South African Journal of Animal Science 2022, 52 (No. 5)

Evaluation of chia gel incorporation as a fat substitute in Nile tilapia fishburger

M.C.C. Rampe[1], F.C. Henry[2], R.F. Oliveira[2#], A.C. Santos Junior[1], A.M. Maradini Filho[3], M.C.J.D. Dardengo[1]

[1]Federal Institute of Education, Science and Technology of Espírito Santo, Alegre, 29520-000, Brazil
[2]Food Technology Laboratory, Center for Agricultural Science and Technology, State University of Norte Fluminense Darcy Ribeiro, Campos dos Goytacazes, 28035-200, Brazil
[3]Federal University of Espírito Santo-CCAE, Alegre, ES, Brazil

(Submitted 7 February 2022; Accepted 30 May 2022; Published 28 January 2023)

Abstract: Chia gel is known for its functional properties such as high water and oil retention capacity, emulsifying activity, and as a stabilizer for foams and emulsions. Thus, the objective of this study was to evaluate the effect of the inclusion of chia gel as a substitute for pork fat in formulations of fishburgers made with Nile tilapia. Five formulations, one control and four with increasing levels of substitution of chia gel (12.50, 25.00, 37.50 and 50.00%) were evaluated. The fishburgers were characterized regarding their physicochemical composition, their technological characteristics, and microbiological viability. With the incorporation of the gel, there was a significant reduction in lipid component and the caloric value of the formulations, in addition to an increase in the percentage of dietary fibre. In addition, no negative effects were observed regarding yield and the main texture parameters studied. However, the formulations with the highest percentage replacement of pork fat by chia gel were darker when compared to the control treatment. Chia gel may be considered as a novel substitute for pork fat; however, it is recommended that techniques be employed to produce lighter gels, thus avoiding possible rejection by the consumer.

Keywords: animal fat substitution, healthy food, meat quality, mucilage of chia, *Oreochromis niloticus*, *Salvia hispanica* L.
[5]Corresponding author: fortunatorodrigo@ymail.com

Introduction

Chia (*Salvia hispanica* L.) is an annual, herbaceous plant belonging to the Lamiaceae family, native to southern Mexico and northern Guatemala (Ixtaina *et al.,* 2011; Capitani *et al.,* 2012). Considered a functional food, it has a significant amount of lipids (~40% of the total weight of the seed, with almost 60% as omega-3) and dietary fibre (over 30% of the total weight); both are critical components of the human diet. Chia includes protein of high biological value (~19% of the total weight). In addition, chia contains minerals, vitamins, and natural antioxidants, such as tocopherols (238–427 $mg \cdot kg^{-1}$) and polyphenols, the main phenolic compounds being chlorogenic acid, caffeic acid, quercetin, and kaempferol (Reyes-Caudillo *et al.,* 2008; Capitani *et al.,* 2012; Muñoz *et al.,* 2013).

When in contact with water, chia seeds produce a mucilage, which is a highly viscous and transparent gel called chia mucilage (Muñoz *et al.,* 2012; Campos *et al.,* 2016). The hydrolysis of this mucilage provides a mixture of sugars and uronic acids. Soluble fiber is mainly composed of neutral sugars, such as L-arabinose, D-galactose, L-rhamnose, and D-xylose, indicating the presence of different carbohydrates that constitute the structure of the mucilage (Reyes-Caudillo *et al.,* 2008). Due to its high water retention and water solubilization capacity, it is considered to be potential gel-former of satisfactory quality (Ixtaina *et al.,* 2011; Capitani *et al.,* 2012), which can be used as a substitute ingredient for fat sources, as well as being included as an emulsifying agent or thickening/stabilizer by

URL: http://www.sasas.co.za
ISSN 0375-1589 (print), ISSN 2221-4062 (online)
Publisher: South African Society for Animal Science
http://dx.doi.org/10.4314/sajas.v52i5.06

the industry, providing functional and nutritional quality to foods (Muñoz *et al.,* 2012; La Rosa *et al.,* 2015; Fernandes & Salas-Mellado, 2018).

Hamburgers are among the most consumed industrialized meat products in the world (De Oliveira *et al.,* 2014), and formulations using tilapia meat as raw material for this product have been studied by several researchers (Messias *et al.,* 2016; Mitterer-Daltoé *et al.,* 2017; Muzzolon *et al.,* 2018; Mattje *et al.,* 2019). However, most products have high percentages of saturated fat, which are intentionally added to improve sensory and technological attributes, such as flavour, aroma, and texture (De Oliveira *et al.,* 2013; De Oliveira *et al.,* 2014). The direct consequence of consuming large amounts of saturated fats is the increase in chronic diseases already known by most of the population, such as hypertension, obesity, and dyslipidaemia (De Oliveira *et al.,* 2013; Souza *et al.,* 2014).

