ (1% NaCl + 0.552% KCl + 0.738% $CaCl_2$) in dry fermented sausages, verified an increase in mean L* value compared to the control treatment.

The addition of the chia flour (Chia and Chia+$CaCl_2$ treatments) in chicken nuggets increased ($P < 0.05$) the a* parameter in relation to the Control and $CaCl_2$ treatments. The

$CaCl_2$ addition did not influence the a* parameter in relation to the Control treatment (with 100% NaCl). The increase in a* parameter was also observed by Barros et al. (2018), with addition of 10 g/100 g chia flour in chicken nuggets. Horita et al. (2014) found no differences in a* in frankfurter sausages reformulated with NaCl substitution by salt blends (75% NaCl + 25% KCl; 75% NaCl + 25% $CaCl_2$; 75% NaCl + 12.5% $CaCl_2$ + 12.5% KCl; 50% NaCl + 25% $CaCl_2$ + 25% KCl; 50% NaCl + 50% KCl and 50% NaCl + 50% $CaCl_2$).

The addition chia flour (Chia and Chia+$CaCl_2$ treatments) in chicken nuggets caused a decrease ($P < 0.05$) in b* values in relation to the others treatments. Barros et al. (2018) also verified a decrease in the b* parameter in chicken nuggets added with chia flour. It was also possible to observe (Table 11) that the $CaCl_2$ formulation showed a lower ($P < 0.05$) b* value than Control. Differently, Horita et al. (2011) did not find differences in mean b* values in reduced-fat mortadella prepared with salts blends (1% NaCl + 0.5% KCl + 0.5% $CaCl_2$; 1% NaCl + 0.5% KCl + 0.5% $MgCl_2$; 0.5% NaCl + 1% KCl + 0.5% $CaCl_2$; 0.5% NaCl + 1% KCl + 0.5% $MgCl_2$ and 1% NaCl + 1% KCl) as partial substitutes for NaCl. This difference may be explained by the different meat products studied.

The $CaCl_2$ treatment showed lower ($P < 0.05$) cooking yield than Chia and Chia+$CaCl_2$ formulations (Table 11). This observed difference can be explained by the presence of chia flour and the replacement of NaCl by $CaCl_2$. Chia flour may have improved the cooking yield due to its excellent water retention and absorption capacity (CAPITANI, SPOTORNO, NOLASCO and TOMÁS, 2012) because of its high fibre content (34.46 g/100 g in dry basis; SEGURA-CAMPOS et al., 2014). The used of divalent salts, as $CaCl_2$ and $MgCl_2$ (HAMM, 1986) and the reduction of the NaCl content (RUUSUNEN et al., 2005) probably decreased the water-holding capacity of meat, increasing the cooking loss. However, all reformulated nuggets ($CaCl_2$, Chia and Chia+$CaCl_2$) did not differ ($P > 0.05$) in relation to the Control treatment. Barros et al. (2018) also did not observe significant differences in the cooking yield amoung the chicken nuggets added with chia flour (5–20 g/100 g) and the control treatment. Differently, Verma, Sharma and Banerjee (2010) verified that both the formulation containing 40% NaCl substitution bysalt blends (potassium chloride, citric acid, tartaric acid and sucrose) and the incorporation of 8, 10 and 12 g/100 g apple pulp into low-fat chicken nuggets, presented low cooking yield in comparison to the control.

For the mean pH values (Table 11), it was verified that all different treatments of chicken nuggets did not present significant differences ($P > 0.05$). Kim et al. (2015) also found no differences in pH in chicken nuggets reformulated with various contents (2.5, 5, 7.5 and 10%) of chicken skin and wheat fiber mixture. The water activity (aw) of the Chia treatment decreased ($P < 0.05$) in relation to the other treatments, which did not difer ($P > 0.05$) among themselves. This was probably due to the high water retention capacity of chia fluor and the lower moisture content of Chia nuggets. Barros et al. (2018) also verified that the aw decreased in nuggets with 15% or more of chia flour addition.

Regarding TPA analyses, the hardness parameter results obtained for Control treatment did not differ ($P > 0.05$) from all other evaluated reformulations ($CaCl_2$, Chia and Chia+$CaCl_2$). Barros et al. (2018) also observed that the addition of up to 10 g/100 g of chia flour in chicken nuggets did not interfere in the hardness of the meat product when compared to the nuggets without chia flour addition. On the other hand, in the present study, the Chia treatment presented higher ($P < 0.05$) hardness values in comparison to $CaCl_2$ and Chia+$CaCl_2$, probably due to a lower myofibrillar protein extraction ability of the $CaCl_2$ when compared to the NaCl.

