

# FORMULATION AND EVALUATION OF RAINBOW TROUT (*ONCORHYNCHUS MYKISS*) CHORIZO ADDED WITH WHEAT BRAN OR WHEAT GERM

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## ABSTRACT

Meat products can be formulated and enriched with different types of meats and ingredients to improve their nutritional quality or promote consumer's health. Therefore, we aimed to formulate a rainbow trout chorizo added with bran or germ and evaluate its physicochemical and sensory acceptance. Three chorizo formulations (F) were designed: F1, rainbow trout chorizo without added wheat bran or germ; F2, rainbow trout added with wheat bran and F3, rainbow trout added with wheat germ. Ash, protein, fibre, and pH of rainbow trout chorizo formulations were not significantly different ( $P > 0.05$ ). F3 had the highest fat content ( $35.04 \pm 4.44\%$ ) ( $P < 0.05$ ) while there was no significant difference ( $P > 0.05$ ) between F0 and F2 ( $28.56 \pm 1.72\%$  and  $28.01 \pm 2.90\%$ , respectively). Regarding sensory analysis, panellists accepted all three formulations. Hence, rainbow trout chorizo added with either wheat bran or germ represents a healthier option compared to the traditional pork chorizo.

**Keywords:** Chorizo, rainbow trout, fibre, wheat bran, wheat germ, consumer acceptance, meat quality.

## PRACTICAL APPLICATION

Nowadays, traditional foods have been developed or evolved to give a new consumption experience. This has given traditional ingredients the opportunity to merge with others to generate innovative foods. Chorizo is a traditional Mexican food widely used in Mexican cuisine. This is a good source of protein but at the same time a source of fat, so it is very important to improve its nutritional quality. Therefore, the use of new meat and fibrous ingredients can constitute an innovative alternative to improve the nutritional profile of chorizo and, consequently, increase its preference by consumers when, at the same time, underutilized food ingredients are given a market opportunity.

## 1. INTRODUCTION

Chorizo is a seasoned ground-pork sausage produced and consumed worldwide [1]. In Europe, mainly Spain and Portugal, chorizo is a fermented, cured or smoked pork sausage that can be eaten without further cooking, while in Mexico it needs to be cooked as it is made with raw meat (mainly pork), lard and native dry chilli peppers [2-4]. Mexico produced 35,193 tons of chorizo in 2019 [5] and it is one of the most popular sausages in Mexico and Latin America [4, 6]. Meat products, such as chorizo, can be formulated and enriched with an assortment of ingredients to modify their characteristics, quality or improve consumers' diet [7-12]. This re-formulation of traditional meat products allows the use of regional raw materials, which in turn widen the range of foods on the market [13, 14].

In contrast to meat, fish despite its high nutritional value, is not consumed as widely. For instance, worldwide the average person consumes only about 20 kg of fish and 40 kg of other meats, mainly pork and poultry [15, 16]. Furthermore, the FAO has estimated that 35% of the annual seafood and fish production is lost or wasted [16]. Fish is a high quality and easily digestible source of protein, it contains essential amino acids, and fats (long-chain omega 3), vitamins D, A and B and minerals such as calcium, iodine, zinc, iron and selenium [17-19]. Fish is rich in unsaturated fats and helps protect against coronary heart disease, and also assists the development of the brain and the nervous system [20-22]. Trout is considered the only freshwater-fish that is a source of omega 3, 6 and 9 and it also provides proteins with high biological value, minerals such as selenium, phosphorus, potassium and magnesium, and vitamins B12, niacin and B6, and moderate levels of thiamine and riboflavin [22-24].