Recently, studies have demonstrated the possibility of including chia gel in formulations to replace traditional fat sources in products such as bakery product mixes (Felisberto *et al.,* 2015; Fernandes & Salas-Mellado, 2017) and mayonnaise (Fernandes & Salas-Mellado, 2018). Other studies investigated using this gel as an emulsifying and stabilizing agent in ice cream (Campos *et al.,* 2016) and as a thickener in soy-based desserts (Spada *et al.,* 2014). However, there are no records in the literature of studies aiming to evaluate the inclusion of chia mucilage in meat or fish products.

Thus, this study aimed to evaluate the effect of including chia gel as a substitute ingredient for pork fat in fishburger formulations made with Nile tilapia meat (*Oreochromis niloticus*).

Materials and Methods

Experimental procedures for mucilage extraction, preparation of fishburger formulations, and physicochemical and microbiological analyses were performed at the Meat Processing, Applied Chemistry and Biotechnology Laboratories of the Federal Institute of Espírito Santo (IFES), Campus de Alegre, ES-Brazil. In addition, colour, water activity, and texture analyses were performed at the Agricultural Products Technology and Unit Operations Laboratory of the Agricultural Sciences Center of the Federal University of Espírito Santo (CCA-UFES), in Alegre, ES-Brazil.

The raw materials used to prepare fishburgers were as follows: Nile tilapia fillet, pork fat, chia gel, salt, antioxidant, preservative, garlic powder, and sugar. The tilapia fillets came from Piscicultura Ventania, located in the city of Espera Feliz-MG, under inspection of the Instituto Mineiro de Agropecuária, with registration number, 3887. The remaining ingredients were supplied by the Agroindustry Section of the Federal Institute of Espírito Santo, Campus of Alegre—ES-Brazil.

For the extraction of mucilage, 3 kg of chia seed (*Salvia hispanica* L.) was purchased from a local company in the city of Cachoeiro de Itapemirim, ES-Brazil. Then, it was homogenized, divided into 500 g aliquots, stored in vacuum packaging, and kept at room temperature until the extraction and analysis process.

The extraction of chia mucilage began with hydration, followed by separation/filtration, drying, and subsequent weighing. The seeds were hydrated with distilled water, establishing a seed/water ratio of 1:31 (weight:volume). This mixture was kept in a magnetic stirrer (Marconi brand) for 2 h under constant stirring at 85 °C (Orifici *et al.,* 2018).

After hydration, the mixture was stirred in a mixer (400 W, Philips Walita) for 30 s to release the mucilage firmly adhering to the seed surface. Subsequently, the mucilage was separated from the seed by double filtration, using a Prismatec vacuum pump. Finally, for drying, the liquid mucilage was added to non-stick trays and taken to a forced air circulation oven at a temperature of 55 °C for 20 h. Dried mucilage was weighed on a semi-analytical scale, vacuum-packed, and stored at room temperature until the time of use. As determined in preliminary tests, the gel was made at a concentration of 5 g of chia mucilage/100 g of gel.

Five formulations of tilapia fishburgers were prepared with a control treatment consisting exclusively of tilapia meat, pork fat, and additives; and four treatments with partial replacement of pork fat by chia gel: 12.50; 25.00; 37.50; and 50.00% (Table 1). Prior to the formulation of fishburgers, chia gel was prepared by hydrating the chia mucilage with distilled water at 80 °C for 30 min in a magnetic stirrer and kept under refrigeration for 24 h for complete hydration (Tavares *et al.,* 2018). In the preparation of fishburger formulations, the tilapia fillets and pork fat were thawed in refrigeration chambers kept at 6 °C for 12 h and then crushed in an industrial grinder using discs of 8.0 and 3.5 mm in diameter, respectively. The ingredients of each formulation were mixed, hand homogenized, and then moulded into 8.0 cm diameter manual moulds, individually separated by waxed paper, and packed as 10 hamburgers per polyethylene container (235 × 180 × 29 mm), wrapped with plastic film, and kept frozen until the moment of the analysis.

The fishburger samples were analysed in triplicate for moisture content, ash, protein, lipid, and dietary fibre according to the official methodology of the AOAC (2011). Moisture content was evaluated using the gravimetric method, drying in an oven at 105 °C until constant weight. The mineral matter was determined using the gravimetric method after the incineration of the organic matter in a muffle furnace at 550 °C. Protein analysis was performed according to the conventional Kjeldahl method, and fat content was measured by direct Soxhlet extraction. Dietary fibre content was established using the gravimetric method after acid digestion, and the non-nitrogen extract was calculated by difference. The total energy value was estimated considering the Atwater conversion factors of 4 kcal/g protein, 4 kcal/g carbohydrates, and 9 kcal/g lipids, as recommended by Watt & Merrill (1963).