The treatments containing chia flour (Chia and Chia+$CaCl_2$) presented low ($P <0.05$) mean values of cohesiveness and springiness. Pintado et al. (2016) also verified a reduction in cohesiveness and springiness parameters of frankfurters with 10% chia flour addition, compared to the control. A decrease in cohesiveness was also observed by Verma, Sharma and Banerjee (2010), in low-fat chicken nuggets reformulated with salt substitute blend (potassium chloride, citric acid, tartaric acid and sucrose) and enriched with apple pulp (8, 10 and 12 g/100 g). The Chia+$CaCl_2$ treatment differed ($P < 0.05$; Table 11) from the Control and Chia formulations, but was similar ($P > 0.05$) to $CaCl_2$ for the chewiness parameter. Verma, Sharma and Banerjee (2012b) observed a decrease in chewiness in low-fat chicken nuggets reformulated with 40% replacement of NaCl by mixture of salts (potassium chloride, citric acid, tartaric acid and sucrose) and added with bottle gourd (5, 7.5 and 10 g/10 g).

3.2 Fatty acid profile

The results of the fatty acid profiles of the different chicken nuggets are showed in Table 12. All the different treatments did not show differences ($P > 0.05$) in the total SFA content. The Chia+$CaCl_2$ treatment differed ($P < 0.05$) from the Control formulation for the total MUFA content. Contrarily, Pintado et al. (2016) observed that the SFA and MUFA content decreased with the addition of 10 g/100 g chia flour to frankfurters. Probably, this difference is due to the different meat products studied, which have different meat raw materials.

The chicken nuggets treatments containing chia flour showed an increase ($P < 0.05$) in the total PUFA content. This increase in total PUFA content can be attributed to the higher ($P < 0.05$) α-linolenic fatty acid (omega-3), in view that the chia flour present high content of this fatty acid (63.4 g/100 g; according to MÉSIAS, HOLGADO, MÁRQUEZ-RUIZ and MORALES, 2016). The same was observed by Barros et al. (2018) in chicken nuggets added with chia flour (5–20 g/100 g). The consumption of 130 g portion (BRASIL, 2003) of Chia e Chia+$CaCl_2$ nuggets can make a very important contribution to daily dietary intake of α-linolenic acid. Considering the total lipids around 16% presented by these products, their omega-3 content is around 1.7 g/130 g, close to the 2.22 g/day recommended by Simopoulos, Leaf and Salem Jr (1999). Furthermore, The Chia and Chia+$CaCl_2$ tratments can be labeled as "high omega-3 content" (BRASIL, 2012; COMMISSION REGULATION (EU) No. 116/2010).

Table 12 – Fatty acid profiles of the different treatments of chicken nuggets, with or without added of chia flour and different salts.

g/100 g Fatty acid	Treatments				
	Control	**$CaCl_2$**	**Chia**	**Chia+$CaCl_2$**	**SEM**
Lauric (C12:0)	0.24^{ab}	0.17^{bc}	0.28^{a}	0.12^{c}	0.02
Myristic (C14:0)	0.85^{a}	0.73^{ab}	0.88^{a}	0.67^{b}	0.03
Pentadecanoic (C15:0)	0.08^{a}	0.07^{a}	0.08^{a}	0.06^{a}	0.00
Palmitic (C16:0)	32.09^{a}	32.81^{a}	31.98^{a}	31.66^{a}	0.40
Margaric (C17:0)	0.15^{a}	0.14^{a}	0.16^{a}	0.11^{a}	0.01
Stearic (C18:0)	8.11^{a}	7.61^{a}	7.05^{a}	7.67^{a}	0.20
Arachidic (C20:0)	0.24^{a}	0.25^{a}	0.38^{a}	0.26^{a}	0.02
ΣSFA	41.75^{a}	43.93^{a}	40.30^{a}	40.55^{a}	0.81
Miristoleic (C14:1 n7)	0.09^{a}	0.13^{a}	0.14^{a}	0.07^{a}	0.02
Palmitoleic (C16:1 n7)	0.35^{a}	0.42^{a}	0.33^{a}	0.32^{a}	0.01
7-hexadecenoic (C16:1 n9)	2.06^{a}	1.95^{a}	1.24^{b}	1.13^{b}	0.12
Heptadecenoic (C17:1 n7)	0.10^{a}	0.10^{a}	0.07^{a}	0.07^{a}	0.01
Oleic (C18:1 n9)	36.15^{a}	36.01^{a}	34.08^{b}	35.56^{c}	0.57
Vaccenic (C18:1 n7)	0.10^{a}	0.73^{a}	0.14^{a}	0.59^{a}	0.13
Paullinic (C20:1 n7)	0.12^{b}	0.19^{ab}	0.26^{a}	0.14^{b}	0.02
ΣMUFA	38.95^{a}	37.79^{ab}	36.22^{ab}	33.88^{b}	0.68
Linoleic (C18:2 n6*)	17.82^{a}	17.11^{a}	14.06^{a}	15.54^{a}	0.56
γ-linolenic (C18:3 n6)	0.11^{a}	0.14^{a}	0.12^{a}	0.10^{a}	0.01
α-linolenic (C18:3 n3**)	1.21^{c}	0.92^{c}	7.85^{b}	9.83^{a}	1.04
Arachidonic (C20:4 n6)	0.16^{a}	0.13^{a}	0.11^{a}	0.11^{a}	0.01
ΣPUFA	19.30^{bc}	18.29^{c}	22.62^{ab}	25.58^{a}	0.86
PUFA/SFA	0.46^{b}	0.43^{b}	0.59^{ab}	0.64^{a}	0.03
n6:n3* **	14.73	18.60	1.79	1.58	–