Traditional meat products commonly lacked fibre, but, fibre from various sources (e.g., fruits, cereals, vegetables, etc.) can be readily incorporated into meat products to produce a functional, healthier food [3, 7, 25]. Fibre is usually

classified as insoluble or soluble: for example, insoluble fibre increases faecal mass which helps intestinal motility, it has antioxidant properties, positively modifies the blood cholesterol profile and has a beneficial effect on the microbiome of the large intestine; soluble fibre retains water and form gels with a viscous consistency in the stool, which gives a laxative effect [27]. Both types of fibre improve bile acid absorption and reduce LDL cholesterol, and postprandial insulinemia [28]. The importance of fibre not only lies in the effect it has on the human body but also in the modifications (e.g., pH, fermentation process, cooking yield, etc.) it generates when it is added to foods and meat products without modifying the sensory characteristics [10, 11, 29, 30].

Therefore, we aimed to devise a chorizo by substituting most of the pork and fat with rainbow trout and adding wheat bran or germ. We then evaluated its chemical (pH, moisture, ashes, protein, fat and fibre) and colour characteristics as well as its sensory acceptance.

## 2. MATERIALS AND METHODS

### 2.1. Elaboration of chorizo

Three chorizo formulations (F) (Table 1) were designed; F1, rainbow trout and pork without fibre, F2, rainbow trout and pork with wheat bran and, F3, rainbow trout and pork with wheat germ. The rainbow trout was skinned, eviscerated and filleted, and then ground at between -1 and 2°C and mixed with previously ground pork and bacon in a food processor (84145, Hobart, Ohio, USA). The rest of the ingredients were prepared and pre-mixed to a homogeneous paste as follows: salts (sea of Cortés, Pragna<sup>®</sup>, and table salt, La Fina<sup>M.R.</sup>), mixed spices (Complete seasoning, SASSÓN, ALZA<sup>®</sup>), chillies (boiled in water, blended and sieve) and vinegar (organic apple vinegar, Spectrum<sup>®</sup>) were blended together. The meat mixture (rainbow trout – pork – bacon) was divided into three equal parts, one per treatment and the other ingredients (pre-mixed) were incorporated manually into each meat mixture (final temperature <9°C), before stuffing the mix into 4 cm-diameter artificial sausage skins (previously soaked in water). The sausages were vacuum-packed and aged at 18°C for 3 days. After ageing, they were stored between 3 to 5°C for 24 h. Each formulation was considered as a treatment and prepared in triplicates following a completely random design.

Table 1. Formulation for the elaboration of rainbow trout and pork chorizo added with wheat barn or wheat germ

Ingredients (%)	Chorizo formulations		
	Without wheat or bran added (F1)	Wheat Barn (F2)	Wheat Germ (F3)
Rainbow trout meat	53.33	49.11	48.00
Pork	17.77	16.37	16.06
Bacon	8.88	8.19	8.02
Table salt	1.33	1.23	1.20
Sea salt	0.89	0.81	0.80
Ancho chilli <sup>1+</sup>	2.66	2.46	2.40
Pasilla chilli <sup>2+</sup>	0.26	0.25	0.24
Guajillo chilli <sup>3+</sup>	1.06	0.98	0.96
Vinegar	11.11	10.23	10.03
Mixed spices <sup>4</sup>	2.67	2.46	2.40
Fibre	0	7.89	9.67

<sup>+</sup> Chillies were cooked in boiling water, blended, and sieved before use

<sup>1</sup> Dehydrated poblano chilli

<sup>2</sup> Dehydrated chilaca chilli

<sup>3</sup> Dehydrated mirasol chilli

<sup>4</sup> Commercial mix, SASSÓN, (Complete seasoning, ALZA<sup>®</sup>)

## 2.2. Physicochemical analysis

The pH, moisture, ash, protein, fat and fibre were analysed in triplicate according to either Mexican regulations or AOAC methods using analytical grade reagents. The pH was analysed according to NOM-F-317-S-2013 [31] with a previously calibrated Orion™ Versa Star potentiometer (Thermo Fisher Scientific, ThermoScientific™, Waltham, USA). Moisture was evaluated according to NOM-116-SSA1-1994 in a stove (13306M, NOVATECH, Mexico) at atmospheric pressure between 100 and 105°C, for 2 h [32]. Ashes were determined following the AOAC (2005) method 923.03 in an oven (NOVATECH, Mexico) and subsequently calcined in an oven (TE-M12AT, Felisa®) at 550°C for 3 hours [33]. Protein was evaluated according to NMX-F-068-S-1980 [34] with a Kjeldahl digester and distiller (KJR model). Fat was measured following procedure 991.36 [35] extracted with petroleum ether by the Soxhlet method in a BUCHI automatic extraction system B-811 (Labortechnik AG, Flawil, Switzerland). Finally, fibre was determined according to the ANKOM method [36].

