Jiménez-Muñoz, LM.; Hernández-Carrión, M.; Hernando Hernando, MI.; Filomena-Ambrosio, A. (2023). Sensory Studies on Snacks and Dips Elaborated with Lionfish Surimi. Journal of Culinary Science & Technology. 21(4):1-19. https://doi.org/10.1080/15428052.2021.2002227

Sensory Studies on Snacks and Dips Elaborated with Lionfish Surimi

Luis M Jiménez-Muñoz[a], María Hernández-Carrión[b], Isabel Hernando[c], and Annamaria Filomena-Ambrosio[a,d]

[a]Research Group in Procesos Agroindustriales. GIPA, Universidad de La Sabana, Chía, Colombia; [b]Products and Processes Design Group (Ppdg), Department of Chemical and Food Engineering, Universidad de Los Andes, Bogotá, Colombia; [c]Research Group of Food Microstructure and Chemistry. Department of Food Technology, Universitat Politècnica de València, Valencia, Spain; [d]Research Group in Alimentación, Gestión de Procesos Y Servicio. EICEA, Universidad de La Sabana, Chía, Colombia

ABSTRACT

Lionfish (*Pterois volitans*) have proliferated over the Caribbean Sea causing massive damage to coral reefs ecosystems. The development of products using lionfish is a control strategy that aims to decrease the negative impact of this species. In this research, the lionfish was processed to obtain surimi with a different set of binders (liquid egg white and starch) and high-power ultrasound. The surimi was used to elaborate two novel products: snacks and dipping sauce. A sensory panel was organized to determine the culinary applications with the highest appeal. The most liked fish snacks were obtained with ultrasound: (1) without binders and (2) with starch (3%). In case of dipping sauce, the most liked one was made by conventional method and egg white (1.5%). The use of ultrasound to obtain lionfish surimi in combination with binders demonstrated its potential to be used in the preparation of novel products with high sensory qualities.

ARTICLE HISTORY

Received 8 February 2021
Revised 30 September 2021
Accepted 31 October 2021

KEYWORDS

Check all that apply; ultrasound; binders; lionfish

Introduction

Lionfish (*Pterois volitans*) is an invasive species that poses serious threats to the integrity of the reef food web of the Atlantic and is suitable for human (Morris, 2012; Bustos-Montes, Wolff, Sanjuan-Muñoz, & Acero, 2020; Cen-López, A., & Aguilar-Perera, A. 2020). Adding value to lionfish products might contribute to the introduction of this species to the dietary customs of the communities and increase the diversification of consumption. One way to add value could be using the fillets as raw material to process surimi, a cooked gel product that utilizes fish protein to produce seafood analog products (Park, Yoon, & Kim, 2014; Priyadarshini, Xavier, Dhanabalan, Nayak, & Balange, 2021).

Surimi seafood is a cooked gel product manufactured from marine species. Surimi is a gel-like product, and it is usually prepared by incorporating ingredients such as starch, egg white proteins, salt in a continuous matrix of interconnected proteins (Campo & Tovar, 2008). Starch is used in the manufacture of surimi products due to its good water holding capacity and the ability to partially replace fish proteins while maintaining the desired gel characteristics at a reduced cost. The egg white is a protein additive used to increase the hardness, whiteness, and brightness of the gel (Park, Oizumi, T., & Hunt, 2013). The use of high-power ultrasound has been shown to improve functional properties in surimi-based products, such as increasing the gel strength (Gao et al., 2021).

There is an increasing trend for consumers to demand ready-to-eat products due to their ease for consumption but there is also a need for the consumers to obtain daily nutrients needed from healthy products (Poti et al., 2015). Surimi could be used to prepare these highly-demanded ready to eat products; in these regards, two different products are proposed in this work: fish snacks and fish dipping sauces. Fish snacks are made by forming a dough from a mixture of a binder, comminuted fish, salt, sugar, and water. The product is later sliced and fried in hot oil which causes it to expand into a porous, low-density product (Fang, Huang, & Sung, 2021; Kyaw et al., 1999). Fish dipping sauces, due to their characteristic flavor and taste, are popular condiments for cooking and dipping (Lopetcharat, Choi, Park, & Daeschel, 2001).

Therefore, as proposed by Aguilera-Perera (2013), diversification of lionfish products is a strategy that indirectly aims to decrease the negative impact of this species by increasing its consumption. However, the basis of this approach is that consumers are willing to buy lionfish-products and so far, this assumption has not been thoroughly studied. To study the consumer perception of these new products, this work used Check-All-That-Apply (CATA) in order to understand what attributes could encourage the consumption of diversified products from this species. CATA is an increasingly popular methodology that allows collecting information about attribute perception of a large number of non-trained panelists (consumers) (Xia et al., 2020). Given the immense threat that lionfish poses to the marine ecosystems, as well as the limited strategies to control this species, the aim of this study was to evaluate consumer perception and liking of a snack and a dipping sauce prepared from lionfish surimi obtained using ultrasound or conventional method and different binders concentrations (egg white and corn starch). This could provide an insight on the necessary parameters needed to take into account when formulating lionfish surimi-based products.

Materials & methods

Surimi preparation

Lionfish was acquired in local markets of Cartagena (Colombia) transported and stored at a temperature of −20°C.

Surimi was obtained following the methodology described by Filomena et al., (2015) using two methods, conventional method (CN) and ultrasound method (US). To obtain surimi by conventional method, chopped lionfish fillets were washed with cold distilled water at 4°C at a 1:3 w/w ratio (fillet: water) for 3 washing cycles, 15 minutes each. To obtain surimi by ultrasound method, chopped lionfish fillets were leached during two washing cycles and were placed in the ultrasonic bath (ELMA, Germany) set to 37 kHz and 150 W for 15–20 minutes.