[a, b, c]Equal letters on the same row indicate that there is no significant difference at 5%. SEM: Standard error of mean. Control – 1.5 g/100 g NaCl + 20 g/100 g chicken skin; $CaCl_2$ – 0.375 g/100 g NaCl + 0.712 g/100 g $CaCl_2$; Chia – 10 g/100 g chicken skin + 10 g/100 g chia flour and Chia+$CaCl_2$– 0.375 g/100 g NaCl + 0.712 g/100 g $CaCl_2$ + 10 g/100 g chia flour. *n6 = omega-6. **n3 = omega-3. ***n6:n3 = linoleic (C18:2):α-linolenic (C18:3).

The addition of chia flour in chicken nuggets increased ($P < 0.05$) the PUFA:SFA ratio and decrease of the n6:n3 ratio. However, the results of the PUFA:SFA ratio of the different chicken nuggets treatments are not in agreement with the recommended. According to Food and Agricultural Organisation/World Health Organisation (FAO/WHO, 2008) the consumption of SFAs must be <10% and PUFAs between 6 and 11%. Therefore, it is possible to infer that the PUFA:SFA ratio in the diet should be > 1. In contrast, the n6:n3 ratios of the chicken nuggets added with chia flour are in agreement with the recommended, which should be ≤5:1 (WHO/FAO, 1994). According to Simopoulos (2004), a high intake of omega-6 fatty acids, in a high n6:n3 ratio, is associated with several diseases, such as cardiovascular disease, rheumatoid arthritis, cancer, diabetes, autoimmune diseases, asthma, obesity and depression. In this way, this author report that balanced consumption of n6:n3, by the lower ingestion of n6 and increase of n3 may reduce the risk of these chronic diseases.

3.3 Microbiological analyzes

The microbiological analysis showed thatthe addition of chia flour and $CaCl_2$ as substitute of chicken skin and NaCl in chicken nuggets, respectively, did not affect the microbial growth. The results indicated that the total Coliforms, *Escherischia Coli* and *Staphylococus aureus* counts were <10 CFU/g sample (estimated values). The same was observed for count of aerobic psychotrophic (<10 CFU/g). *Salmonella* sp. was absent in all treatments. These results were expected, since the Good Manufacturing Practices (GMP) were prioritized throughout processing to ensure the microbiological safety of chicken nuggets. Furthermore, the nuggets were cooked (pasteurized) until a minimum internal temperature of 72 °C followed by frozen storage (-18 °C). Akesowan (2016), also did not find microbial growth in the control nuggets samples and reformulated with konjac flour/xanthan gum mixture and shiitake mushrooms powder, during the period of frozen storage.

3.4 Sensory analyses

Table 13 shows the results of the acceptance test of the different treatments of chicken nuggets, with or without addition of chia flour and different salts. It was observed that the Chia and Chia+$CaCl_2$ treatments presented lower sensory acceptance ($P<0.05$) in all the evaluated parameters compared to Control and $CaCl_2$ treatments. Barros et al. (2018), evaluating the addition of different proportions (5, 10, 15 and 20 g/100 g) of chia flour in chicken nuggets, verified that the acceptance of the internal appearance and overall quality parameters decreased with the addition of chia flour. Nevertheless, the addition of up to 10 g/100 g chia flour was considered acceptable, although from this proportion (≥ 10 g/100 g) a decrease in the scores for aroma and flavour attributes were observed. Similarly, Pintado et al. (2016), studying differents strategies for the addition of 10 g/100 g chia flour in frankfurters, found that although these meat products were accepted by the consumers, low scores were assigned on all evaluated attributes. Therefore, the lower sensory acceptance of the chicken nuggets added with chia flour in present study were mainly due to the darker colour and flavour (scores <5) of the products. Other studies were carried out with addition of chia in meat products, with different incorporation strategies. Pintado et al. (2015) used emulsion gels containing 5 g/100 g chia flour in frankfurters as a total substitute for pork back fat. Heck et al. (2017) studied 50% substitution of pork back fat by chia oil microparticles (25 g/100 g chia oil and 2% sodium alginate solution) in beef burger. And Pintado et al. (2018) evaluated the addition of emulsion gel containing 20 g/100 g chia flour in fresh sausages as partial substitute for pork back fat. All these authors verified that the attributes colour and flavour were the ones that showed greater rejection by the consumers.