Nutritionist Pro® 2.2 Software (Axxya Systems-Nutritionist Pro, Stafford, TX) was used to analyse the nutritional composition of the formulations and they were compared with a commercial pork chorizo.

## 2.3. Colour evaluation

The colour of the chorizos was measured in triplicate in terms of CIELAB parameters CIE L\* (whiteness or brightness), CIE a\* (redness or greenness) and CIE b\* (yellowness or blueness) with a Specular Component Included (SCI) viewing angle. Colour was measured inside the chorizos on approximately 30-g slices with a spectrophotometer (Chroma meter, Konica Minolta, CR-410, Japan) which was placed at 90° and in direct contact with the sample. The spectrophotometer was calibrated before each sample was measured with a light trap in a white tile.

## 2.4. Sensory analysis

Chorizo sensory acceptance was carried out on day one through an acceptability test with an untrained panel of 100 individuals residing in Chihuahua, Chih. Mexico. The panel was constituted by 58 men and 42 women in an age range between 20 and 45 years old. For the sensory analysis the chorizo was cooked at 65°C for 15 min. Then, 15 g- portions were placed in hermetically sealed containers, which were kept at 60°C until evaluation. The sensory evaluation was conducted according to a five-point hedonic scale (1-like extremely, 2-like slightly, 3-neither like nor dislike, 4-dislike slightly and 5-dislike extremely). Treatments were identified with a three random number code as follows: F1 (538), F2 (724) and F3 (469). In random order, panellists obtained a sample (15 g at 60°C) of each treatment, and were asked to evaluate colour, flavour, odour, texture and general acceptability.

## 2.5. Statistical analysis

Data were analysed with the GLM procedure in SAS [37], FREQ and CORRESP procedures in Minitab® [38]. Chemical determinations were evaluated with a one-way ANOVA for a completely random design, with the following model:  $y_{ij} = \mu + \alpha_i + \epsilon_{ij}$ , where  $y_{ij}$  is the responding variable measured in the  $j$ -th repetition of the  $i$ -th treatment,  $\alpha_i$  is the effect of the  $i$ -th treatment,  $\epsilon_{ij}$  is the random error corresponding to the  $j$ -th repetition of the  $i$ -th treatment. A Tukey test was performed to compare means with a significance of  $P < 0.05$ . Sensory results were assessed with a chi-square test with a two-tailed frequency comparison for the null hypothesis. Sensory data was plot after the correspondence procedure. The correspondence analysis permitted to visualise and assess the relationships between treatments and levels (v1-like extremely, v2-like slightly, v3-neither like nor dislike, v4-dislike slightly and v5-dislike extremely) of the sensory attributes on which the chi-square test detected a significant association. The graphs show the similarities among treatments and the similarities among the levels of the attributes (v1 – v5) and the correspondence between treatments and attribute levels, all of them as approximate chi-square distances, using the points of the first two principal components. They represented the largest total inertia (total association between levels of both categorical variables). Points located further from the origin indicate the most influential categories. Points on opposite sides of the graph indicate that a component contrast these categories.

## 3. RESULTS AND DISCUSSION

### 3.1. Chemical composition

There were no significant differences ( $P < 0.05$ ) among formulations in terms of chemical composition, except for moisture and fat (Table 2). Meat-containing mixtures for chorizo have an initial pH of approximately 5.8 [39]; however, the values vary when using starter cultures, and during the ageing process or because of the ingredients in the formulation [2, 40, 41, 42]. The pH was statistically similar ( $P > 0.05$ ) among treatments and it ranged from  $5.26 \pm 0.85$  to  $5.93 \pm 0.28$ , hence, they can be graded as highly acidified sausages [43]. The pH of meat products is relevant, because values above 6.0 or close to neutrality support growth of undesirable bacteria, which decrease shelf life, while acid flavours at pH below 4.5 render them intolerable to the consumer [44, 45]. Fish has a higher pH than pork or beef, hence it decomposes faster, therefore, fibre had a positive effect as it promoted acidity, thus increasing the shelf life.

