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Effect of Chia Seed on Physicochemical and Sensory Characteristics of Common Carp Restructured as Functional Food

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Abstract: Physicochemical and sensory characteristics of restructured meat of common carp (*Cyprinus carpio*) fortified with 0-8 g/100 g of chia seed flour (CSF) was evaluated. It had a higher nutritional value (higher fibre content and protein retention] ($p < 0.05$) and better cooking characteristics (higher cooking yield and moisture retention) ($p < 0.05$) than the control. The colour (a*, b*) increased; lightness and whiteness index decrease ($p < 0.05$). Hardness increase ($p < 0.05$) occurred because of CSF addition. Differential scanning calorimetry showed that fibre fortification did not interfere with the thermal transitions of the restructured meat. No significant differences were detected with the preference test scores of 4% or 8% CSF compared with the control. Restructured (4%-8% CSF) had a higher content of fibre and fat, which could be linoleic and linolenic acid, and an increase in the content of protein compared with those of commercial products, among had 1.62 and 2.25 mg AGE/g. Therefore, the restructured properties of common carp were governed by CSF addition.

Key words: Protein gel, common carp, chia seeds, restructured meat, physicochemical properties.

1. Introduction

Obesity is a chronic disorder with multiple causes that may affect an individual in isolation or act collectively at the population level. Virtually all obese people develop symptoms of chronic disease by the age of 40, and the majority will require medical intervention for obesity-related disease before they are 60 [1]; therefore, obesity is now regarded as a growing epidemic around the world. According to the World Health Organization [2] one billion adults are overweight, and more than 300 million people are obese. Without a population-level, multisectoral and multidisciplinary approach to curb the problem, this figure will surpass 1.5 billion by 2015. Altogether, there are more than 42 million children under five who are overweight globally.

Since the early 1980s, in Mexico, the odds of being overweight and obese have tripled: 39.05% of the population is overweight, and 32.15% is obese, which equates to seven out of 10 Mexicans between the ages of 30 and 60 years [3]. According to United Nations International Children's Emergency Fund [4], the country is first in the world for childhood obesity, second for adults after the United States, and first in the case of women [2].

Among the causes of these diseases is the intake of energy-dense foods rich in fats, salt and carbohydrates and low in vitamins, minerals and fibre, coupled with a decline in physical activity and a sedentary rhythm of

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life. Obesity and overweight are preventable by performing regular physical activity, balancing the energy content consumed, limiting the intake of sugars and total fat and increasing the consumption of fruits, vegetables, legumes, whole grains and nuts [2]; all these actions translate into a higher intake of fibre.

Studies show that increased consumption of foods rich in insoluble fibre is strongly associated with reduced diabetes [5] and, in turn, comorbid cardiovascular disease complications. In this regard, there are various food products contributing to the dietary required amount or a portion of the necessary fibre. A food product's functionality regarding dietary fibre may have several benefits, such as adjuvant texture, an increased volume of products low in sugar, fat substitutes, added colour and natural antioxidant activity [6]. In addition to contributing to the improvement of the textural features, a fibre-providing food product can improve the sensory appeal and shelf life of food, due to its ability to retain water and form gels and to mimic fat, texturing and thickening effects [7]. Examples of these soluble fibres derived from grains and the fractions of various fruit are pectins [8], beta-glucans, beet cellulose fibre [9], polydextrose [10], etc. Dietary fibre linked with soy proteins by their functional properties has been widely utilised in various branches of the food industry, including the meat industry [11]. Potato skins, a byproduct of the industry of potatoes shells, are rich in fibre and also have been used as a source of dietary fibre in breadmaking [12]. The seeds of *Salvia hispanica* L., better known as chia, are a pseudocereal rich in soluble and insoluble fibre, and they contain 25% to 35% polyunsaturated fatty acids, antioxidants, such as cinnamic, chlorogenic and caffeic acid, and the flavonoids myricetin, quercetin and kaempferol [13]. Thus, it is an excellent ingredient for dieters because it has beneficial effects, such as reducing blood cholesterol and blood glucose and modifying insulinaemic responses, as well as changes in the function of the intestine and antioxidant activity [13]. Several authors [14-17] have added various types of fibre, such as wheat to hake and mackerel, dietary fibre wheat to surimi giant squid, pea fibre to surimi, carrageenan and komjac carrageenan-flour in bass, Solka-Floc (cellulose fibre) in surimi pollock (*Alaska pollock*) and powdered cellulose dietary fibre to obtain restructured meat based on seafood or aquaculture species. Among these, the common carp is a species underutilised around the world [18], but it presents significant nutritional characteristics. So far, there have not been any reports on the use of the chia seed as a source of fibre for the production of restructured meat from this species, so the use of these two products could be an alternative for consumption, taking advantage of a fishing product that is infrequently marketed because of its size, due to its content of thorns or the abundance of large fish that are already processed and contribute to health. Therefore, the aim of this study was to evaluate the effect of chia flour (CSF) (*Salvia hispanica* L.) on physicochemical and sensory characteristics of developed restructured meat of common carp (*Cyprinus carpio*) as a functional food based.

2. Materials and Methods

2.1 Samples

Ten carp (*Cyprinus carpio*) with weights of 1.5 kg were obtained from the San Luis Mextepec business community, State of Mexico, Mexico, and they were transported to the laboratory under refrigeration at 5 °C in high-density polyethylene bags (HDPB). Afterward, they were washed, eviscerated and stored at 4 °C until further use. Chia seeds were purchased from the central supply of Toluca, Mexico, and they were ground to achieve the texture of flour, after which the chia flour was stored in HDPB.

2.2 Physicochemical Analysis

2.2.1 Water-holding Capacity (WHC)

The evaluation of WHC was described according to

Dublán et al. [19]. Five grams of common carp muscle were homogenised with 8 mL of 0.6-M NaCl. The homogenate was placed in an ice bath and stirred with a glass rod for 1 min. The tubes were left on ice for 30 min, stirred again for 1 min and centrifuged at 8,000 × g for 15 min. The supernatant volume was measured. WHC was reported by the difference as millilitres of 0.6-M NaCl held/100 g of muscle. All determinations were performed in triplicate.