Table 1. Ingredients of tilapia fishburger formulations with replacement of pork fat by chia gel

	Treatments				
	Control	**T1**	**T2**	**T3**	**T4**
Ingredients					
Tilapia meat [1]	77.76	77.76	77.76	77.76	77.76
Pork fat [2]	19.44	17.01	14.58	12.15	9.72
Chia gel [3]	0.00	2.43	4.86	7.29	9.72
Salt [4]	2.00	2.00	2.00	2.00	2.00
Sodium isoascorbate [5]	0.30	0.30	0.30	0.30	0.30
Sodium nitrite [6]	0.30	0.30	0.30	0.30	0.30
Sugar [7]	0.10	0.10	0.10	0.10	0.10
Garlic powder [8]	0.10	0.10	0.10	0.10	0.10
Total	100	100	100	100	100

[1] Skinless tilapia fillet. [2] Bacon without meat and skin. [3] 5% chia gel (g mucilage/100 g gel). [4] Globo® brand sodium chloride. [5] Antioxidant INS 316 (Ibracor LF from Ibrac®). [6] Preservative INS 250 (Ibrac® LF 600 Cure). [7] Paineiras® brand. [8] Adicel® brand. Control = pork fat only; T1 = 12.50%; T2 = 25.00%; T3 = 37.50% and T4 = 50.00% replacement of pork fat with chia gel

Colour analysis was performed with the aid of a Model MiniScan EZ-HunterLab colorimeter, using D65 illuminant and an observation angle of 10° (CIELab system). The results are expressed by angular coordinates: L* = luminosity (0 = black and 100 = white); a* (−80 to zero = green, from zero to +100 = red); and b* (−100 to zero = blue, from zero to +70 = yellow). Four fishburgers were analysed from each formulation (group), three samples/fishburger were taken, and each sample was analysed three times in the apparatus, totalling 36 replicates.

The pH was measured in a pot (Schott Handylab) using 5 g of each fishburger sample homogenized in 50 mL of distilled water for 5 min. Water activity (Aw) was determined by direct reading of the samples at 25 °C using an AW meter (Aqualab TE, Ecagon Devices, Pullman, WA, USA).

The instrumental texture profile (TPA) was analysed using the Texture Analyzer Brookfield texturometer, connected to a computer equipped with the Texture Pro CT V1.4 Build 17® program. Three samples measuring 30 × 30 × 5 mm were taken from four fishburgers, totalling 12 replicates. The test was performed using a cylindrical acrylic probe with a diameter of 38.1 mm (TA4/1000), with 50% sample compression and a pre-test and test speed of 2 mm/s and 5 s of retention between the two compressions. The following parameters were obtained: hardness, cohesiveness, elasticity, gumminess, and chewability.

The fishburgers were cooked and prepared while still frozen using an electric grill (Fun Kitchen brand) at 200 °C. The average time of 8 min for cooking the fishburgers was standardized, turning them every 2 min and ensuring that the temperature in the centre of the product reached 75 °C (Arisseto & Pollonio, 2005). The fishburger yield is the difference between the weight of the raw and grilled whole hamburger, also analysing the reduction in diameter and thickness of raw and grilled fishburgers (Bainy *et al.,* 2015).

The microbiological analyses of the samples were performed according to the official methods adopted by the Brazilian Ministry of Agriculture, Livestock, and Supply as reported by Silva *et al.* (2007). The results were compared with the standards stipulated by RDC n° 12 (2001) for thermotolerant coliforms at 45 °C, coagulase-positive *Staphylococcus,* and *Salmonella* sp.

The experimental design used was a completely randomized design with five treatments (control, T1, T2, T3, and T4) and four replications. The results of the physicochemical, instrumental, and cooking parameters of fishburgers were submitted to analysis of variance (ANOVA), and the averages were compared using Tukey's test at 5% probability using the statistical software, SAEG Version 9.1 (2007). Analyses were performed in triplicate.

Results and Discussion

Table 2 displays the results of the proximate composition analysis (moisture, ash, lipid, protein, fibre, and non-nitrogen extract) and the caloric value of fish burgers.

Table 2. Physicochemical composition of tilapia fishburger formulations with replacement of pork fat by chia gel

Composition	Control	T1	T2	T3	T4
Moisture (%)	63.92 ± 0.79 [c]	65.09 ± 0.64 [b]	66.17 ± 0.55 [b]	70.09 ± 0.82 [a]	70.38 ± 0.65 [a]
Ash (%)	2.98 ± 0.14	3.08 ± 0.09	3.07 ± 0.10	3.00 ± 0.08	3.06 ± 0.09
Lipid (%)	16.73 ± 0.64 [a]	15.95 ± 0.37 [a]	14.27 ± 0.54 [b]	10.95 ± 0.65 [c]	10.18 ± 0.67 [c]
Protein (%)	16.04 ± 0.55 [a]	15.50 ± 0.46 [ab]	14.97 ± 0.66 [bc]	14.34 ± 0.66 [c]	14.09 ± 0.47 [c]
Fiber (%)	0.06 ± 0.01 [e]	0.11 ± 0.01 [d]	0.18 ± 0.01 [c]	0.20 ± 0.01 [b]	0.22 ± 0.02 [a]
NNE [1] (%)	0.25 ± 0.31 [c]	0.25 ± 0.16 [c]	1.33 ± 0.41 [c]	1.41 ± 0.34 [b]	2.06 ± 0.53 [a]
CV [2] (Kcal)	215.76 ± 5.61 [a]	206.61 ± 4.47 [a]	193.68 ± 3.87 [b]	161.58 ± 6.26 [c]	156.24 ± 5.68 [c]

[1] Non-nitrogen extract; [2] Caloric value. Control = pork fat only; T1 = 12.50%; T2 = 25.00%; T3 = 37.50% and 50.00% replacement of pork fat with chia gel. Values are averages ± standard deviation of analyses performed in triplicate. Equal letters on the same line do not differ statistically from each other using the Tukey test ($p > 0.05$).