Moisture was highest ( $71.35 \pm 1.79\%$ ) in F1 and lowest ( $65.37 \pm 2.00\%$ ) in F3 ( $P < 0.05$ ). The three rainbow trout chorizo formulations had a notably higher moisture content than chorizos from pork, beef, or rabbit [2, 39, 42]. Rainbow trout meat without other ingredients has an average moisture percentage of 75% [46]. The inclusion of fibre in meat products and its effect on moisture is not conclusive and is even contradictory. There is evidence that fibre (e.g., oats, wheat, etc.) modifies moisture and fat retention [2, 9, 11], the effect of fibre on food moisture depends mainly on particle size, pH, and ionic strength [11, 47]. Moisture is also dependent on the meat and processes, for instance, rabbit chorizos have a higher content of moisture than pork ones, and mature chorizos have less water [2, 42]. Hence, the effect of fibre, ageing and rainbow trout meat, would explain the differences in this variable with respect to other chorizos.

Ash content did not differ significantly among treatments ( $P > 0.05$ ) but the highest percentage was found in F3 (0.331). Mexican chorizos have an average ash content between 1 and 5% [39, 42, 48], while chorizo containing walnut fibre have 4% [9]. The amount of salt in the formulation dictates the percent of ash in the final product [49]. Fat and moisture in sausages are usually inversely proportional [48, 50]; F3 had a higher percentage of fat ( $35.04 \pm 4.44\%$ ) than F1 and F2 ( $P < 0.05$ ), this is because wheat germ is the part of the grain that contains more fat. Chorizos and other meat products with fibre have higher levels of fat than products without fibre [2, 11], as fibre absorbs and retains more fat, insoluble fibre more than soluble [51]. Despite the high percentage of fat (28 and 35%), these ones were still within the normal ranges for this type of product [2, 9, 48, 52]. The fat content of a conventional pork chorizo is between 27 and 33%; however, 50% are saturated fats, and provide a total of 230 calories for every 100 g of product [53]. Meanwhile, rainbow trout fat contributes only 45 to 54 calories per 100 g since more than a third of the total is monounsaturated [20].

Protein content was not significantly different ( $P > 0.05$ ) and ranged between  $11.75 \pm 1.00$  and  $12.59 \pm 0.93\%$  for F1 and F2, respectively. Protein parameters from other studies ranged from 15 to 40%, but this will depend on the processing, the meat and the ingredients in the formulation [48, 50]. Protein content can be increased in meat products, by adding other protein sources, such as soy derivatives or due to loss of moisture during ageing [42, 54].

Table 2. Chemical composition of rainbow trout and pork chorizo added with wheat bran or wheat germ (means  $\pm$  standard deviation)

Parameter	Chorizo formulations		
	Without wheat or bran added (F1)	Wheat bran (F2)	Wheat germ (F3)
pH	$5.93 \pm 0.28^a$	$5.36 \pm 0.81^a$	$5.26 \pm 0.85^a$
Moisture (%)	$71.35 \pm 1.79^a$	$67.89 \pm 2.23^b$	$65.37 \pm 2.00^c$
Ashes (%)	$0.310 \pm 0.065^a$	$0.309 \pm 0.07^a$	$0.331 \pm 0.64^a$
Protein (%)	$11.75 \pm 1.00^a$	$12.59 \pm 0.93^a$	$12.20 \pm 1.33^a$
Fat (%)	$28.56 \pm 1.72^a$	$28.01 \pm 2.90^a$	$35.04 \pm 4.44^b$
Total fibre (%)	$0.00 \pm 0.0^a$	$1.23 \pm 0.03^a$	$1.30 \pm 0.08^a$

<sup>a,b,c</sup> Means within a row with different literals are significantly different ( $P < 0.05$ ).