2.2.2 pH

pH values were determined using a Hanna Instruments potentiometer (pH 210, Italia Srl). Ten grams of muscle were ground in 90 mL distilled water for 1 min. After filtration of the mixture, the pH value was determined [20].

2.2.3 Titratable Acidity

The titratable acidity was determined by the A.O.A.C. [21], Part 942.15 method.

2.2.4 Colour

The colour of the common carp muscle, CSF and restructured meat was determined using a Chroma Meter CR-400 colorimeter, according to the CIELAB model. We obtained the values of L*, a* and b* as estimates of the luminosity (L*) on a scale from 0 to 100 and indicators of red-green (a*) and yellow-blue (b*). These measurements were used to calculate the whiteness of the gels according to the equation:

$$\text{Whiteness} = 100 - [(100 - L^*)^2 + a^{*2} + b^{*2}]^{1/2}.$$

From the coordinates, the hue (H*) and chroma (C*) were calculated as follows [22]:

$$\text{Hue} = \tan^{-1} b^*/a^*$$

$$\text{Chroma} = (a^2 + b^2)^{1/2}.$$

2.3 Proximal Analysis

Protein was analysed by the Kjeldahl method, the ether extract by the Soxhlet method [23], the moisture by A.O.A.C.14,003 [21], ash by the method of calcination in a muffle furnace at 500 °C [21], and the neutral detergent fibre by A.O.A.C. [24] using an ANKOM mark 200 Fiber Analyzer (Ankom Technology Corp., Fairport, NY).

2.3.1 Myofibrillar Protein (MP)

MP was prepared from the common carp muscle according to Ngapo et al. [25], with slight modifications. One hundred grams of common carp muscle were homogenised by blending for 10 min with ice-cold distilled water 1:1:1 (w/w/v) and then were magnetically stirred for 10 min in an ice bath. The myofibril suspension was filtered through two layers of cheesecloth to remove connective tissues, stirred and filtered twice. The muscle homogenate was centrifuged at 3,000 × g at 4 °C for 25 min, and the supernatant was discarded. Part of the myofibril pellet was placed into a capped glass and stored to immediately begin gel formation. The protein concentration of the myofibril pellet was determined using the biuret method.

2.3.2 Preparation of the Protein Mixture: Common Carp-Chia Seed Flour (CSF)

For each 100 g of myofibrillar protein extracted from the carp, various percentages of CSF, including 0%, 1%, 4% and 8%, were added. The samples were mixed until incorporation and subsequent gelation.

2.3.3 Gelation of Proteins

The gelation of proteins was performed according to Klettner [26]: 30 g of the mixture (carp-chia) with the four different concentrations of flour chia were added to bottles with an internal diameter of 25 mm and a height of 50 mm. The vials were placed into a shaking water bath and gradually heated at a rate of 1 °C min^{-1} until reaching an internal temperature of 80 °C to induce gelation [27]. The vials were subsequently removed from the water bath and cooled in an ice bath at a temperature below 4 °C.

2.3.4 Cooking Loss% of the Restructured Common Carp

The cooking loss of the restructured meat was determined according to Estevez et al. [28]. Fifteen grams of the mixture [carp-chia] for each of the concentrations (0%, 1%, 4% and 8%) were placed in previously weighed test tubes. The tubes were subjected to a heat treatment for 20 min at 80 °C. Water

and the exuded fluids were separated and discarded, and the tubes with the sample were weighed again. The process yield is given by the weight before and after the heat treatment of each sample in the tube.

2.3.5 Differential Scanning Calorimetry (DSC)

The samples weighed between 10 and 15 mg in a capsule that was placed into the sample holder to be subjected to heating; additionally, a reference air capsule was used. Then, the samples were scanned using a heating rate of 10 °C/min at an energy flow of 0.1 to 0.2 mcal/sec. A differential scanning calorimeter (DSC) from Mettler Toledo, which was calibrated between 10 and 100 °C, was used, and the endotherm areas were calculated. The measurement method for the determination of the thermograms is based on that described by Schubring [29].

2.3.6 Quantification of Phenolic Compounds

For samples Folin Ciocalteu method which involves placing 100 µL of extract in test tubes previously covered with foil, add 650 µL of purified water in each tube was applied also added a 375 µl 1 N solution of Folin-Ciocalteu and 1,875 µL of sodium carbonate solution 20%. It was allowed to react for 2 h in the dark. After this time the absorbance was measured in a spectrophotometer at 750 nm [31]. All this was done in triplicate and results are expressed as mg gallic acid/g, based on a standard curve prepared with this reagent.

2.3.7 Consumer Test

The consumer evaluation consisted of 53 untrained judges, including 33 males and 15 females, ranging in age from 18 to 23 years. The AMSA [30] recommends a consumer panel size of at least 50 individuals. The panellists were untrained students recruited from the campus of the University Autonomous of Mexico State. All were already involved in fish meat preference/acceptability tests and were regular consumers of fish meat. The restructured (burger shape) from the muscles of *Cyprinus carpio* were cooked with salt or spices and were boiled in individual bags of HDPB to a final internal temperature of 80 °C. The cooking temperature was monitored by an iron/constantan thermocouple placed in the geometric centre of each restructured sample. After boiling, the burgers were immediately cut into equal sizes and coded with a three-digit random number. The burger samples from the four common carp samples with 0%, 1%, 4% and 8% were given to the panellists in a predetermined, balanced order and were evaluated in a preference-ranking test. The panellists were asked to rank the samples in order of preference, with 1 being the most preferred and 3 being the least preferred. The evaluation took place in individual booths in a sensory testing laboratory under controlled conditions. Between each sample, the panellists were instructed to rinse their mouths with water served at room temperature.