The surimi was pressed and homogenized in a food processor (Oster, Colombia) at room temperature (18°C) using 3% (w/w) salt (Refisal®, Colombia), 2% (w/w) sugar (Incauca®, Colombia) and 0.3% (w/w) sodium citrate (Panreac Química SAU, Spain). The rest of the formulation consisted of different binders such as liquid egg white and corn starch (Maizena®) in concentrations up to 3% as shown in Table 1. The eight lionfish surimi samples were subjected to steam cooking (90°C, 100% humidity, 10 minutes).

Fish snack preparation

After surimi homogenization, the paste was sliced, and the slices were fried in hot oil (160°C, 3 minutes).

Table 1. Coding of lionfish snack and dipping sauce formulations.

Sample	Method	Corn starch concentration % (w/w)	Egg white concentration % (w/w)
CN_3EW	CN	0	3
CN_1.5EW	CN	1.5	1.5
CN_3ST	CN	3	0
CN_CTRL	CN	0	0
US_3EW	US	0	3
US_1.5EW	US	1.5	1.5
US_3ST	US	3	0
US_CTRL	US	0	0

CN: Conventional, US: ultrasound; EW: egg white, ST: corn starch.* The use of binders was always established at three percent, except in the control treatments (ultrasound/conventional), where no binders were used to have a reference point of comparison.

Fish dipping sauce preparation

The eight surimi samples were mixed with white stew (23%, w/w) prepared with onion (3.5%, w/w), coriander (3%, w/w), garlic (0.5%, w/w), and sour cream (Klarens, sour cream, Colombia) (16%, w/w), in a cutter (Click & Mix, Imusa, Colombia) at average speed until a homogeneous mixture was obtained.

Fish snacks and dip sauce consumers' perception study

The sensory analysis was carried out in two sessions. First: the consumers evaluated the snacks and second, they evaluated the dips. In each session samples were tasted, and an acceptability study tested the overall hedonic appreciation and different attributes in relation to their overall liking. For unveiling the attributes underlying product preference, consumers answered a "Check all that apply" (CATA).

General procedure

One hundred consumers were recruited among the employees and students of the Universidad de La Sabana, aged 18–56, based on their willingness to participate and their consumption frequency of fish, snacks, and dips (Table 2).

Each consumer received eight samples of fish snack (FS) or fish dipping sauce (FDS) in a sequential monadic series in a single session. The samples were served at room temperature in dishes coded with three-digit random numbers.

Acceptability study

The consumer acceptance test was performed using a nine-point hedonic scale (9 = like extremely and 1 = dislike extremely) (Rodrigues et al. 2011). For each FS/FDS, the consumers scored their degrees of liking in the following order: "overall liking," "appearance liking," "flavor liking" and "consistency liking."

Check all that apply" (CATA) questionnaire

For each sample, the participants answered a CATA questionnaire featuring 22 attributes for both FS and FDS. The following instruction was given to participants: "Which of the following characteristics better describe this sample? Please check all that you think apply. You can re-

Table 2. Consumer gender and frequency of consumption of snacks, fish and dips.

Snack consumers											
Sex		Snack frequency consumption					Fish frequency consumption				
Women	Men	Daily	Weekly	Monthly	Sporadically	Never	Daily	Weekly	Monthly	Sporadically	Never
62%	38%	10%	36%	6%	46%	2%	0%	34%	26%	32%	8%
Dipping sauce consumers											
Sex	Dip frequency consumption						Fish frequency consumption				
Women	Men	Daily	Weekly	Monthly	Sporadically	Never	Daily	Weekly	Monthly	Sporadically	Never
53%	47%	7%	29%	26%	37%	1%	9%	26%	25%	37%	3%

taste the sample if desired": The terms had been previously selected on the basis of the available literature and an informal tasting by the researchers and a sensory descriptive panel (with training in descriptive analysis but not specifically on fish snacks). For the fish snack the terms belonged to four groups; appearance terms: *good appearance, golden color, uniform color*; consistency terms: *crispy, crunchy, oily, dry, gummy, baked*; flavor terms: *sweet, bitter, odd flavor, fish flavor, flavorless, odorless, fish odor*; use & attitude terms: *nutritive, healthy, believable, not believable, I would buy, I would not buy*.

For the fish dipping sauce, the attributes were also grouped in four terms; appearance terms: *lumpy appearance, uniform color, creamy appearance, nice appearance*; textural terms: *lumpy, gummy, viscous, creamy, adhesive, spreadable*; flavor: *intense aroma, fishy aroma, fishy taste, odd taste, smooth taste, nice taste, normal aroma* and use & attitude terms: *nutritive, healthy, appetizing, I would not buy it* and *I would buy it*.

The 22 terms used for each product were presented following the sequence of evaluation in terms of sensory modality: appearance, consistency, flavor, followed by the non-sensory parameters.

Data analysis

CATA question: A chi-square test was used to study the differences in the FS/FDS from the CATA responses. For each sample, the frequency of use of each sensory attribute was determined by counting the number of consumers that selected that term to describe each sample (Hernández-Carrión, Varela, Hernando, Fiszman, & Quiles, 2015). Cochran's Q test (Parente, Manzoni, & Ares, 2011) was performed on the data of the individual terms to identify significant differences between samples for each of them. A multiple factor analysis (MFA) was run on the table with the frequency of selection of CATA terms data to understand the comparative positioning of the eight FS/FDS, as perceived by the consumers. In addition, the principal component analysis was also applied to the mean values of attribute intensity using a Pearson correlation (Aquino et al., 2014).