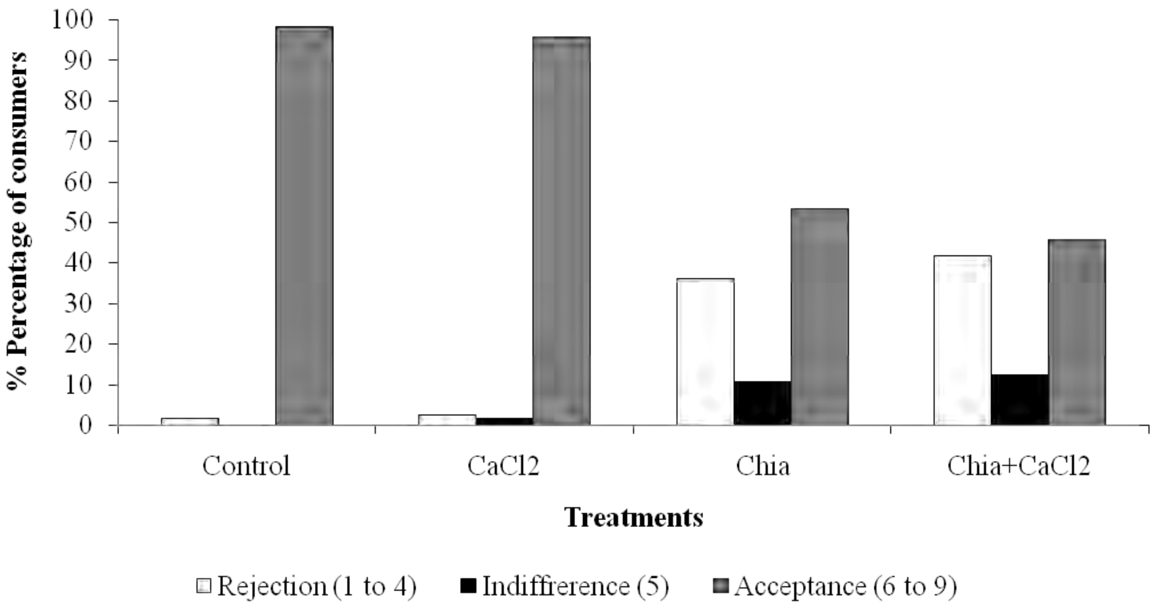
Table 13 – Results of the acceptance test of the different treatments of chicken nuggets, with or without added of chia flour and different salts.

Parameters	Treatments				SEM
	Control	$CaCl_2$	Chia	Chia+$CaCl_2$	
Internal appearance	7.90^a	7.93^a	4.49^b	4.81^b	0.14
Aroma	7.70^a	7.59^a	6.25^b	6.30^b	0.13
Texture	7.83^a	7.66^a	6.29^b	6.59^b	0.14
Flavour	7.93^a	7.84^a	4.76^b	4.64^b	0.16
Overall quality	7.94^a	7.83^a	5.19^b	5.25^b	0.14

$^{a,\,b}$Equal letters on the same row indicate that there is no significant difference at 5%. SEM: Standard error of mean. Control – 1.5 g/100 g NaCl + 20 g/100 g chicken skin; $CaCl_2$ – 0.375 g/100 g NaCl + 0.712 g/100 g $CaCl_2$; Chia – 10 g/100 g chicken skin + 10 g/100 g chia flour and Chia+$CaCl_2$– 0.375 g/100 g NaCl + 0.712 g/100 g $CaCl_2$ + 10 g/100 g chia flour.