2.4 Statistical Analysis

The data were subjected to analysis of variance and Tukey multiple-range tests ($p < 0.05$), using SPSS 8.0 for Windows software (SPSS 1997).

3. Results and Discussion

3.1 pH and Acidity in the Common Carp Muscle

The pH was within the range designated by Huss et al. [31], which indicates that it is a fresh product for processing, with a value of 6.49 ± 0.06; additionally, established that marine and aquatic species should be in the range of 6.3 to 6.9, and that the pH ranges from 6.6-7.5 for decomposing fish and is 7.5 for more decomposed fish and that the average pH of a carp is 6.21; the acidity has a value of 0.038 ± 0.008 because lactic acid, generated in anoxic conditions from glycogen, is the main factor lowering the post-mortem pH in the fish muscles. However, the values for the samples used were within the parameters established for freshness by Huss et al. [31].

3.2 Water-Holding Capacity of Common Carp Muscle

The WHC values represent the percentage of water retained in each meat sample after centrifugation. In

this sense, the muscle of *Cyprinus carpio* had a value of 63.75%. Cardoso and Mendes [32] have reported values of WHC for various species, such as ostrich at 40.34%, beef at 37.30%-37.40%, squid at 75% to 85% and *Argyrosomus regius* at 69.5%, respectively, to indicate that it is fresh raw material. The difference between the values for WHC could be due to the chemical composition, origin and state of maturity of each species. Taking into account the values of pH and acidity, the common carp can be considered a species with good quality parameters for processing.

3.3 Common Carp Muscle Colour

The colour of carp muscle has a dark tone because the blood present in it makes a low L (Table 1) (39.36 ± 0.080) with respect to that of other species. Examples have been reported, such as L = 57.8 for catfish fillets [33]; L = 54.4 for Atlantic halibut fillets, as observed by Roth et al. [34]. In contrast, for carp species, Sequeira et al. [35] observed L = 41.7. This variation in the brightness is due to the species, the origin and the type of habitat present. Additionally, there are variations in a* and b* (5.28 ± 0.11 and 4.81 ± 0.04, respectively), depending on the species. The differences can be related to (a) the fishing season, which in turn can be correlated with the physiological stage of the specimens (mature vs. youth); (b) sex, as it is well established that females are bigger in mantle length than males; and/or c) different fishing areas.

3.4 Proximal Composition of Common Carp (Cyprinus Carpio)

The chemical-composition data indicate that the fresh carp has high protein content (24.01 ± 0.30) and a low fat content (2.43 ± 0.26). The moisture and ash contents were 79.48 ± 0.37 and 0.45 ± 0.01, respectively. This proximal composition may vary according to the species. For example, for tuna (*Thunnus alalunga*), the water, protein and lipid contents were 71-72.2, 25.2-28.1 and 0.61-4.1, respectively, and for salmon (*Salmosalar*), they were 67-77, 21.5-22.3 and 0.3-15.9 [36]. The common carp in this study has a composition below that of tuna protein and above those of other species; additionally, the fat content is between of those of several species. It should be noted that, according to Mráz et al. [37], the lipids of the common carp are mainly composed of a high content of omega-3 fatty acids, especially eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), making it possible to say that this type of meat provides these types of compounds.

3.5 Proximate Analysis and Colour of CSF

In this study, chia flour presented protein levels (23.31 ± 0.12) that are within the parameters outlined in the literature, ranging from 20.01%-35.32% [38, 39]. The values obtained for lipids (34.45 ± 0.07) also correspond to the range reported in the literature; ranging from 29.56-34.88 g/100 g. Luna et al. [39] and Segura et al. [38] have reported values of 27.57, 32.84, 23.81 and 23.35 g/100 g, according to various extraction methods. Finally, the ash was 7.24 g/100 g, coinciding with the result of Capitani et al. [40]; however, content of 6.51 g/100 g and 4.58 g/100 g was reported by Luna et al. [39]. The chia used in this study is produced within the parameters reported by the

Table 1 Colour (L*, a* and b*), chroma, tone, hue and IW of muscle common carp and chia seed flour (*Salvia hispanica* L.) (CSF).

Property	*Common Carp Muscle*	*Salvia hispanica* L.
Lightness (L*)	39.36 ± 0.080	36.45 ± 1.187
Redness (a*)	5.282 ± 0.102	3.49 ± 0.082
Yellowness (b*)	4.805 ± 0.046	16.285 ± 0.315
Chroma (C*)	5.22 ± 0.02	10.96 ± 0.29
Tone	1.15 ± 0.009	1.50 ± 0.37
Hue (H*)	220.59 ± 0.14	256.54 ± 0.57
IW	38.94 ± 0.084	34.069 ± 1.084

literature. The difference observed in the values may be due to the region, temperature, rainfall and months of growth and the extraction methods [40]. The colours obtained in CSF show that the IW and L* (34.06 ± 1.08 and 36.45 ± 1.18, respectively) are low, due to the dark colour that presents the CSF. a* (3.49 ± 0.08) has a tendency to red and b* (16.28 ± 0.31) to yellow, so that the combination has a tendency to brown.

3.6 Gellification of Common Carp Muscle

The restructured sample obtained was a surimi based on common carp: irreversible heat-induced protein denaturation or a protein endothermic transition is necessary for the initiation of surimi gelation because sarcoplasmic proteins are removed during the surimi manufacturing. The hardness obtained for the common carp muscle proteins restructured after the gelation process was 5.67 ± 0.41 N, which is a low hardness value, compared with those of other species such as sea bass (*Sea bass*) with a hardness of 10.3 N. For Alaska pollock surimi gels, Tabiloand Barbosa [41] found a hardness of 13.15 N. Compared with the values for seafood-product species, the hardness of the restructured carp sample is higher (1 N), which may indicate that the species under study could be used for the production of restructured and surimi products. Several authors have performed the integration of adjuvants to obtain surimi or restructured products, providing specific functionality and structural or nutritional contributions [7, 42].