Overall liking, appearance, flavor and consistency scores were analyzed using one way ANOVA with a confidence level of 95% to study differences between the formulations for the consumer acceptance test. Least significant differences were calculated by Fisher's test ($p < .05$).

All data analyses were performed using XLSTAT statistical software (Version 2017.5, Microsoft Excel®, Spain), except from acceptability data that were analyzed using the software SPSS (v.24., Colombia).

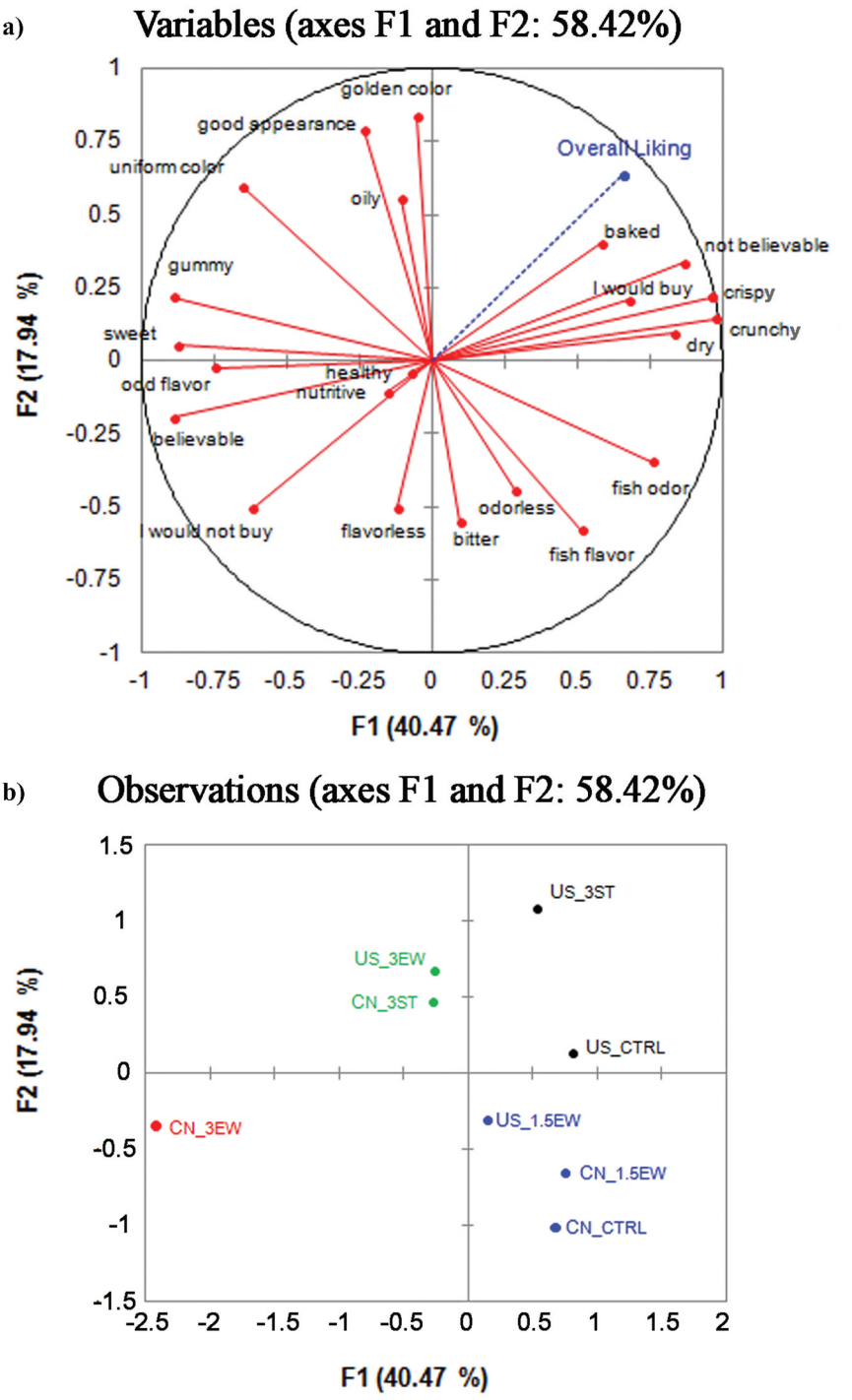


Figure 1. A) Attribute map from the check all that apply (CATA) questionnaire, and B) representation of the eight fish snacks, in the first two dimensions of the Multiple Factor Analysis (MFA) of the CATA counts. CN_3EW and CN_3ST: Conventional method with 3% egg white and 3% corn starch. CN_1.5EW: Conventional method with 1.5 corn starch and egg white. CN_CTRL: Conventional method without binder. US_3ST and US_3EW: Ultrasound method with of 3% corn starch and 3% egg white. US_1.5EW: Ultrasound.

Table 3. Frequency (%) with which terms of the CATA were used by consumers to describe the eight fish snack samples and results from Cochran's Q test for comparison between samples.