Normative Instruction Nº 20 (2000), referring to the Technical Regulation of Identity and Quality of Hamburgers, establishes that the formulations must contain at least 15% protein and a maximum of 23% fat. In this study, all formulations presented fat percentages below the established maximum, with a reduction ($p < 0.05$) of lipid content observed as there was an increase in the replacement levels of pork fat by chia gel. Formulations T3 (14.34%) and T4 (14.09%) displayed protein values slightly below ($p < 0.05$) those recommended by legislation.

With the increased incorporation of chia gel, the reduction in lipid content provided a decrease ($p < 0.05$) in the caloric value. The lipid content is the component that contributes the most to the food calories (9 kcal/g), while carbohydrates and proteins have a caloric coefficient of 4 kcal/g (Watt & Merrill, 1963). The maximum percentage of pork fat replaced by chia gel tested in this study was 50%, corresponding to a 27.6% reduction in total calories. These results agree with Fernandes & Salas-Mellado (2017), who described a decrease in lipid content and caloric value of bread and cakes made with chia gel instead of margarine.

As expected, there was an increase ($p < 0.05$) in the moisture content of the formulations with a higher level of chia gel inclusion, compared to the control group. This effect was demonstrated by the gradual increase in the fibre percentage ($p < 0.05$) when including the chia gel in the formulations. Moisture increase occurred because of water content increase and the greater water retention capacity presented by chia gel fibres. Water holding capacity of any food can be greatly influenced by carbohydrate concentration (Yu *et al.,* 2018). Fernandes & Salas-Mellado (2018) described similar results in the formulations of mayonnaise when replacing egg and soybean oil with chia gel.

Table 3 presents the parameters, L* (brightness), a* (intensity of red), and b* (intensity of yellow) of the different formulations of raw and grilled fishburgers. The chia gel affected ($p < 0.05$) all parameters evaluated.

Table 3. Averages and standard deviations of the instrumental colour of raw and grilled fishburgers made with different levels of pork fat replaced by chia gel

Colour	Formulation				
	Control	**T1**	**T2**	**T3**	**T4**
Fishburger raw					
L*	68.12 ± 1.52 [a]	67.61 ± 1.03 [ab]	65.74 ± 1.39 [b]	62.09 ± 1.83 [c]	60.80 ± 1.54 [c]
a*	1.06 ± 0.4 [b]	2.21 ± 0.23 [a]	2.71 ± 0.50 [a]	2.33 ± 0.49 [a]	2.14 ± 0.43 [a]
b*	11.95 ± 0.49 [a]	12.49 ± 0.28 [a]	12.03 ± 0.45 [a]	10.75 ± 0.74 [b]	10.47 ± 0.50 [b]
Fishburger grilled					
L*	65.50 ± 2.96 [a]	64.27 ± 1.55 [ab]	61.23 ± 1.59 [bc]	58.86 ± 1.17 [c]	57.83 ± 1.63 [c]
a*	5.98 ± 1.72 [b]	6.06 ± 1.32 [b]	8.10 ± 1.44 [ab]	8.45 ± 1.19 [ab]	8.94 ± 0.97 [a]
b*	15.58 ± 1.35 [b]	15.66 ± 1.32 [b]	18.67 ± 1.37 [a]	18.77 ± 1.23 [a]	18.83 ± 1.41 [a]

Control = pork fat only; T1 = 12.50%; T2 = 25.00%; T3 = 37.50%, and T4 = 50.00% replacement of pork fat with chia gel. Values are averages ± standard deviation of analyses performed in triplicate. Equal letters on the same line do not differ statistically from each other using Tukey's test (p >0.05).

Chia gel inclusion to replace pork fat in raw and grilled fishburger samples decreased luminosity (L*), demonstrating the darkening of the samples. However, this effect was expected due to the dark colour of chia mucilage (raw material for preparing the gel) after extraction, due to the impediment of the passage of some impurities, such as natural pigments or seed residues, as well as the combination factors used in the mucilage extraction and drying processes, such as time, temperature and the seed: water ratio used (Campos *et al.,* 2016). Lean fish such as Nile tilapia are used to prepare protein, and the colour of the product ranges from light grey to yellowish-brown. This evidence was even more pronounced when fishburgers were grilled, where there is the summation effect of non-enzymatic browning reactions, which naturally occur in thermally treated products, such as the Maillard and caramelization reactions (Ordoñez, 2005).