3.7 Effect of CSF on the Hardness of Restructured Common Carp

The results of gel strength are shown in Table 2. Adding CSF at 1, 4 and 8% showed a significant difference ($p < 0.05$) in this parameter with respect to the control (0% w/w CSF). This could indicate that a greater concentration of CSF increases the hardness ($p < 0.05$). Similar results were observed by Debusca et al. [7] when cellulose fibre (4% and 8%) was added. This could be due to the crosslinking reactions of CSF-protein, CSF-CSF and protein-protein, which would require more force and energy to break down the gel system. Park et al. [43] reported a similar result that, as the level of the added potato starch increased, the breaking strength of the thermal gel of salted squid paste increased, and the starch-reinforced gel became firm and less elastic.

3.8 Cooking Loss% of the Restructured Common Carp

The changes in the cooking loss of restructured CSF spiked with (0%, 1%, 4% and 8%) are shown in Table 2, showing a significant difference ($p < 0.05$) in the cooking loss between the flour-added and the control groups (0% w/w CSF). A low cooking performance was observed for the control, and the highest yield was observed for the sample with 8% (Fig. 1). The results indicate that the different concentrations of CSF influence the yield because it can prevent water loss during cooking ($p < 0.05$) (Table 2), which provides a protective effect on the product stability with respect to that of the control, thus increasing the concentration of CSF and decreasing the content of free water, suggesting that the water-retention capacity of the restructured gels increased with the addition of CSF; this result coincides with that reported by Yang et al. [42] when 0%, 2%, 4%, 6% and 8% of rice starch was added for the preparation of gels with proteins of grass carp. Additionally, the high water-absorbing ability or the hydrophilic group interacting with free water may have altered the bound water, which was not easily extracted. The same mechanism could work in the case of CSF. The statistical analysis shows an inverse linear relationship between the percent yield and the hardness (positive) and with the content of free water (negative), which could predict the effect of the addition of various concentrations of CSF.

3.9 Colour of the Restructured Common Carp

In Table 3, the tristimulus values L*, a* and b* are

Table 2 Percentage cooking loss, water loss and hardness at various CSF concentrations.

Restructured with CSF	% Cooking loss	Water loss	Hardness
0%	62.521 ± 0.495[a]	5.63 ± 0.11[b]	5.67 ± 0.41[a]
1%	70.797 ± 0.386[b]	4.43 ± 0.40[b]	6.3 ± 0.60[b]
4%	87.376 ± 1.866[c]	2.16 ± 0.90[a]	7.76 ± 0.28[b]
8%	91.155 ± 0.651[d]	1.40 ± 0-17[a]	9.69 ± 1.09[c]

Means in the same column with different letters are significantly different ($p < 0.05$).

Fig. 1 Restructured gels at various CSF concentration 0%, 1%, 4% and 8%.

shown. The whiteness index was significantly reduced ($p < 0.05$), increasing the concentration of CSF, which could be due to the low value of CSF L* (L* = 36.45), which, when combined with the carp protein, caused a decrease in colour; the IW decrease is correlated with a decrease in L* ($p < 0.05$). Similar results were reported by Debusca et al. [7], by increasing the concentration of cellulose fibres in Alaskan pollock surimi; by Xiong et al. [44], who observed a decrease in IW by adding konjac glucomannan. Thus, the IW is correlated with a decrease in L*. A reduction in b* of 1% is correlated with a decrease in the IW* because b* gives a yellow colour, which contributes to the effect of the whiteness of the product; however, by adding up to 1% of CSF, b* increases ($p < 0.05$), retaining a decrease in IW ($p < 0.05$). a* decreased significantly ($p < 0.05$) by adding 1% CSF, indicating that the product becomes darker, tending to a brown colour, but with increasing concentration chia above 1%, a* increased significantly ($p < 0.05$), indicating a slight darkening in the product obtained, that took on a dark-brown coloration. This could be a disadvantage for the product, but the colour obtained resembles an integral-type product (Fig. 1). The results of the whiteness obtained in this study and other studies [14, 7] show different values of L*, a* and b* because of the meat species and the type of fibre used; however, all of these studies show similar trends in IW and L* when different types of fibre were added. The chroma (C*) increased slightly with the addition of 1% CSF, which was significant ($p < 0.05$). From the point of view of colour, CSF could be added to restructured burger with no significant modification in this parameter at other concentrations. The hue [H*] decreased with the addition of CSF ($p < 0.05$) at various concentrations, but it slightly increased when additives were added, and no significant differences were observed between the control and these samples.

3.10 Differential Scanning Calorimetry (DSC)

Heat-induced irreversible protein denaturation or a protein endothermic transition is necessary for the initiation of surimi gelation. Because sarcoplasmic proteins are removed during surimi manufacturing, the proteins present in the restructured gel in the present study were mainly the myofibrillar proteins actin and myosin. DSC was employed to determine if fibre has an effect on the endothermic transition of the restructured gel. Fig. 2 shows that fibre does not interfere with heat-induced protein denaturation, a prerequisite for restructured products such as surimi gelation. Several authors [7, 14] have reported that fibre

Table 3 Colour, chroma, hue and whiteness index restructured gel at various CSF concentrations.