CATA terms	CN_3EW	CN_1.5EW	CN_3ST	CN_CTRL	US_3EW	US_1.5EW	US_3ST	US_CTRL	Q
Good appearance	23	16	26	19	22	23	28	22	0.299
Golden color	31	29	41	27	35	34	37	34	**0.037**
Uniform color	23	15	25	9	21	15	18	16	**0.012**
Crispy	10	40	38	41	37	35	43	46	**<0.0001**
Crunchy	6	37	32	40	35	33	39	43	**<0.0001**
Oily	32	29	29	27	35	31	32	36	0.429
Dry	16	25	24	27	19	25	30	25	0.106
Gummy	37	15	20	13	32	18	17	16	**<0.0001**
Baked	2	6	9	8	12	7	7	11	0.034
Sweet	10	4	4	4	5	4	6	3	0.181
Bitter	6	3	7	12	5	8	1	10	**0.004**
Odd flavor	23	8	15	16	14	19	16	11	**0.022**
Fish flavor	30	37	27	37	31	29	30	36	0.190
Odorless	7	11	8	12	8	20	8	8	**0.010**
Flavorless	3	4	4	3	2	6	1	1	0.401
Fish odor	16	28	25	27	16	22	22	29	**0.015**
Nutritive	9	10	9	7	10	11	7	9	0.877
Healthy	4	7	6	1	5	7	2	4	0.170
Believable	23	9	12	12	11	11	10	13	**0.025**
Not believable	10	23	19	18	22	22	23	22	0.077
I would buy	15	22	15	19	18	24	27	25	0.083
I would not buy	27	17	21	17	14	17	6	20	**0.001**

Highlighted terms correspond to those for which significant differences between samples were identified according to Cochran's Q test ($p < 0.05$).

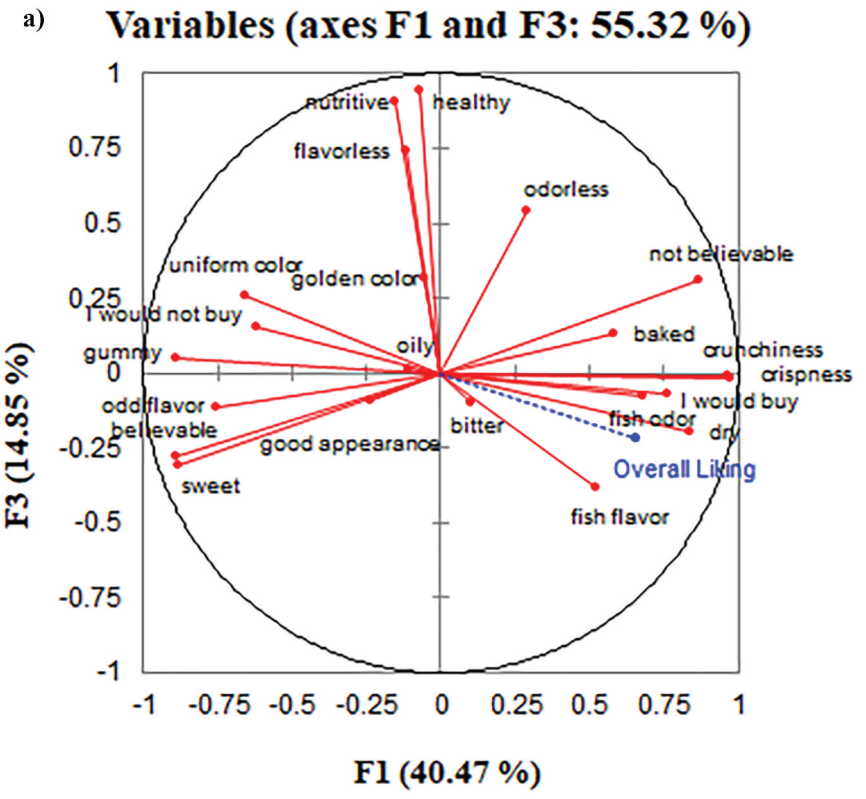
Results and discussion

Fish snacks

CATA questions

Fig. 1A and 2A show the representation of the terms in the three first coordinates of the MFA. The three first factors of the attribute map explained 73.26% of the variance of the experimental data (40.47%, 17.94% and 14.85, respectively). The first factor (X axis) was related to taste attributes; *odd flavor* and *sweet* were placed on the left and *fish odor* was placed on the right. It was also related to consistency attributes such as *crispy, crunchy, dry* and *baked*, which were placed on the right of the axis, whereas *gummy* was placed on the left of the axis. Use & attitude attributes such as *believable* and *I would not buy* were placed on the left of the axis whereas *not believable*, and *I would buy* were placed on the right. The second factor (Y axis, Fig. 1A) was related to the appearance attributes (*good appearance* and *golden color* up), the consistency terms (*oily* up), and the flavor of the snacks (*bitter, flavorless, fish flavor* and *odorless* down). The third factor (Y axis, Fig. 2A) was related to the use & attitude terms (*healthy* and *nutritive* up), the appearance attributes (*golden color* up), and the flavor attributes (*flavorless* and odorless up); in fact, F3 allows separating *fish flavor* from *flavorless* and *odorless*, which couldn't be discriminated by F1 and F2.

a)


Variables (axes F1 and F3: 55.32 %)
nutritive
healthy
flavorless
odorless
not believable
uniform color
golden color
I would not buy
oily
baked
gummy
crunchiness
crispness
odd flavor
I would buy
fish odor
believable
bitter
dry
good appearance
Overall Liking
sweet
fish flavor
F3 (14.85 %)
F1 (40.47 %)

b)