Although the formulations of chicken nuggets containing chia flour had lower mean sensory acceptance when observing the acceptance, rejection and indifference levels (considering the overall quality attribute) of different chicken nuggets (Figure 6), one can verify that 46% (Chia+$CaCl_2$ treatment) and 53% (Chia treatment) of consumers who participated of the sensory test considered these samples acceptable (mean score above 6 = like slightly). Therefore, the formulations of chicken nuggets containing chia flour may be accepted in the market by part of the population, since around 50% of the consumers who evaluated the nuggets in the present study considered these products as acceptable. It is worth emphasizing, the consumption of Chia+$CaCl_2$ treatment can provide benefits to the health of the consumers, for showing high omega-3 and reduced sodium content. For Almeida et al. (2016) the consumers are looking for healthier products. According to Tuorila and Cardello (2002), the consumers who are interested in healthier foods tend to accept these foods even though they have lower sensory acceptance.

Figure 6 – Representation graphic of the acceptance (overall quality), rejection and indifference levels for each treatment of chicken nuggets.



It was expected that the $CaCl_2$ sample could be rejected by the consumers, due to calcium salt be characterized by a bitter taste (LAWLESS et al., 2003). However, the amount of $CaCl_2$ used as NaCl substitute, maintaining the same ionic strength (0.256), did not affect ($P>0.05$) the acceptability of the chicken nuggets in relation to Control treatment (Table 13 and Fig. 6). Probably, the strong and pleasant flavour presented by a deep fried product like nuggets had overcome any possibly off flavour brought by the addition of the $CaCl_2$. Different from the present study, Dos Santos et al. (2015), evaluating dry fermented sausages with NaCl content reduced (50% NaCl) or substituted by KCl, $CaCl_2$ or a mixture of these salts (50% NaCl + 50% KCl; 50% NaCl + 50% $CaCl_2$ and 50% NaCl + 25% KCl + 25% $CaCl_2$.), observed that formulation with 50% NaCl and 50% $CaCl_2$ had a lower overall acceptability scores. Armentero, Aristoy, Barat and Toldrá (2012) also reported a lower sensory acceptance in dry-cured hams prepared with blends of salts containing KCl and $CaCl_2$ (50% NaCl + 50% KCl and 55% NaCl + 25% KCl + 15% $CaCl_2$ + 5% $MgCl_2$).

4 Conclusion

The addition of 10 g/100 g of chia flour and/or the replacement of 75% of NaCl with $CaCl_2$, with equivalent ionic strength to 1.5% NaCl, in chicken nuggets, can be considered good strategies to obtain a healthier meat product, due to its high α-linolenic (omega-3) and low sodium contents. The addition of 10 g/100 g chia flour increased the protein content in chicken nuggets, but decreased its sensory acceptance. Therefore, a replacement below 10 g/100 g of chicken skin for chia flour in chicken nuggets may be recommended. Differently, the substitution of 75% NaCl for $CaCl_2$ did not affect the acceptability of the meat product and reduced more than 40% of the sodium content and can also be recommended.

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GENERAL CONCLUSIONS

In this thesis, three studies were conducted aiming the reformulation of chicken nuggets in order to obtain healthier products.

In the first study (Chapter 1), chicken nuggets were reformulated through the replacement of 0–20% of the chicken skin with chia flour, aiming to produce a fibre-enriched product with a healthier fatty acid profile. Results showed that, despite causing lower sensory acceptance, the addition of up to 10% chia flour replacing the chicken skin can be recommended. At these levels, most of the technological characteristics of the chicken nuggets were not compromised and the obtained product could be considered to show a good balance between the sensory impairment and the nutritional gains, being considered as a source of fibre and presenting a high n-3 content.

In the second study (Chapter 2), chicken nuggets with 25, 50 and 75% of the NaCl replaced with $CaCl_2$ (with an ionic strength equivalent to 1.5% NaCl) were evaluated. Results showed that even the highest replacement level (50%) did not compromise most of the evaluated physicochemical characteristics of the meat product. With this strategy, it was possible to observe a reduction of sodium content above 30% and an increase in the calcium content, corresponding to 16.9% of the daily recommended intake of calcium per nuggets portion (130 g). Although $CaCl_2$ is known for its bitter taste, the low amount of $CaCl_2$ used as NaCl substitute, maintaining the same ionic strength (0.256), was not able to affect the acceptability of the chicken nuggets. Thus, the replacement of up to 50% of the NaCl with $CaCl_2$ can be recommended, in order to obtain healthier chicken nuggets.

Finally (Chapter 3), the addition of 10 g/100 g of chia flour (replacing same level of chicken skin) and/or the replacement of 75% of NaCl with $CaCl_2$ (with ionic strength equivalent to 1.5% NaCl) in chicken nuggets were evaluated. The obtained products can be labeled as “high in omega-3” and/or with “reduced sodium content”. Although the formulations containing chia flour (with or without the replacement of NaCl with $CaCl_2$) presented low mean values in all the sensory attributes, they were considered acceptable by about 50% of the consumers. Thus, the tested strategy of concurrently replacing chicken skin with chia flour and NaCl with $CaCl_2$ in chicken nuggets can be recommended, since the obtained product are healthier due to its high omega-3 and low sodium contents.