The nutritional profile (Table 3) showed that 100 g of rainbow trout and pork chorizo, either with or without wheat fibre had half the calories of the commercial chorizo, these also have less fat and contribute a lower percentage of the daily inclusion of this component to an adult diet. The inclusion of barn orgerm wheat increased the daily percentage of the recommended dietary fibre for adults. On the other hand, cholesterol levels were lower in rainbow trout and pork chorizos with and without wheat brand or germ. Meanwhile chorizos formulated with or without barn orgerm wheat can be labelled as low in cholesterol since the Daily value percentage of these chorizos is below 5%.

Table 3. Nutritional profile\* of 100 g of rainbow trout and pork chorizo added with wheat bran or wheat germ and pork chorizo

Component	Chorizo formulations			
	Pork chorizo	Without wheat or bran added(F1)	Wheat bran (F2)	Wheat germ (F3)
Calories	201.22	109.98	101.35	134.28
Fat, Total (g)/DV <sup>^</sup> (%)	18.67/23.95	8.60/11.03	8.32/10.67	8.71/11.17
Saturated Fat (g)/ DV <sup>^</sup> (%)	6.84/34.22	2.91/14.56	2.74/13.74	2.79/13.96
Calories from Fat	168.10	77.40	74.89	78.41
Calories from Sat Fat	61.59	26.21	24.72	25.13
Monounsaturated Fat (g)	8.04	3.27	3.08	3.09
Polyunsaturated Fat (g)	1.76	1.22	1.33	1.69
Sugar, Total (g)	0.48	0.48	0.44	1.62
Total Carbohydrate (g)/ DV <sup>^</sup> (%)	2.35/0.86	2.34/0.85	2.17/0.79	7.15/2.60
Dietary Fiber, Total (g)/ DV <sup>^</sup> (%)	0.95/3.41	0.95/3.39	3.28/11.74	2.14/7.65
Protein (g)/ DV <sup>^</sup> (%)	14.00/28.01	14.49/29.00	14.66/29.33	15.33/30.67
Cholesterol (mg)/ DV <sup>^</sup> (%)	51.19/17.07	12.8/4.27	11.79/3.93	11.56/3.85
Sodium (mg)/ DV <sup>^</sup> (%)	998.46/43.41	990.03/43.05	910.16/39.57	895.54/38.94

\*Formulations analysed using Nutritionist Pro<sup>®</sup> 2.2 Software (2021, Axxya Systems-Nutritionist Pro, Stafford, TX).

### 3.2. Colour

Luminosity (CIE L<sup>\*</sup>) ranged from 46.16 ± 2.16 to 47.02 ± 2.60 without significant difference (P>0.05), as seen in Table 4. L<sup>\*</sup> is related to moisture, fat and other ingredients (e.g., chilli) in the formulation [55]. The L<sup>\*</sup> values in all treatments were higher than those reported in chorizos formulated with other meats (e.g., mutton, rabbit, and pork) and fibres [2, 9, 48].

Colour CIE a<sup>\*</sup> ranged from 16.46 ± 1.13 to 19.24 ± 0.84 and colour b<sup>\*</sup> from 34.54 ± 1.64 to 37.45 ± 1.71. F1 was significantly different (P<0.05) from F2 and F3, differences among treatments might be associated with the oxidation of their pigments. Colour values in rainbow trout chorizo matched chorizos formulated with other meats (e.g., mutton, rabbit and pork) and fibre [2, 9]. Differences in CIE L<sup>\*</sup>, a<sup>\*</sup> and b<sup>\*</sup> can also be associated with the formulation in general; type and water content of the meat, amount of fat, type and amount of chili, among other ingredients [55, 56].