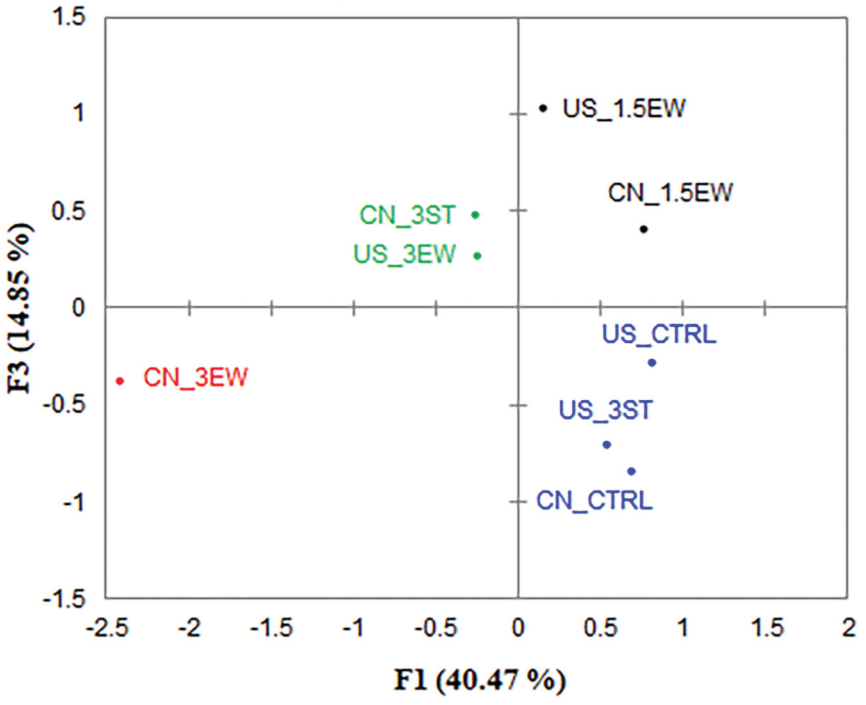

Observations (axes F1 and F3: 55.32 %)
US_1.5EW
CN_1.5EW
CN_3ST
US_3EW
US_CTRL
CN_3EW
US_3ST
CN_CTRL
F3 (14.85 %)
F1 (40.47 %)

Figure 2. A) Attribute map from the check all that apply (CATA) questionnaire, and B) representation of the eight fish snacks, in the first and third dimensions of the Multiple Factor Analysis (MFA) of the CATA counts. CN_3EW and CN_3ST: Conventional method with 3% egg white and 3% corn starch. CN_1.5EW: Conventional method with 1.5 corn starch and egg white. CN_CTRL: Conventional method without binder. US_3ST and US_3EW: Ultrasound method with of 3% corn starch and 3% egg white. US_1.5EW: Ultrasound.

The Chi-square test ($p < .0001$) indicated statistically significant differences between the descriptions of the samples. Cochran's Q test was performed on the data to identify the significant differences between the samples for each of the terms included on the CATA question. The results (Table 3) showed that significant differences ($p < .05$) were found between the samples for many of the analyzed attributes. No statistically significant differences ($p > .05$) were found for *good appearance, healthy, oily, sweet, fish flavor, dry, I would buy, nutritive, flavorless*, and *not believable* among the samples.

Fig. 1B shows that snacks were clearly separated into four groups according to their sensory characteristics. Sample CN_3EW was associated with attributes *odd flavor, believable*, and *I would not buy*; samples US_1.5EW, CN_1.5EW and CN_CTRL were associated with *bitter, fish flavor* and *fish odor*. The snacks US_3EW and CN_3ST were perceived as samples with *uniform color, good appearance, oily* and *golden color*. Finally, samples US_3ST and US_CTRL were associated to the attributes *dry, crunchy, crispy*, and *baked*. At the same time, this area of the perceptual space was associated to the highest overall liking and to the CATA parameter *I would buy*. The right crunchiness and crispness would drive the liking and the purchase intent in this category. Although fish snacks were fried and not baked, consumers tended to choose this attribute for these samples (US_3ST and US_CTRL) since its appearance made them perceive these snacks as a baked product.

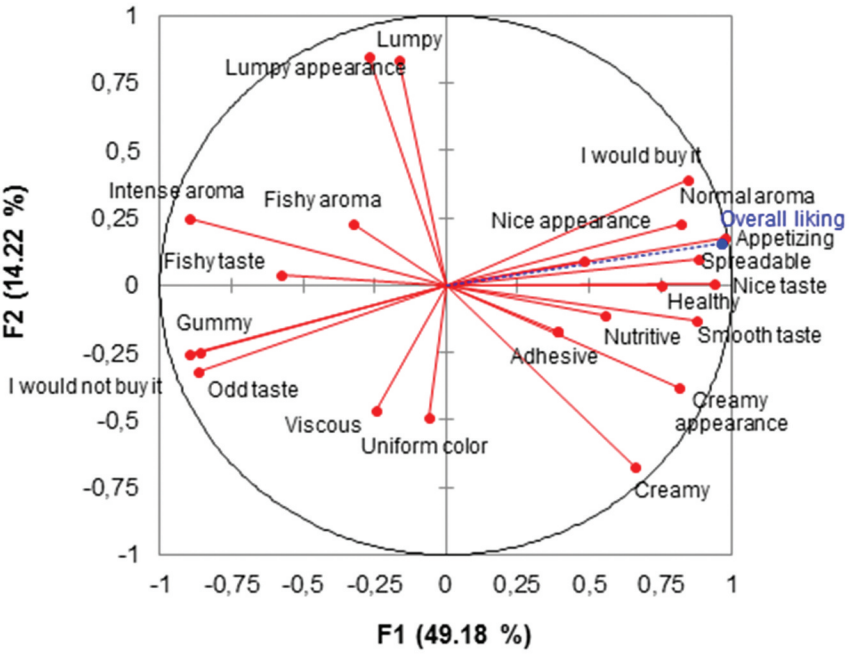
The Fig. 2B shows that snacks were clearly separated into four groups according to their sensory characteristics. Sample CN_3EW was associated with attributes *odd flavor, believable* and *sweet*; samples US_1.5EW and CN_1.5EW were associated with *baked* and *not believable*. The snacks US_3EW and CN_3ST were perceived as samples with *uniform color, oily* and *golden color*. Finally, samples US_3ST, CN_CTRL and US_CTRL were

Table 4. Scores for overall liking, appearance liking, flavor liking, and consistency liking for lionfish surimi snacks.