Other authors using chia gel as a fat substitute in cake formulations (Felisberto *et al.,* 2015; Fernandes & Salas-Mellado, 2017), in bread (Fernandes & Salas-Mellado, 2017), and ice cream (Campos *et al.,* 2016) claimed similar results. Bainy *et al.* (2015) described L* values of 69.13 for raw tilapia fishburgers and 63.89 for grilled ones, similarly to those found in the current study. An a* value greater than zero indicates reddish coloration in all tested formulations. In raw fishburgers, the presence of chia gel, regardless of the inclusion percentage, promoted an increase in the value of a* compared to the control formulation (without chia gel). As for grilled products, this difference was more pronounced than the control with the formulation of higher chia gel inclusion levels (T4). A b* value greater than zero displays a yellow hue in raw and grilled fishburgers. In raw products, there was a reduction (p <0.05) in yellow hue with a 37.5% fat replacement, while in grilled samples, there was an increase (p <0.05) in the yellow intensity of the samples studied with a 25% replacement.

Table 4 shows the results of the analysis of pH, Aw, texture profile, and cooking parameters of fishburgers. There was an effect (p <0.05) for the variables of elasticity, chewiness, diameter reduction, and thickness reduction.

Table 4. Averages and standard deviations of physicochemical variables and cooking parameters of fishburgers with different levels of replacement of pork fat by chia gel

Parameter	Formulation				
	Control	T1	T2	T3	T4
pH	6.66 ± 0.10	6.56 ± 0.10	6.55 ± 0.02	6.53 ± 0.07	6.52 ± 0.10
Water activity	0.97 ± 0.01	0.97 ± 0.00	0.98 ± 0.01	0.98 ± 0.01	0.97 ± 0.01
Hardness (N)	60.12 ± 2.76	61.05 ± 2.97	61.54 ± 2.01	62.05 ± 2.33	62.13 ± 2.58
Cohesiveness	0.73 ± 0.04	0.72 ± 0.03	0.73 ± 0.03	0.74 ± 0.03	0.75 ± 0.02
Elasticity (mm)	3.22 ± 0.24 [b]	3.99 ± 0.27 [a]	4.06 ± 0.19 [a]	4.08 ± 0.06 [a]	4.10 ± 0.19 [a]
Gumminess (N)	43.70 ± 2.48	44.16 ± 2.03	45.07 ± 2.22	46.08 ± 2.61	46.61 ± 2.64
Chewability (mJ)	140.70 ± 11.48 [b]	176.42 ± 15.69 [a]	182.99 ± 13.71 [a]	188.22 ± 10.57 [a]	191.40 ± 14.45 [a]
Yield (%)	79.59 ± 1.53	80.48 ± 1.96	80.87 ± 0.83	81.08 ± 0.90	81.58 ± 0.77
DR [1] (%)	11.52 ± 0.66 [a]	10.47 ± 0.68 [b]	9.99 ± 0.69 [b]	9.70 ± 0.78 [b]	9.53 ± 0.69 [b]
TR [2] (%)	11.23 ± 0.56 [a]	9.85 ± 0.58 [b]	9.57 ± 0.62 [bc]	9.16 ± 0.60 [c]	9.02 ± 0.56 [c]

[1] Diameter reduction; [2] Thickness reduction. Control = pork fat only; T1 = 12.50%; T2 = 25.00%; T3 = 37.50%, and T4 = 50.00% of pork fat replacement by chia gel. Values are averages ± standard deviation of analyses performed in triplicate. Equal letters on the same line do not differ statistically from each other using Tukey's test (p >0.05)

Some parameters evaluated in foods, such as pH and water activity (Aw), must be studied; together with the nutrient availability and storage temperature, they will determine whether the food system is conducive to the development of microorganisms or not. This reflects directly on the shelf life, which in turn is related to the quality and safety of the product (Pinto, 2015). In the current study, there was no significant effect on the pH and water activity (Aw), demonstrating no interference of the chia gel for these parameters under the conditions evaluated. Bainy *et al.* (2015) obtained similar results, as they assessed the physicochemical properties and texture of raw, grilled, and cooked tilapia hamburgers (*Oreochromis niloticus*).

Hydrocolloids such as chia gel can act as food texture modifiers mainly due to their thickening effect (Capitani *et al.,* 2012; Muñoz *et al.,* 2012). However, the addition of chia gel had little impact on the food texture parameters of fishburgers, making them more elastic and with higher chewiness when compared to the control formulation. This effect is due to the characteristic of chia gel, which provides an increase in the elasticity of food systems (La Rosa *et al.,* 2015), also influencing the increase in energy required to chew the product, since the calculation of chewability is gumminess x elasticity. Fish proteins have a lot of outstanding functional attributes, including fat binding capacity and gelling properties (Zhou et al., 2019), which make them more interesting hydrocolloids. Due to its many useful functional properties, minced fish has successfully been used for the preparation of several foodstuffs (such as hamburgers), conferring juiciness, cohesion–adhesion, succulence, desired texture, fat absorbing ability, tenderness, chewiness, and gel-forming capacity (Khan et al., 2020).