SUGGESTIONS FOR FUTURE STUDIES

Although the present studies evaluated the addition of chia flour in chicken nuggets as substitute for chicken skin (commonly used fat source) to improve the lipid profile and to enrich with fibres and replacement of sodium chloride with calcium chloride (same ionic strength; IS = 0.256) aiming to reduce the sodium content in this meat product, some studies are still possible to be proposed:

- Reformulate chicken nuggets with substitution below 10 g/100 g of chicken skin by chia flour;
- Check the sensory acceptance of chicken nuggets containing chia flour by consumers (specific grups) who seek to consume healthier products;
- Reformulate chicken nuggets with 100% replacement of sodium chloride by calcium chloride, maintaining the same ionic strength;
- Evaluate the antioxidant capacity of chia flour in chicken nuggets during storage, mainly because it is a fried meat product;
- In order to make the chicken nuggets even healthier, in the frying process, one could use a fat with a healthier lipid pofile, because it is known that the palm fat used in the present study presents 50% of saturated fatty acids;
- Evaluate shelf life of chicken nuggets containing 10% replacement of chicken skin by chia flour and 75% sodium chloride with calcium chloride.

ANNEX

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Title: Omega-3- and fibre-enriched chicken nuggets by replacement of chicken skin with chia (Salvia hispanica L.) flour

Author: Julliane Carvalho Barros,Paulo Eduardo Sichetti Munekata,Manoela Alves Pires,Isabela Rodrigues,Oussama Slaoui Andaloussi,Christianne Elisabete da Costa Rodrigues,Marco Antonio Trindade

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Annex B – Approval report of the survey by the Research Ethics Committee of the FZEA/USP (Process 49161415.3.0000.5422).

FACULDADE DE ZOOTECNIA E ENGENHARIA DE ALIMENTOS DA USP

PARECER CONSUBSTANCIADO DO CEP

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: Processamento de Nuggets adicionado com farinha de chia e com redução de sódio

Pesquisador: Julliane Carvalho Barros
Área Temática:
Versão: 1
CAAE: 49161415.3.0000.5422
Instituição Proponente: UNIVERSIDADE DE SAO PAULO
Patrocinador Principal: FUNDACAO DE AMPARO A PESQUISA DO ESTADO DE SAO PAULO

DADOS DO PARECER

Número do Parecer: 1.241.132

Apresentação do Projeto:
O projeto apresenta alternativas para que os nuggets de frango se tornem um produto cárneo mais saudável, com a inclusão de farinha de chia no lugar da gordura animal (pele de frango) e na redução do cloreto de sódio substituído pelo cloreto de cálcio. A justificativa é adequada, assim como a metodologia.

Objetivo da Pesquisa:
O objetivo da pesquisa será avaliar a inclusão de farinha de chia e cloreto de cálcio em nuggets de frango com a preservação das características tecnológicas adequadas e mantença da boa aceitação sensorial.

Avaliação dos Riscos e Benefícios:
Não há riscos para os candidatos à análise sensorial, visto que serão realizados teste microbiológicos antes do consumo. Como benefícios seria a apresentação de um produto mais saudável, com a redução dos níveis de gordura e sódio.

Comentários e Considerações sobre a Pesquisa:
A pesquisa será de grande valia para a busca de um alimento mais saudável para o consumidor. A análise sensorial está adequada para responder aos objetivos do projeto.

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Continuation: Annex B – Approval report of the survey by the Research Ethics Committee of the FZEA/USP (Process 49161415.3.0000.5422).

FACULDADE DE ZOOTECNIA E ENGENHARIA DE ALIMENTOS DA USP

Continuação do Parecer: 1.241.132

Considerações sobre os Termos de apresentação obrigatória:

O TCLE está apresentado de forma correta.

Recomendações:

Recomendamos a aprovação do projeto.

Conclusões ou Pendências e Lista de Inadequações:

Não há.

Considerações Finais a critério do CEP:

Este CEPH aprova o desenvolvimento do projeto.