Table 4. Colour of rainbow trout and pork chorizo added with wheat bran or wheat germ (means ± standard deviation)

Parameter	Chorizo formulations		
	Without wheat or bran added (F1)	Wheat bran (F2)	Wheat germ (F3)
$L^*$	46.68 ± 2.99 <sup>a</sup>	46.16 ± 2.16 <sup>a</sup>	47.02 ± 2.60 <sup>a</sup>
$a^*$	19.24 ± 0.84 <sup>a</sup>	16.58 ± 0.70 <sup>b</sup>	16.46 ± 1.13 <sup>b</sup>
$b^*$	37.45 ± 1.71 <sup>a</sup>	34.54 ± 1.64 <sup>b</sup>	35.18 ± 1.93 <sup>b</sup>

CIE  $L^*$  Luminosity

CIE  $a^*$  Positive values tendency to red

CIE  $b^*$  Positive values tendency to yellow

<sup>a, b, c</sup> Means within a row with different superscripts are significantly different ( $P < 0.05$ )

### 3.3. Sensory evaluation

The addition of bran and germ wheat fibre did not affect statistically ( $P > 0.05$ ) odour, colour, flavour or the general appearance of the three types of chorizos (Table 5). Texture was statistically different ( $P < 0.05$ ) among treatments. Correspondence graphs of each attribute are shown in Figure 1. Regarding odour, correspondence for F1 and F3 was 'neither like nor dislike', while for F2 was 'like slightly'. The answer 'neither like nor dislike' could be associated with the chillies and spices in the formulation, as these might neutralise the odour of the fish. In terms of colour (Figure 1), F3 had some correspondence with 'like extremely', while F1 had a correspondence with 'dislike slightly', and F2 had a correspond of 'neither like nor dislike'. Regarding the flavour attribute (Figure 1), F1 had a correspondence of 'neither like nor dislike', F2 had a correspondence of 'like slightly' and F3 had a correspondence of 'like extremely'. In relation of texture (Figure 1), F3 had a correspondence of 'like extremely', while F2 and F1 had a correspondence of 'like slightly', hence, it can be considered that fibre chorizos were as well accepted.

Table 5. Sensory attributes of rainbow trout and pork chorizo added with wheat bran or wheat germ

Attribute	Chi-squared	Probability	P
Odour	9,742	0.2836	NS
Colour	3,212	0.9204	NS
Flavour	13,248	0.1036	NS
Texture	18,268	0.0193	<0.05
General appearance	8,514	0.3849	NS

Significance  $P < 0.05$ .