The average yield of fishburgers was not affected (p >0.05) by chia gel inclusion. Chia gel is mainly composed of soluble fibres, which in addition to contributing to the food product's structure stabilization, increases water retention capacity within the matrix in which it was inserted, reducing cooking losses (Ixtaina *et al.,* 2011; Capitani *et al.,* 2012). Fernandes & Salas-Mellado (2017) described a similar result, as the authors claimed no change in the specific volume of bread and cakes with replacement of margarine by chia gel of up to 50%.

Fay *et al.* (2015) evaluated the use of different extenders in blue-striped grunt fishburger (*Haemulon plumieri*) and obtained weight losses ranging from 11.5 to 28%. Bainy *et al.* (2015) found 85.3% yields in grilled tilapia fishburgers. In this study, the fishburgers were grilled, and the average yield found was 80.72%. Similarly, gel inclusion in the formulations proved to be advantageous, as it provided lower percentage reductions in both fishburger diameter and thickness, confirming the potential of this ingredient for moisture retention and providing minor changes in the structure of the grilled fishburgers. The cooking parameters indicate the potential use of chia gel when used in fish products. Similar results were found by Cristofel *et al.* (2021), who added chia to tilapia fishburger causing less water loss, colour change, smaller reductions in diameter and in thickness, and a greater cooking yield.

Table 5 displays the microbiological analyses.

Table 5. Averages of microbiological analysis in fishburgers with different levels of replacement of pork fat by chia gel

Parameter	Formulation					
	Control	T1	T2	T3	T4	Reference *
Thermotolerant coliforms (NMP/g)	5	<5	<5	<5	<5	$<10^3$
Coagulase positive *Staphylococcus* spp. (UFC/g)	<1	<1	<1	<1	<1	$<10^3$
Salmonella sp. (in 25 g)	Absence	Absence	Absence	Absence	Absence	Absence

* BRAZIL (2001); Control = pork fat only; T1 = 12.50%; T2 = 25.00%; T3 = 37.50% and T4 = 50.00% replacement of pork fat with chia gel

Burgers generally undergo much industrial handling. For this reason, they are ideal mediums for microorganism growth, and they are highly perishable. However, from the results of the microbiological analyses found in this study, it can be stated that the fishburgers produced complied with the requirements of Resolution Nº 12 of 2 January, 2001 (Brazil, 2001), ensuring that the formulations followed good manufacturing practices and that the raw materials used had satisfactory microbiological qualities that do not cause risks for consumers.

Conclusions

Chia gel can be substituted for pork fat and reduce caloric value and lipid percentage of fishburger made with Nile tilapia meat (*Oreochromis niloticus*) without harming the product's yield and main texture. However, we suggest new studies with respect to performance in improving the process of obtaining chia mucilage (raw material for getting the gel) in order to obtain gels with a lighter colour and gels that are similar to pork fat colour to avoid possible consumer rejection, since the colour is the primary sensory parameter in food at purchase. Due to the paucity in the literature and the potential presented by chia gel, further studies assessing the effect of including this ingredient in other meat products, especially those that are fish-based, are recommended.

Acknowledgements

To the Federal Institute of Science and Technology of Espírito Santo (IFES, Campus de Alegre, ES-Brazil). To the State University of Norte Fluminense Darcy Ribeiro for the Ph.D. scholarship granted to the third author.

Authors' Contributions

Conceptualization, MCCR; methodology, MCCR and FCH; formal analysis, MCCR and RFO; investigation, MCCR, FCH, RFO, ACSJ, AMMF, and MCJDD; data curation, MCCR; writing—original draft preparation, MCCR; writing—review and editing, FCH and RFO; visualization, MCCR; supervision, MCCR; project administration, MCCR.

Conflicts of Interest

The authors declare that there is no conflict of interest.

References

Agência Nacional de Vigilância Sanitária. RDC nº 12, de 02 de Janeiro de 2001. Regulamento técnico sobre padrões microbiológicos para alimentos. Diário Oficial da República Federativa do Brasil. Brasília, Agência Nacional de Vigilância Sanitária. 2001. Available online: www.anvisa.gov.br/alimentos (accessed on 10 August 2021).

AOAC. Official Methods of Analysis, 18th ed.; Association of Official Analytical Chemists: Washington, DC, USA, 2011.

Arisseto, A.P. & Pollonio, M.A.R. 2005. Avaliação da estabilidade oxidativa do hambúrguer tipo calabresa, formulado com reduzidos teores de nitrito e diferentes percentagens de gordura, durante armazenamento congelado. Higiene Alimentar 136, 72–80.

Bainy, E.M., Bertan, L.C., Corazza, M.L. & Lenzi, M.K. 2015. Effect of grilling and baking on physicochemical and textural properties of tilapia (*Oreochromis niloticus*) fish burger. J. Food Sci. Technol. 52, 5111–5119. https://doi.org/10.1007/s13197-014-1604-3.

Campos, B.E., Ruivo, T.D., Scapim, M.R.S., Madrona, G.S. & Bergamasco, R.C. 2016. Optimization of the mucilage extraction process from chia seeds and application in ice cream as a stabilizer and emulsifier. Food Sci. Technol. 65, 874–883. https://doi.org/10.1016/j.lwt.2015.09.021.