Este parecer foi elaborado baseado nos documentos abaixo relacionados:

Tipo Documento	Arquivo	Postagem	Autor	Situação
TCLE / Termos de Assentimento / Justificativa de Ausência	Termo_de_consentimento_livre_e_esclarecimento.doc	02/09/2015 11:24:32	Julliane Carvalho Barros	Aceito
Projeto Detalhado / Brochura Investigador	PROJETODEPESQUISA_JullianeCarvalhoBarros.pdf	02/09/2015 11:28:35	Julliane Carvalho Barros	Aceito
Folha de Rosto	comite_de_etica_sensorial.pdf	02/09/2015 11:24:16	Julliane Carvalho Barros	Aceito
Informações Básicas do Projeto	PB_INFORMAÇÕES_BÁSICAS_DO_PROJETO_581973.pdf	03/09/2015 08:36:27		Aceito

Situação do Parecer:

Aprovado

Necessita Apreciação da CONEP:

Não

PIRASSUNUNGA, 23 de Setembro de 2015

Assinado por:
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APPENDIX

Appendix A – Sensory analysis sheet used to evaluate the chicken nuggets in the 1^{st} and 3^{rd} stage.

Nome:______________________________ **Sexo:** ( )Mas ( )Fem **Idade:**____ **Data:**__/__/___ **Ficha**___
Você está recebendo uma amostra de **Nugget de Frango**. Por favor, avalie o produto e marque na escala o quanto você gostou ou desgostou.

Número da amostra:____________

ESCALA		Nota	
9-Gostei muitíssimo **8**-Gostei muito **7**-Gostei moderadamente **6**-Gostei ligeiramente **5**-Nem gostei/nem desgostei **4**-Desgostei ligeiramente **3**-Desgostei moderadamente **2**-Desgostei muito **1**-Desgostei muitíssimo	**APARÊNCIA INTERNA**		Comentários:
	AROMA		Comentários:
	TEXTURA		Comentários:
	SABOR		Comentários:
	QUALIDADE GLOBAL		Comentários:

Appendix B – Free and Informed Consent Form used in sensory analysis of the chicken nuggets.

Termo de Consentimento Livre e Esclarecido

Consentimento formal de participação no projeto de pesquisa: "Nuggets de frango adicionado com farinha de chia e com redução do teor de sódio".

Nome: ____

Endereço:______________________________Bairro: ____________

Cidade: ___________________CEP:_______________Fone:_________

Justificativa: Os produtos empanados permitem agregar valor e conveniência às carnes, atendendo, dessa forma, interesses tanto dos frigoríficos como dos consumidores. Assim, a substituição da gordura animal (pele de frango) utlizada na massa dos nuggets pela farinha de chia, poderá proporcionar uma melhoria no perfil lipidico desta massa cárnea, uma vez que a chia é conhecida por ser rica em ácidos graxos insaturados e ômega 3, tornando-o mais saudável. Outra estratégia a ser adotoada visando a reformulação para tornar produtos cárneos mais saudáveis é a redução do teor de sódio, pela substitutição do cloreto de sódio por cloreto de cálcio, onde a significativa parcela do sódio presente na dieta provém de alimentos industrializados e dentre esses se destacam os derivados cárneos.

Objetivos do projeto: O objetivo deste projeto é a reformulação de nuggets de frango para tornar este produto cárneo mais saudável, utilizando duas diferentes estratégias: 1) Adição de farinha de chia em substituição à gordura animal normalmente utilizada (pele de frango), visando melhoria do perfil de ácido graxos e enriquecimento com fibras, e 2) Redução do teor de sódio, substituindo parcialmente o cloreto de sódio por cloreto de cálcio.

Procedimentos: Será realizada a avaliação sensorial dos nuggets de frango aplicando-se o teste de aceitação utilizando escala hedônica de nove pontos, onde os extremos variam de "1 – desgostei muitíssimo" e "9 – gostei muitíssimo". Os nuggets de frango serão avaliados quanto aos atributos aroma, textura, sabor, gosto salgado e qualidade global. Serão recrutados no mínimo 100 consumidores de nuggets de frango, que tenham interesse e disponibilidade para participarem dos testes. Durante a análise sensorial, os nuggets de frango serão aquecidas em forno elétrico a 180°C por 12 minutos, após a cocção serão servidos aos provadores amostras codificadas com três dígitos aleatórios, juntamente com um copo de água mineral em temperatura ambiente para que possam realizar o enxágüe da boca durante o intervalo de uma amostra e outra. A duração do teste para cada pessoa será de aproximadamente 15 minutos.

Outras informações:

O provador pode se recusar a continuar com a avaliação sensorial a qualquer momento, sem penalização alguma e sem prejuízo ao seu cuidado.

Os provadores não terão qualquer tipo de **despesas em decorrência da participação nesta pesquisa.**

Não há possibilidade de risco ou qualquer tipo de desconto em função da participação nesta pesquisa, uma vez que todos os ingredientes utilizados nos produtos são inteiramente seguros e serão de boa qualidade e procedência e o processo de fabricação será realizado de acordo com as normas de Boas Práticas de Fabricação.