Restructured		L*	a*	b*	Croma	Hue	IW
Without additives	0%	79.30 ± 0.72^{f}	1.79 ± 0.35^{b}	10.63 ± 0.08^{cd}	259.40 ± 0.36^{a}	15.46 ± 0.30^{d}	70.82 ± 0.13^{f}
	1%	73.36 ± 0.83^{e}	0.47 ± 0.10^{a}	8.59 ± 0.30^{a}	263.94 ± 0.79^{c}	12.74 ± 0.13^{b}	63.85 ± 0.50^{e}
	4%	67.58 ± 0.20^{d}	1.36 ± 0.11^{ab}	9.78 ± 0.16^{b}	260.35 ± 1.08^{ab}	12.96 ± 0.25^{b}	58.17 ± 0.44^{d}
	8%	64.08 ± 0.64^{cd}	1.74 ± 0.31^{b}	10.16 ± 0.575^{bc}	260.64 ± 0.85^{ab}	13.80 ± 0.15^{bc}	51.77 ± 0.30^{b}
With additives*	*8%	57.14 ± 1.52^{a}	3.31 ± 1.11^{c}	10.83 ± 0.20^{d}	258.92 ± 0.92^{a}	14.61 ± 0.64^{cd}	48.59 ± 0.97^{a}
	*4%	59.08 ± 2.45^{ab}	1.82 ± 0.61^{b}	11.69 ± 0.19^{e}	262.24 ± 1.04^{bc}	14.98 ± 0.96^{d}	52.48 ± 01.07^{b}

* (onion, garlic, salt, black pepper, parsley and dry chile).

Means in the same column with different letters are significantly different ($p < 0.05$).

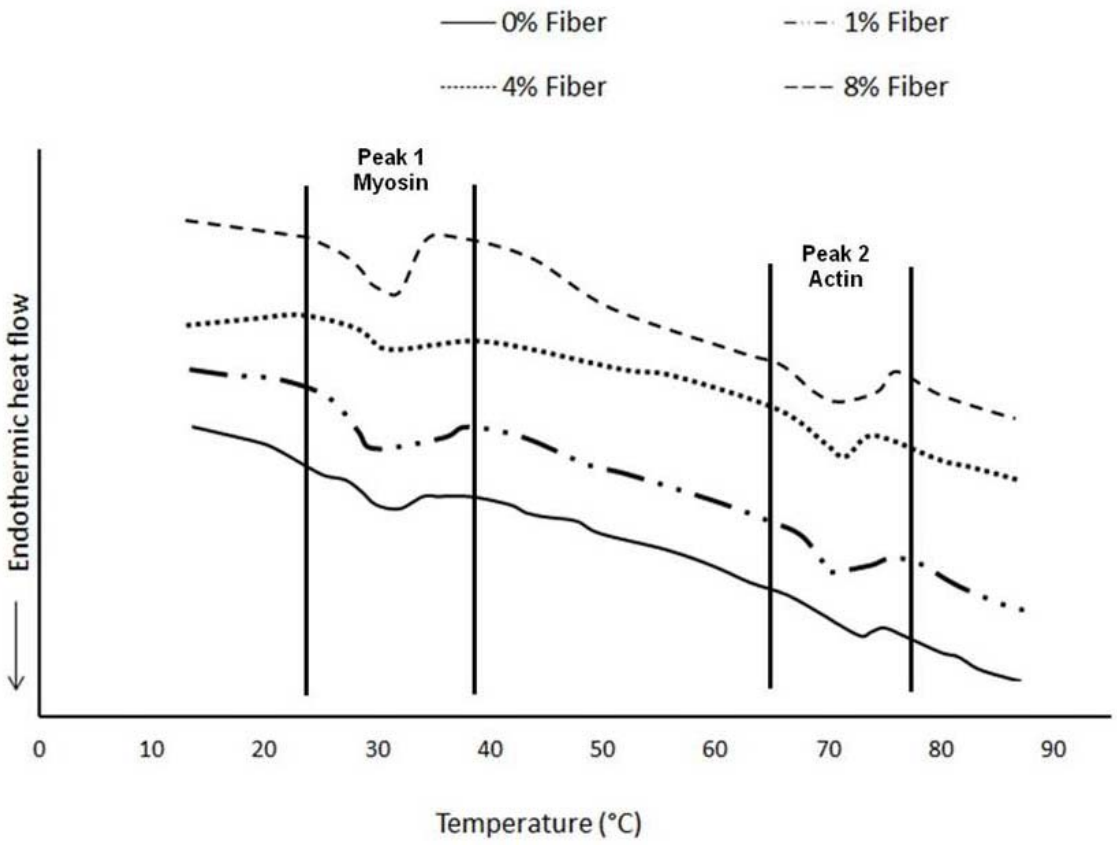

Fig. 2 Differential scanning calorimetry (DSC) thermogram of restructured gel with different levels of added CSF.

is chemically inert and does not participate in protein denaturation. The fibre does not interfere with the thermal transition/denaturation of products such as surimi myosin or actin, and it improved the textural properties.

3.11 Proximal Analysis of Restructured Gel at Various CSF Concentrations

After the proximal-analysis results were observed for each of the samples (Table 4), there were significant difference ($p < 0.05$) in the protein of each restructured from 0% to 8% of CSF. With the two restructured samples (4% and 8%), burger products were developed, and they were compared with commercial products (Table 5). The products obtained in this study contain a higher percentage of protein than commercial products and also an increase in the dietary fibre and fat. The increase of fat in the burgers with 4% and 8% CSF could be because chia seed oil has approximately 250-390 g/kg fresh matter (FM) [45]. The fatty acids (FA) of chia oil are highly unsaturated, and their main components are linoleic

Table 4 Proximal analysis of the restructured gel at various CSF concentration.

Gel	% Protein	% Lipid	% Fibre	% Moisture	% Ash
0%	16.83 ± 0.06^{d}	2.43 ± 0.26^{a}	0.88 ± 0.086^{a}	79.38 ± 0.37^{d}	0.45 ± 0.01^{a}
1%	16.41 ± 0.17^{c}	5.54 ± 1.11^{b}	5.88 ± 0.10^{b}	71.54 ± 0.56^{c}	0.62 ± 0.06^{b}
4%	13.25 ± 0.03^{b}	11.06 ± 0.63^{c}	7.09 ± 0.036^{c}	67.84 ± 0.72^{b}	0.74 ± 0.02^{c}
8%	12.32 ± 0.34^{a}	14.21 ± 0.56^{d}	10.91 ± 0.034^{d}	61.48 ± 0.71^{a}	1.06 ± 0.08^{d}

Means in the same column with different letters are significantly different ($p < 0.05$).