Sample	Overall Liking	Appearance Liking	Flavor Liking	Consistency Liking
CN_3EW	4.5 (2.8)^{a}	5.0 (2.9)^{ab}	5.2 (2.9)^{a}	3.2 (2.7)^{a}
CN_1.5EW	5.6 (2.4)^{b}	4.5 (2.6)^{a}	5.9 (2.8)^{ab}	5.8 (3.2)^{bc}
CN_3ST	5.5 (2.5)^{b}	6.7 (2.4)^{c}	6.2 (2.8)^{bc}	6.2 (3.1)^{cd}
CN_CTRL	5.4 (2.4)^{ab}	4.9 (2.4)^{a}	5.3 (2.6)^{ab}	6.4 (2.7)^{cd}
US_3EW	6.0 (1.9)^{b}	6.5 (2.6)^{c}	6.2 (2.4)^{abc}	4.9 (2.9)^{b}
US_1.5EW	5.7 (2.6)^{b}	6.2 (2.6)^{c}	5.6 (2.9)^{ab}	6.6 (2.8)^{cd}
US_3ST	7.3 (1.8)^{c}	6.5 (2.2)^{c}	7.1 (2.0)^{c}	7.2 (2.5)^{de}
US_CTRL	7.0 (1.9)^{c}	5.9 (2.9)^{bc}	6.3 (2.4)^{bc}	7.7 (2.0)^{e}

Values within a column with different letters are significantly different ($p < 0.05$).
Values between parentheses are the standard deviations.

a) **Variables (axes F1 and F2: 63.40 %)**



b) **Observations (axes F1 and F2: 63.40 %)**

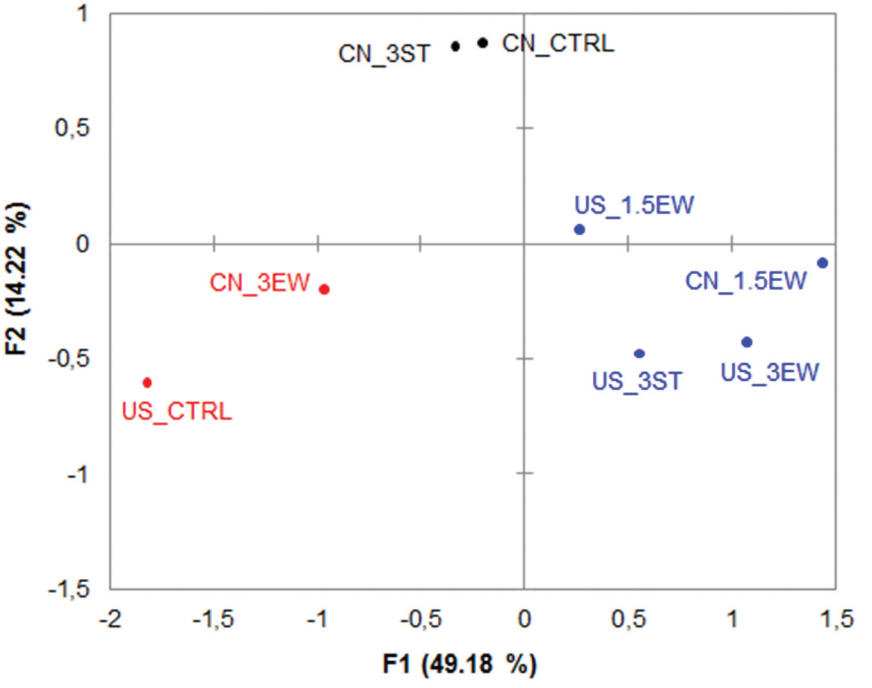


Figure 3. A) Attribute map from the check all that apply (CATA) questionnaire and B) representation of the eight fish dipping sauce, in the first two dimensions of the Multiple Factor Analysis (MFA) of the CATA counts. CN_3EW and CN_3ST: Conventional method with 3% egg white and 3% corn starch. CN_1.5EW: Conventional method with 1.5 corn starch and egg white. CN_CTRL: Conventional method without binder. US_3ST and US_3EW: Ultrasound method with of 3% corn starch and 3% egg white. US_1.5EW: Ultrasound.

associated to the attributes *dry, crunchy, crispy, fish flavor* and *fish odor*. This area of the perceptual space was associated to the highest overall liking and to the CATA parameter *I would buy*. The right crunchiness and crispness would drive the liking and the purchase intent in this category.

Results showed that consumers did not relate the samples to attributes like healthy or nutritive. Several studies have shown the low association of these attributes to deep fried products because of their high oil uptake (Kurek, Ščetar, & Galić, 2017; Teixeira, A., & Rodrigues, S. 2020; Su, et al., 2021).The negative correlation between *gummy* and *crispy* (−0.81) or *gummy* and *crunchy* (−0.79) indicates that when people think of gummy as an attribute of the product, they don´t think of crispy or crunchy. On the contrary, a high correlation coefficient (0.99) between *crunchy* and *crispy* attributes indicates that the consumer associates them together.

One of the main reasons why consumers perceived sample US_3ST as *crispy*, which is an important characteristic of fried products could be attributed to the effect of corn starch on the product texture. According to Jamilah et al. (2009), the use of starches on fish crackers and *Keropok lekor* – a traditional fish snack Malaysian food, was helpful in creating new desirable textures.