Em função do exposto no item anterior, não há **previsão de indenização em decorrência da participação neste projeto.**

Os testes para avaliação sensorial dos nuggets, nos quais os provadores experimentarão os produtos desenvolvidos **serão acompanhados** pela aluna proponente (Julliane Carvalho Barros).

Quaisquer outros esclarecimentos poderão ser solicitados antes, durante e após a pesquisa.

Eu,____,RG____________,

CPF______________, abaixo assinado, concordo em participar do estudo "Nuggets de frango adicionado com farinha de chia e com redução do teor de sódio".

Tenho pleno conhecimento da justificativa, objetivos, benefícios esperados e dos procedimentos a serem executados, bem como da possibilidade de receber esclarecimentos sempre que considerar necessário. Será mantido sigilo quanto à identificação de minha pessoa e zelo a minha privacidade. Ao mesmo tempo assumo o compromisso de seguir as recomendações estabelecidas pelos pesquisadores.

Eu li e entendi todas as informações contidas neste documento.

Aluna responsável: Julliane Carvalho Barros – Engenharia de Alimentos.

Contato: jullianebarros@usp.br

Pirassununga,_____de__________de_____Assinatura: ________________________

Appendix C – Sensory analysis sheet used to evaluate the chicken nuggets with sodium reduction (2st stage).

Nome: ____ **Data:** ___/___/___ **Ficha** ______

Sexo: ( ) Mas ( ) Fem **Idade:**______

Você está recebendo uma amostra de *Nugget* de Frango. Por favor, avalie o produto e marque na escala o quanto você gostou ou desgostou da **Textura, Sabor** e **Qualidade Global**:

Número da amostra ____________

TEXTURA	SABOR	QUALIDADE GLOBAL
( ) Gostei muitíssimo	( ) Gostei muitíssimo	( ) Gostei muitíssimo
( ) Gostei muito	( ) Gostei muito	( ) Gostei muito
( ) Gostei moderadamente	( ) Gostei moderadamente	( ) Gostei moderadamente
( ) Gostei ligeiramente	( ) Gostei ligeiramente	( ) Gostei ligeiramente
( ) Nem gostei/nem desgostei	( ) Nem gostei/nem desgostei	( ) Nem gostei/nem desgostei
( ) Desgostei ligeiramente	( ) Desgostei ligeiramente	( ) Desgostei ligeiramente
( ) Desgostei moderadamente	( ) Desgostei moderadamente	( ) Desgostei moderadamente
( ) Desgostei muito	( ) Desgostei muito	( ) Desgostei muito
( ) Desgostei muitíssimo	( ) Desgostei muitíssimo	( ) Desgostei muitíssimo
Comentários:_____________	Comentários:_____________	Comentários:_____________
________________________	________________________	________________________
________________________	________________________	________________________

Por favor, agora avalie a **intensidade do GOSTO SALGADO** desta amostra de *nugget* de frango e indique, utilizando as escalas abaixo, o quão próxima do ideal ela se encontra:

(1) Gosto **extremamente menos salgado** que o ideal
(2) Gosto **muito menos salgado** que o ideal
( )3 Gosto **moderadamente menos salgado** que o ideal
( )4 Gosto **ligeiramente menos salgado** que o ideal
( ) 5Gosto **salgado ideal**
( ) 6Gosto **ligeiramente mais salgado** que o ideal
( ) 7Gosto **moderadamente mais salgado** que o ideal
( ) 8Gosto **muito mais salgado** que o ideal
( ) 9Gosto **extremamente mais salgado** que o ideal

Agora marque **todas as características que chamaram a sua atenção** no *nugget* de frango que você acabou de provar:

( ) Saboroso	( ) Rançosa	( ) Sabor fraco
( ) Seco	( ) Sabor ruim	( ) Odor fraco de frango
( ) Textura dura	( ) Tempero fraco	( ) Tempero forte
( ) Sem sabor	( ) Sabor metálico	( ) Pouco crocante
( ) Aparência interna escura	( ) Aparência interna clara	( ) Sabor amargo
( ) Sem tempero	( ) Sabor forte	( ) Tempero ideal
( ) Sabor fraco de carne de frango	( ) Gordurosa	( ) Sabor forte da carne de frango
( ) Odor forte de frango	( ) Textura macia	( ) Pouco rançosa
( ) Pouco gordurosa	( ) Odor de *nugget*	( ) Crocante
( ) Suculento	( ) Sabor estranho	

Appendix D – Images of the chicken nuggets processing steps.

Reference: Personal file. (a) Ingredients homogenization. (b) Molding for nuggets formatting. (c) Coating system: pre-dust, batter and breading. (d) Breaded nuggets. (e) Nuggets frying stage. (f) Ready-to-eat nuggets.