Capitani, M.I., Spotorno, V., Nolasco, S.M. & Tomás, M.C. 2012. Physicochemical and functional characterization of by-products from chia (*Salvia hispanica* L.) seeds from Argentina. Food Sci. Technol. 45, 94–102. https://doi.org/10.1016/j.lwt.2011.07.012.

De Oliveira, D.F., Coelho, A.R., Burgardt, V.C.F., Hashimoto, E.H., Lunkes, A.M., Marchi, J.F. & Tonial, I.B. 2013. Alternatives for a healthier meat product: A review. Braz. J. Food Technol. 16, 163–174. https://doi.org/10.1590/S1981-67232013005000021.

Cristofel, C.J., Grando, R.C., Tormen, L., Francisco, C.T.P. & Bertan, L.C. 2021. Effect of the use of guabiroba bark and functional ingredients on the characteristics of Nile Tilapia burger. J. Food Process. Preserv. 45, e15040. https://doi.org/10.1111/jfpp.15040.

De Oliveira, D.F., Mileski, J.P.F., Carli, C.G., Marchi, J.F., Silva, D.C., Coelho, A.R. & Tonial, I.B. 2014. Golden flaxseed flour as a substitute for animal fat in reduced-sodium beef hamburgers. Braz. J. Food Technol. 17, 273–282. https://doi.org/10.1590/1981-6723.0714.

Fay, J.F.A., Vieira, P.H.S., Silva, B.W., Veloso, R.R. & Filho, P.R.C.O. 2015. Fishburger de biquara (*Haemulon Plumierii* - Lacepède, 1801) com adição de diferentes extensores. Acta Technol. 10, 91–105. https://doi.org/10.35818/acta.v10i2.379.

Felisberto, M.H., Wahanik, A.L., Gomes-Ruffi, C.R., Clerici, M.T.P.S., Chang, Y.K. & Steel, C.J. 2015. Use of chia (*Salvia hispanica* L.) mucilage gel to reduce fat in pound cakes. Food Sci. Technol. 63, 1049–1055. https://doi.org/10.1016/j.lwt.2015.03.114.

Fernandes, S.S. & Salas-Mellado, M.M. 2017. Addition of chia seed mucilage for reduction of fat content in bread and cakes. Food Chem. 227, 237–244. https://doi.org/10.1016/j.foodchem.2017.01.075.

Fernandes, S.S. & Salas-Mellado, M.M. 2018. Development of mayonnaise with substitution of oil or egg yolk by the addition of chia (*Salvia hispanica* L.) mucilage. J. Food Sci. 83, 74–83. https://doi.org/ 10.1111/1750-3841.13984.

Ixtaina, V.Y., Martínez, M.L., Spotorno, V., Mateo, C.M., Maestri, D.M., Diehl, B.W.K., Nolasco, S.M. & Tomás, M.C. 2011. Characterization of chia seed oils obtained by pressing and solvent extraction. J. Food Compos. Anal. 24, 166–174. https://doi.org/10.1016/j.jfca.2010.08.006.

Khan, S., Rehman, A., Shah, H., Aadil, R.M., Ali, A., Shehzad, Q., Ashraf, W., Yang, F., Karim, A. & Khaliq, A. 2020. Fish protein and its derivatives: The novel applications, bioactivities, and their functional significance in food products. Food Rev. Int. https://doi.org/10.1080/87559129.2020.1828452.

La Rosa, G.A., Alvarez-Ramireza, J., Vernon-Cartera, E.J., Carrillo-Navasa, H. & Pérez-Alonso, C. 2015. Viscoelasticity of chia (*Salvia hispanica* L.) seed mucilage dispersion in the vicinity of an oil–water interface. Food Hydrocoll. 49, 200–207. https://doi.org/10.1016/j.foodhyd.2015.03.017.

Mattje, L.G.B., Tormen, L., Bombardelli, M.C.M., Corazza, M.L. & Bainy, E.M. Ginger essential oil and supercritical extract as natural antioxidants in tilapia fish burger. J. Food Process. Preserv. 43, e13942. https://doi.org/10.1111/jfpp.13942.

Messias, C.R., Konopka, D.N., Biassi, D.C., Vianna, R.B., Quast, E., Bainy, E.M. & Poliseli-Scopel, F.H. (2016). Sensory training and characterization of fish burger formulations made with filleting byproducts of tilapia (*Oreochromis niloticus*). Braz. J. Food Res. 7, 125–142. https://doi.org/10.3895/rebrapa.v7n2.3652.

Ministério da Agricultura, Pecuária e Abastecimento. Instrução nº 20, de 31 de julho de 2000. Regulamentos Técnicos de Identidade e Qualidade de Almôndega, de Apresuntado, de Fiambre, de Hamburguer, de Kibe, de Presunto Cozido e de Presunto. Instrução Normativa nº 20, de 31/07/2000. Diário Oficial da União, Brasília, 31/07/2000, pp. 7–9. Available online: http://extranet.agricultura.gov.br/sislegisconsulta/consultarLegislacao.do?operacao=visualizar&id=1681 (accessed on 15 August 2021).