Table 5 Comparison of proximal analysis of restructured samples, obtained with commercial products.

Gel	%Protein	%Lipid	%Fibre	%Moisture	%Ash	mg AGE/g
[1]Commercial sausage	11.77 ± 0.06^{c}	11.76 ± 0.14^{e}	0.06 ± 0.03^{a}	72.94 ± 0.11^{de}	3.47 ± 0.07^{g}	-
[2]Commercial sausage	10.65 ± 0.07^{b}	10.39 ± 0.09^{c}	2.39 ± 0.07^{c}	73.28 ± 0.14^{e}	3.28 ± 0.08^{fg}	-
[3]Commercial ham	11.93 ± 0.07^{c}	1.87 ± 0.07^{a}	-	82.86 ± 0.22^{g}	3.34 ± 0.13^{g}	-
[4]Commercial ham	12.87 ± 0.09^{e}	2.23 ± 0.07^{a}	0.79 ± 0.01^{b}	81.01 ± 0.25^{f}	3.11 ± 0.11^{f}	-
[5]Commercial burger	7.26 ± 0.06^{a}	12.97 ± 0.14^{f}	4.63 ± 0.12^{d}	72.96 ± 0.19^{de}	2.18 ± 0.04^{e}	-
[6]Commercial burger	13.34 ± 0.1^{f}	17.53 ± 0.35^{h}	0.07 ± 0.02^{a}	68.91 ± 0.34^{c}	0.01 ± 0.01^{a}	-
[7]Restructured common carp [*Cyprinus carpio*]	16.83 ± 0.06^{g}	2.43 ± 0.26^{b}	7.82 ± 0.46^{f}	72.46 ± 0.37^{d}	0.46 ± 0.01^{a}	-
[8]Burger 4% CSF	13.25 ± 0.03^{f}	11.06 ± 0.63^{d}	7.09 ± 1.56^{e}	67.84 ± 0.72^{b}	0.75 ± 0.02^{c}	1.62 ± 0.08^{a}
[9]Burger 8% CSF	12.32 ± 0.34^{d}	14.21 ± 0.56^{g}	10.91 ± 1.04^{g}	61.48 ± 0.71^{a}	1.07 ± 0.08^{d}	2.25 ± 0.05^{b}

1, 2, 3, 4 turkey; 5 chicken; 6 soy protein: beef; 7, 8 and 9 restructured gel with 0, 4 and 8 CSF %, respectively.

Table 6 Preferences for the restructured gel expressed as rank sums and preference %.

Restructured	Rank sums	Preference means for groups	Preference (%)
Most preferred 8% CSF	94	1.77^{a}	49^{a}
4% CSF	98	1.84^{a}	51^{a}
Least preferred 0% CSF	124	2.33^{b}	-

Means in the same column with different letters are significantly different ($p < 0.05$).

(LA, C18: 2n-6, 188 g/kg of the total FA) and linolenic acid (ALA, C18: 3n-3; 641 g/kg of the total FA). The meal is high in protein and fibre, and it can be used as animal and human food [46]. Furthermore, several authors have reported that rat diets that included chia have induced a dramatic decrease in triglycerides and an increase in HDL cholesterol; additionally, Brissette et al. [47] observed in clinical data that the consumption of *Salvia hispanica* L. seeds may increase satiety and aid weight loss in type 2 diabetes mellitus (T2DM). Thus, they may be useful for body-weight regulation in overweight/obese individuals with type 2 diabetes mellitus (T2DM). The results of total phenolics content (TPC) presented in Table 5 indicated that TPC were higher in both products prepared with 8% and 4% of CSF (2.25 mg/g GAE and 1.62 mg/g GAE) respectively, compared to the commercial products. The consumption of this type can not only be restructured for alternative uses of underutilised aquaculture products such as common carp, but it can also be supplemented with chia seeds, which may be consumed in a normal diet to produce the aforementioned effects.

3.12 Consumer Tests

The results of the consumer tests are summarised in Table 6. The preference test indicated that the restructured samples with 4% chia seed flour were the most preferred (rank sum = 98), followed by the restructured samples with 8% chia seed flour (rank sum = 94) and those with 0% chia seed flour (rank sum = 124). The data analysis found significant differences between product ranks ($p < 0.05$). In this case, the consumers were capable of significantly

differentiating between the restructured meats from the 0% CSF groups that reached the highest rank sum. Because the meat from the 0% CSF group was the least preferred, this suggests that the two samples were essentially identical in terms of preference. According to this result, the preference among both samples showed no significant difference. This could be used as the basis for the development of a restructured meat as a functional food type.

4. Conclusions

This study demonstrated that dietary fibre from CSF has positive effect on physicochemical and sensory characteristics of common carp restructured and can be used to fortify this kind of products based on aquaculture or marine species, so, populations who have an insufficient dietary fibre intake, with this healthful and beneficial product could cover part of it. The fortification of restructured meat with the dietary fibre contained in CSF up to 4 g/100 g improved the hardness, cooking yield and fibre content, maintaining a similar protein content to that of commercial products. DSC showed that CSF did not interfere with the thermal transitions of the restructured proteins. The colour properties were affected by the fortification, resulting in a wholemeal colour product. The scores for preferences in the tested groups were significantly higher than those for the control samples. These results are promising for the future implications of manufacturing and marketing of restructured gel from aquaculture or seafood, which are untapped species fortified with dietary fibre that have possible health benefits. Although the results are encouraging, an assessment of the storage stability is recommended.

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References

[1] Corey, K. E., and Kaplan, L. M. 2014. "Obesity and Liver Disease: The Epidemic of the Twenty-First Century." *Clinic in Liver Disease* 18 (1): 1-18.

[2] World Health Organization, WHO. 2014. Obesity and Overweight. (online) Available from www.who.int/mediacentre/factsheets/fs311/en/. Access time March 28, 2016.