Another reason for US_3ST to be perceived as a product with high crispness and crunchiness is the use of ultrasound for processing. Some studies have previously shown that ultrasound pretreatment enhanced the rate of mass transfer of moisture from the internal structure of the potato chips samples to the surrounding oil during frying (Dehghannya, Naghavi, & Ghanbarzadeh, 2015; Oladejo, Ma, & Qu, 2017; Zhang, Xie, & Fan, 2021). This rapid mass transfer might have improved the textural parameters of samples processed with US, thus being preferred by consumers. Musielak, Mierzwa, and Kroehnke (2016) suggested that applying ultrasound decreased the drying time and improved the quality of the products.

Acceptability study

For the eight snacks, the overall liking (OL) scored between 4.5 and 7.3 (Table 4). The liking of appearance, flavor and consistency was in line with the OL, which indicated that the most liked samples were well liked in those parameters. The sample US_3ST obtained the maximum score for the OL and flavor liking while sample US_CTRL obtained highest score for consistency liking. The fish snack CN_3EW had the significantly lowest ($p < .05$) OL and

texture liking score, indicating that it was the least acceptable sample by the consumers regarding these attributes. The bad performance of this sample compared with its counterpart (US_3EW) was because consumers perceived it with lack of crispness and crunchiness.

The higher acceptability scores found in surimi snacks treated by ultrasound could be due to the fact that they were perceived by the consumers as more crispy and crunchy as shown in CATA analysis. Oladejo et al. (2017) obtained crispier and crunchier potato chips when they were pre-treated using ultrasound than without pretreatment.

Fish dipping sauce

CATA questions

Fig. 3A shows the attribute map in which the two factors accounted for 63.4% of the variance (49.18% and 14.22% respectively). Most of the attributes were well represented in the perceptual space defined by the first two factors of the MFA. The first factor (X axis) was related to textural and appearance attributes where *gummy* was placed on the left of the axis, while *adhesive, spreadable, nice appearance* and *creamy appearance* were placed on the right of the axis. This factor was also related to flavor attributes; *odd taste, intense aroma* and *fishy taste* were located on the left of the axis and *smooth taste, nice taste* and *normal aroma* on the right. Use & attitude terms such as *nutritive, healthy, appetizing* and *I would buy it* were located on the right of the axis, while *I would not buy it* was located on the left of the axis. The second factor (Y axis) was related to textural and appearance attributes where *lumpy* and *lumpy appearance* were placed up on the axis while *viscous* and *uniform color* were located down of the axis.

The Chi-square test ($p < .0001$) indicated statistically significant differences between the descriptions of the samples, meaning that the samples were not all equally perceived. Cochran's Q test was used to identify the significant differences between the samples for each of the terms included on the CATA question. The results (Table 5) showed that statistically significant differences ($p < .05$) were found between the samples for most of the analyzed attributes, but no significant differences were found for *creamy appearance, adhesive*, and *viscous*. Fig. 3B shows that surimi dips were divided into three groups according to their sensory attributes. Samples US_CTRL and CN_3EW were associated to the attributes *gummy, odd taste, fishy taste, I would not buy it* and *viscous*. Samples CN_3ST and CN_CTRL were associated to the textural attributes *lumpy* and *lumpy appearance*. Finally, samples US_1.5EW, CN_1.5EW, US_3ST and US_3EW were related to *adhesive, creamy, spreadable, creamy appearance, nice appearance, nice taste, smooth taste* and *normal aroma*. The positive attributes *healthy, nutritive*, and *appetizing* were mainly associated to samples US_1.5EW, CN_1.5EW, US_3ST and US_3EW. At the

Table 5. Frequency (%) with which terms of the CATA were used by consumers to describe the eight surimi dip samples and results from Cochran's Q test for comparison between samples.

CATA terms	CN_3EW	CN_1.5EW	CN_3ST	CN_CTRL	US_3EW	US_1.5EW	US_3ST	US_CTRL	Q
Nice appearance	21	24	39	34	26	28	22	26	**0.014**
Uniform color	66	69	80	52	84	57	60	72	**<0.0001**
Lumpy appearance	33	29	40	37	39	44	51	41	**0.014**
Creamy appearance	40	58	46	54	48	43	42	47	0.061
Spreadable	50	68	60	74	64	67	56	54	**<0.000**
Lumpy	37	27	50	41	32	55	51	44	**<0.0001**
Adhesive	20	25	18	27	25	21	24	27	0.561
Viscous	20	16	18	20	19	18	16	19	0.976
Gummy	34	20	23	11	18	19	22	26	**0.006**
Creamy	44	59	56	58	58	40	38	51	**<0.000**
Smooth taste	9	42	36	38	27	11	28	16	**<0.0001**
Nice taste	25	52	49	50	52	43	38	32	**<0.000**
Fishy taste	69	69	62	51	68	69	68	68	**0.026**
Odd taste	42	20	22	19	24	22	26	27	**0.001**
Fishy aroma	53	52	50	44	27	52	46	46	**0.001**
Intense aroma	50	23	29	22	26	50	39	55	**<0.000**
Normal aroma	20	38	35	37	44	35	37	22	**0.001**
Appetizing	16	37	33	45	34	31	32	25	**<0.000**
Healthy	11	22	17	21	18	9	22	8	**<0.000**
Nutritive	20	19	20	31	17	17	17	11	**0.001**
I would buy it	22	54	43	47	42	44	49	27	**<0.0001**
I would not buy it	61	23	41	29	34	31	38	42	**<0.0001**

Highlighted terms correspond to those for which significant differences between samples were identified according to Cochran's Q test ($p < 0.05$).

same time, this area of the perceptual space was associated to the highest overall liking (OL, superimposed as supplementary variable) and to the CATA question *I would buy it*. So, it can be inferred that a surimi dip with the right adhesiveness, and creamy texture, together with a smooth and nice taste would drive the liking and the purchase intent of these kinds of products by consumer.