Mitterer-Daltoé, M.L., Nogueira, B.A., Rodrigues, D.P. & Breda, L.S. 2017. Sensory perception in the replacement of NaCl by MSG in fish burgers. Acta Sci. Technol. 39, 565–572, 2017. https://doi.org/10.4025/actascitechnol.v39i5.28660.

Muñoz, L.A., Cobos, A., Diaz, O. & Aguilera, J.M. 2012. Chia seeds: Microstructure, mucilage extraction, and hydration. J. Food Eng. 108, 216–224. https://doi.org/10.1016/j.jfoodeng.2011.06.037.

Muñoz, L.A., Cobos, A., Diaz, O. & Aguilera, J.M. 2013. Chia seed (*Salvia hispanica*): An Ancient grain and a new functional food. Food Rev. Int. 29, 394–408. https://doi.org/10.1080/87559129.2013.818014.

Muzzolon, E., Biassi, D.C., Konopka, D.N., Oliveira, J., Poliseli-Scopel, F.H. & Bainy, E.M. 2018. Processamento de fishburguer utilizando subprodutos da filetagem de tilápia: Caracterização físico-química, análise do congelamento e avaliação da vida de prateleira. Braz. J. Food Res. 9, 154–173. https://doi.org/10.3895/rebrapa.v9n1.5251.

Ordoñez, J.A. 2005. Tecnologia de Alimentos—Alimentos de Origem Animal; Artmed: Porto Alegre, Brazil.

Orifici, S.C., Capitani, M.I., Tomás, M.C. & Nolasco, S.M. 2018. Optimization of mucilage extraction from chia seeds (*Salvia hispanica* L.) using response surface methodology. J. Sci. Food Agric. 98, 4495–4500. https://doi.org/10.1002/jsfa.8974.

Pinto, J.V. 2015. Elaboração de Manual Prático para Determinação de Vida-de-Prateleira de Produtos Alimentícios; Universidade Federal do Rio Grande do Sul: Porto Alegre, Brazil.

Reyes-Caudillo, E., Tecante, E. & Valdivia-López, M.A. 2008. Dietary fibre content and antioxidant activity of phenolic compounds present in Mexican chia (*Salvia hispanica* L.) seeds. Food Chem. 107, 656–663. https://doi.org/10.1016/j.foodchem.2007.08.062.

SAEG. Sistema para Análises Estatísticas: Versão 9.1; Viçosa, M.G., Ed.; Fundação Arthur Bernardes: Viçosa, Brazil, 2007.

Silva, N., Junqueira, V.C.A., Silveira, N.F.A., Taniwaki, M.H., Santos, R.F.S. & Gomes, R.A.R. 2007. Manual de métodos de análise microbiológica de alimentos, 3rd ed.; Livraria Varela: São Paulo, Brazil.

Souza, A.H., Gohara, A.K., Rotta, E.M., Chaves, M.A., Silva, C.M., Dias, L.F., Gomes, S.T.M., Souza, N.E. & Matsushita, M. 2014. Effect of the addition of chia's by-product on the composition of fatty acids in hamburgers through chemometric methods. J. Sci. Food Agric. 95, 928–935. https://doi.org/10.1002/jsfa.6764.

Spada, J.C., Dick, M., Pagno, C.H., Vieira, A.C., Bernstein, A., Coghetto, C.C., Marczak, L.D.F., Tessaro, I.C., Cardozo, N.S.M. & Flôres, S.H. 2014. Caracterização física, química e sensorial de sobremesas à base de soja, elaboradas com mucilagem de chia. Ciência Rural 44, 374–379. https://doi.org/10.1590/S0103-84782014000200029.

Tavares, L.S., Junqueira, L.A., Guimarães, I.C.O. & Resende, J.V. 2018. Cold extraction method of chia seed mucilage (*Salvia hispanica* L.): Effect on yield and rheological behavior. J. Food Sci. Technol. 55, 457–466. https://doi.org/10.1007/s13197-017-2954-4.

Watt, B. & Merrill, A.L. 1963. Composition of Foods: Raw, Processed, Prepared; Agriculture Handbook, 8; Consumer and Food Economics Research Division/Agricultural Research Service: Washington, DC, USA, p. 198.

Yu, C., Wu, F., Cha, Y., Zou, H., Bao, J., Xu, R. & Du, M. 2018. Effects of high-pressure homogenization on functional properties and structure of mussel (*Mytilus edulis*) myofibrillar proteins. Int. J Biol. Macromol. 118, 741–746. https://doi.org/10.1016/j.ijbiomac.2018.06.134.

Zhou, X., Chen, H., Lyu, F., Lin, H., Zhang, Q. & Ding, Y. 2019. Physicochemical properties and microstructure of fish myofibrillar protein–lipid composite gels: Effects of fat type and concentration. Food Hydrocoll. 90, 433–442. https://doi.org/10.1016/j.foodhyd.2018.12.032.