[3] National Institute of Public Health (INSP). National Health and Nutrition Survey National Results, Mexico, 2012. Available from: http://ensanut.insp.mx/doctos/ENSANUT2012_Sint_Ejec-24oct.pdf.

[4] United Nations International Children's Emergency Fund (UNICEF). Mexico: Health and Nutrition (UNICEF), 2015. (In Spanish). Available from: http://www.unicef.org/mexico/spanish/17047.htm.

[5] Isken, F., Klaus, S., Osterhoff, M., Pfeiffer, A. F., and Weickert, M. O. 2010. "Effects of Long-Term Soluble vs. Insoluble Dietary Fiber Intake on High-Fat Diet-Induced Obesity in C57BL/6J Mice." *The Journal of Nutritional Biochemistry* 21 (4): 278-84.

[6] Viuda-Martos, M., Ruiz-Navajas, Y., Fernández-López, J., and Pérez-Álvarez, J. A. 2010. "Effect of Orange Dietary Fibre, Oregano Essential Oil and Packaging Conditions on Shelf-Life of Bologna Sausages." *Food Control* 21 (4): 436-43.

[7] Yangilar, F. 2013. "The Application of Dietary Fibre in Food Industry: Structural Features, Effects on Health and Definition, Obtaining and Analysis of Dietary Fibre: A Review." *Journal of Food and Nutrition Research* 1 (3): 13-23.

[8] Rodríguez, R. A. J., Fernández-Bolaños, J., Guillén, R., and Heredia, A. 2006. "Dietary Fibre from Vegetable Products as a Source of Functional Ingredients." *Trends in Food Sciences and Technology* 17 (1): 3-15.

[9] Nelson, A. L. 2001. *High-Fiber Ingredients: Eagan Press Handbook Series*. American Association of Cereal Chemists, USA, St Paul, MN: Eagan Press, 29-44.

[10] Mitchell, H. L.2001. "Fibre-Enriched Beverages and Litesse Registered." *Soft Drinks International* 25-27.

[11] Waszkowiak, K., and Szymandera-Buszka, K. 2008. "The Application of Wheat Fibre and Soy Isolate Impregnated with Iodine Salts to Fortify Processed Meats." *Meat Science* 80 (4): 1340-4.

[12] Sudha, M. L., Baskaran, V., and Leelavathi, K. 2007. "Apple Pomace as a Source of Dietary Fiber and Polyphenols and Its Effect on the Rheological Characteristics and Cake Making." *Food Chemistry* 104 (2): 686-92.

[13] Reyes-Caudillo, E., Tecante, A., and Valdivia-López, M. A. 2008. "Dietary Fibre Content and Antioxidant Activity of Phenolic Compounds Present in Mexican Chia (*Salvia hispanica* L.) Sedes." *Food Chemistry* 107 (2): 656-63.

[14] Sánchez-Alonso, I., Haji-Maleki, R., and Borderias, J. 2007. "Wheat Fiber as a Functional Ingredient in Restructured Fish Products." *Food Chemistry* 100 (3): 1037-43.

[15] Sánchez-González, I., Rodríguez-Casado, A., Careche, M., and Carmona, P. 2009. "Raman Analysis of Surimi Gelation by Addition of Wheat Dietary Fibre." *Food Chemistry* 112: 162-8.

[16] Cardoso, C., Mendes, R., Vaz-Pires, P., and Nunes, M.L. 2011. "Production of High Quality Gels from Sea Bass: Effect of MTGase and Dietary Fibre." *LWT—Food Science and Technology* 44: 1282-90.

[17] Debusca, A., Tahergorabi, R., Beamer, S. K., Matak, E., and Jaczynski, J. 2014. "Physicochemical Properties of Surimi Gels Fortified with Dietary Fiber." *Food Chemistry* 148: 70-6.

[18] FAO. Cultured Aquatic Species Information Programme, *Cyprinuscarpio* (Linnaeus, 1758). Rome Food and Agriculture Organization of the United Nations, 2014. (In Spanish). Available from:http://www.fao.org/fishery/culturedspecies/Cyprinus_carpio/es#.

[19] Dublán-García, O., Cruz-Camarillo, R., Guerrero-Legarreta., I., and Ponce-Alquicira, E. 2006. "Effect of Refrigerated Storage on Proteolitic Activity and Physicochemical and Microstructural Properties of Giant Squid (*Dosidicusgigas*) Mantle Muscle." *Muscle Foods* 17: 291-310.

[20] NMX-F-317-S-1978. pH Determination in Foods, 1978. (in Spanish)

[21] AOAC Official Method 1990. *Association of Official Analytical Chemist.* Washington DC, USA: AOAC International.

[22] López-Vargas, J. H., Fernández-López, J., Pérez-Álvarez, J.A., and Viuda-Martos, M. 2014. "Quality Characteristics of Pork Burger Added with Albedo-Fiber Powder Obtained from Yellow Passion Fruit (*Passifloraedulis Var. Flavicarpa*) Co-Products." *Meat Science* 97: 270-6.

[23] AOAC Official Method 2000. 2003. Food Composition, Additives, Natural Contaminants. Gaithersburg, MD, USA: AOAC International.

[24] AOAC Official Method 1997. *Fiber (Acid Detergent) and Lignin in Animal Feed.* Arlington, TX, USA: AOAC International.

[25] Ngapo, T., Wilkinson, B., Chong, R., and Haisman, D. 1992. "Gelation of Bovine Myofibrillar Protein Induced by 1.5 Gluconolacone." In *38th International Congress of Meat Science and Technology, Clermont-Ferrand, Francia*, 1095-8.

[26] Klettner, P. G. 1994. "Meat and Meat Products. Measuring Texture and Consistency with Testing Machines." *Die Fleischwirtschaft* 74: 842-4.

[27] Paredi, M. E., Davidovich, L. A., and Crupkin, M. 1999. "Thermally Induced Gelation of Squid (Illexargentinus) Actomyosin. Influence of Sexual Maturation Stage." *Journal of Agricultural and Food Chemistry* 47: 3592-5.