CATA test allowed the association of certain attributes of the product category to the willingness to buy. This leads to a better understanding of which technologies could be used to develop a product with better sensory characteristics. Samples treated with US regardless the type of binder had great sensory appreciation and were perceived as healthier and more nutritious, compared to the other samples. The use of EW and ST as binders would improve the texture of the sauces and consequently, the liking by the consumers. The effect of the addition of binders such as egg white and starch on the textural properties of surimi has been previously studied (Kong et al., 2016; Murphy, Gilroy, Kerry, J, F., & Kerry, 2005). The strength of the gel in surimi products have been shown to increase with the presence of protein additives such as egg white (Kuhn, Prentice-Hernandez Carlos, Soares, & Soares, 2004) and the starch addition in a mixed gel matrix, normally improves surimi

Table 6. Scores for overall liking, appearance liking, flavor liking, and consistency liking for lionfish surimi dipping sauce.

Sample	Overall Liking	Appearance Liking	Flavor Liking	Consistency Liking
CN_3EW	5.6(2.0)^{c}	5.3(2.0)^{ab}	5.1(2.7)^{b}	5.4(2.4)^{b}
CN_1.5EW	6.5(2.0)^{a}	5.6(1.9)^{ab}	6.3(2.2)^{a}	5.8(2.5)^{ab}
CN_3ST	5.9(2.2)^{bc}	5.2(2.2)^{b}	6.0(2.5)^{a}	5.6(2.2)^{b}
CN_CTRL	5.9(2.0)^{abc}	5.2(2.0)^{b}	6.0(2.3)^{a}	5.6(2.6)^{b}
US_3EW	6.4(1.8)^{ab}	5.5(1.9)^{ab}	6.6(2.2)^{a}	5.8(2.3)^{ab}
US_1.5EW	5.9(2.3)^{bc}	5.7(2.3)^{ab}	6.1(2.6)^{a}	5.6(2.6)^{b}
US_3ST	6.3(2.1)^{ab}	5.8(1.9)^{a}	6.4(2.5)^{a}	6.5(2.2)^{a}
US_CTRL	4.8(2.2)^{d}	5.2(2.2)^{b}	4.4(2.6)^{c}	5.4(2.5)^{b}

Values within a column with different letters are significantly different ($p < 0.05$).
Values between parentheses are the standard deviations.

hardness and cohesiveness due to the ability of the binder to swell, absorb and bind water in the gel when gelatinized (Lee, Wu, & Okada, 1992; Mi et al., 2021).

Acceptability study

For the eight surimi dipping sauces, the overall liking (OL) scores were between 4.8 and 6.5 (Table 6). The liking of appearance, flavor and consistency was in line with the OL, as in the case of the snacks. Significant differences ($p < .05$) were obtained for all the attributes. CN_1.5EW obtained the maximum score for the OL while US_CTRL obtained the minimum score for the OL. These results could indicate that panelists rejected *gummy* surimi dipping sauces with *odd* and *fishy taste* (Fig. 3)

The sample US_3ST (Table 6) obtained the highest score for the appearance liking and consistency liking, which was attributed to the high *adhesiveness* and the *creamy appearance* of the product. CN_3ST, CN_CTRL and US_CTRL obtained the significantly lowest scores ($p < .05$) for appearance liking. In relation to consistency liking, CN_3EW, CN_3ST, CN_CTRL, US_1.5EW and US_CTRL had the significantly lowest scores ($p < .05$). The fact that consumers rejected these samples could be related to the *lumpy appearance* perceived by consumers for samples CN_3ST, CN_CTRL and the *gummy* texture of samples US_CTRL and CN_3EW.

Regarding flavor liking, the sample US_CTRL had the significantly lowest score ($p < .05$), while samples pre-treated with ultrasounds with addition of EW and ST (US_1.5EW, US_3EW, US_3ST), and samples prepared by conventional method without binder addition (CN_CTRL) and with addition of 1.5% EW and ST (CN_1.5EW) and 3% ST (CN_3ST) had the highest significant scores ($p < .05$). Similar results were obtained by Jafarpour, Ha., and Rez (2012) which found that panelists selected surimi samples with 3% egg white and 3% starch as the best sensory parameters.

These results could indicate that panelists tend to prefer *adhesive, spreadable* and *creamy* surimi dipping sauces with *nice* and *creamy appearance* and *nice* and smooth *taste*.

Conclusions

This work highlighted panelists positive perception of different lionfish products. The application of combined methods of consumer profiling to food development using new raw materials as lionfish and emerging technologies proved to be a successful approach. In this study, snacks made with ultrasound and 3% corn starch and ultrasound without binder addition were consumers favorites indicating that consumers prefer *dry, crispy* and *crunchy* snacks. For the dipping sauce, the highest acceptability by the panelists was for the samples pre-treated with ultrasound and elaborated using egg white and starch, and sample prepared by conventional method and 1.5 egg white were the consumers favorites indicating that consumer prefer *adhesive, spreadable* and *creamy* surimi dipping sauces with *nice* and *creamy appearance* and *nice* and smooth *taste*. The use of lionfish in combination with ultrasound-assisted processing is an excellent option to obtain two surimi-derived products – snacks and dips- with excellent possibilities for culinary use and good acceptance by consumers

Funding

This work was supported by the Ministerio de Ciencia, Tecnología e Innovación (MINCIENCIAS) [761–2016]; Universidad de La Sabana [EICEA-98–2015].

Disclosure statement

No potential conflict of interest was reported by the author(s).

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