[28] Estevez, M., Ventanas, S., and Cava, R. 2005. "Physicochemical Properties and Oxidative Stability of Liver Paté as Affected by Fat Content." *Food Chemistry* 92: 449-57.

[29] Schubring, R. 2007. "DSC Measurements on Sharks." *Thermochimica Acta* 458: 124-31.

[30] AMSA. 1995. "American Meat Science Association & National Livestock and Meat Board." *Research Guidelines for Cookery, Sensory Evaluation and Instrumental Tenderness Measurements of Fresh Meat*. Chicago, IL: AMSA.

[31] Singh, R. P., Murthy, K. N. C., and Jayaprakasha, G. K. 2002. "Studies on the Antioxidant Activity of Pomegranate (*Punica granatum*) Peel and Seed Extracts using in Vitro Models" *Journal of Agricultural of Food Chemistry* 50: 81-6.

[32] [32] Huss, H. H., Ababouch, L., and Gram, L. 2004. "Assessment and Management of Seafood Safety and Quality. FAO Fisheries." Technical Paper No. 444. Food and Agriculture Organisation, Rome.

[33] Cardoso, C., and Mendes, R. 2013. "The Effect of Linseed and Psyllium fibre on the Gelling Properties of Unwashed Mince from Farmed Meagre (*Argyrosomus regius*)." *International Journal of Food Science and Technology* 48: 2023-33.

[34] Desai, M. A., Joseph, P., Suman, S. P., Silva, J. L., Kim, T., and Schilling, M. W. 2014. "Proteome Basis of Red Color Defect in Channel Catfish (*Ictalurus punctatus*) Fillets." *LTW-Food Science and Technology* 57: 141-8.

[35] Roth, B., Foss, A., and Imsland, A. K. 2009. "Relationship between Muscle pH and Flesh Color of Atlantic Halibut." *Journal Food Science* 74: S123-5.

[36] Sequeira-Munoz, A., Chevalier, D., Le Bail, A., Ramaswamy, H. S., and Simpson, B. K. 2006. "Physicochemical Changes induced in Carp (*Cyprinus carpio*) Fillets by High Pressure Processing at Low Temperature." *Innovative Food Science and Emerging Technologies* 7: 13-18.

[37] Briones-Labarca, V., Perez-Won, M., Zamarca, M., Aguilera-Radic, J. M., and Tabilo-Munizaga, G. 2012. "Effects of High Hydrostatic Pressure on Microstructure, Texture, Colour and Biochemical Changes of Red Abalone (*Haliotisrufecens*) during Cold Storage Time." *Innovative Food Science and Emerging Technologies* 13: 42-50.

[38] Mráz, J., Máchová, J., Kozák, P., and Pickova, J. 2012. "Lipid Content and Composition in Common

Carp-optimization of n-3 Fatty Acids in Different Pond Production Systems." *Journal of Applied Ichthyology* 28: 238-44.

[39] Segura-Campos, M. R., Salazar-Vega, I. M., Chel-Guerrero, L. A., and Betancut-Ancona, D. A. 2013. "Biological Potential of Chia (*Salvia hispánica* L.) Protein Hydrolysates and Their Incorporation into Functional Foods." *LWT-Food Science and Technology* 50: 723-31.

[40] Luna-Pizarro, P., Lopes Almeida, E., Cristina Sammán, N., and Kil Chang, Y. 2013. "Evaluation of Whole Chia (*Salvia hispánica* L.) Flour and Hydrogenated Vegetable Fat in Pound Cake." *LWT-Food Science and Technology* 54: 73-79.

[41] Capitani, M. I., Sportono, V., Nolasco, S. M., and Tomás, M. C. 2012. "Physicochemical and Functional Characterization of By-products from Chia (*Salvia hispanica* L.) Seeds of Argentina." *LWT-Food Science and Technology* 45: 94-102.

[42] Tabilo-Munizaga, G., and Barbosa-Canovas G. V. 2004. "Color and Textural Parameters of Pressurized and Heat-Treated Surimi Gels as Affected by Potato Starch and Egg White." *Journal of Food Research International* 37: 767-75.

[43] Yang, Z., Wang, W., Wang, H., and Ye, Q. 2014. "Effects of A Highly Resistant Rice Starch and Pre-Incubation Temperatures on the Physicochemical Properties of Surimi Gel from Grass Carp (*Ctenopharyn Odon Idellus*)." *Food Chemistry* 145: 212-9.

[44] Park, S., Cho, S., Kimura, M., Nozawa, H., and Seki, N. 2005. "Effects of Microbial Tranglutaminase and Starch on the Thermal Gelation of Salted Squid Muscle Paste." *Fisheries Science* 71: 896-903.

[45] Xiong, G., Cheng, W., Ye, L., Du, X., Zhou, M., Lin, L., Geng, S., Chen, M., Corke, H., and Cai, Y. 2009. "Effects of Konjac Glucomannan on Physicochemical Properties of Myofibrillar Protein and Surimi Gels from Grass Carp (*Ctenopharyngodon idella*)." *Food Chemestry* 116: 413-8.

[46] Ayerza, R. 1995. "Oil Content and Fatty Acid Composition of Chia (*Salvia hispanica* L.) from Five Northwestern Locations in Argentina." *Journal of the American Oil Chemists' Society* 72: 1079-81.

[47] Peiretti, P. G., and Gai, F. 2009. "Fatty Acid and Nutritive Quality of Chia (*Salviahispanica* L.) Seeds and Plant during Growth." *Animal Feed Science and Technology* 148: 267-75.

[48] Brissette, C. E., Jenkins, A. L., Choleva, L., and Vuksan, V. 2013. "The Effect of *Salvia hispanica* L. Seeds on Weight Loss in Overweight and Obese Individuals with Type 2 Diabetes Mellitus." *Canadian Journal of Diabetes* 37: S61.