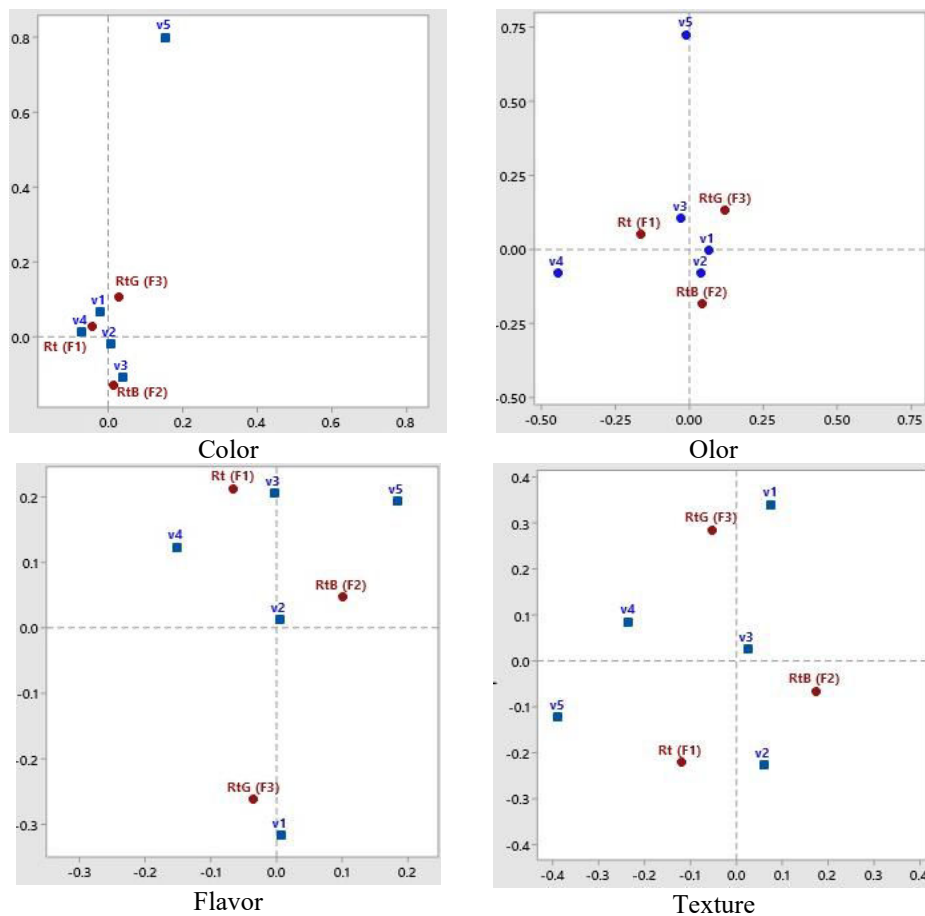


Figure 1. Correspondence between rainbow trout and pork chorizos with added wheat fibre and level of acceptance. v1-like extremely, v2-like slightly, v3-neither like nor dislike, v4-dislike slightly and v5-dislike extremely. Rt = rainbow trout and pork chorizo without fibre, RtB = rainbow trout and pork chorizo with wheat bran and RtG = rainbow trout and pork chorizo with wheat germ.

Regarding general appearance (Figure 2), F1 had a correspondence of ‘dislike slightly’, while F2 had a correspondence of ‘like slightly’ and F3 had some correspondence ‘like extremely’. According to the results, only texture was significantly different ( $P < 0.05$ ) among treatments. This may be since the inclusion of fibres changes the moisture content ( $P < 0.05$ ) and as a consequence the texture of the chorizos with bran or germ wheat ( $P < 0.05$ ). Any food with beneficial ingredients must be attractive (in terms of colour, flavour, odour and texture) for the consumer and stimulate appetite [57].

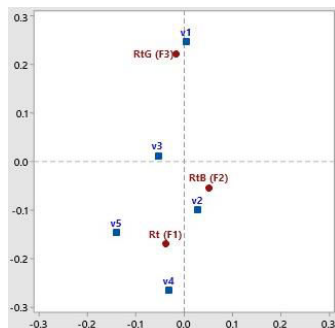


Figure 2. Correspondence of general appearance between rainbow trout and pork chorizos with added fibre and level of acceptance. v1-like extremely, v2-like slightly, v3-neither like nor dislike, v4-dislike slightly and v5-dislike extremely. Rt = rainbow trout chorizo without fibre, RtB = rainbow trout and pork chorizo with wheat bran and RtG = rainbow trout and pork chorizo with wheat germ.

#### 4. CONCLUSIONS

Chorizo is a popular meat product worldwide, and it can be formulated or enriched with different ingredients to modify its characteristics or attract more consumers. This study examined the properties of chorizo with a percentage of the pork replaced with rainbow trout meat and with added bran or germ wheat. Finally, we conclude that rainbow trout and bran or germ wheat might be considered as components in the formulation of chorizos, which would increase the utilisation of rainbow trout, typically an underused source of protein. Also, Chorizo made with rainbow trout and bran, or germ wheat would be a healthier option than regular pork chorizos and would be a method of increasing the consumption of fish meat and wheat ingredients.

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#### AUTHOR CONTRIBUTIONS

*Jurado-Guerra Jesus Arnulfo*: as the main author, he made the experimental work of this research and analyzed data.

*Flores-Mancha Martha Azucena*: She drafted the manuscript.

*Juarez-Moya Juliana*: She participated in the experimental design, planning the research.

*Lechuga-Valles Ruth*: She contributed in the experimental work.

*Rentería-Monterrubio Ana Luisa*: She contributed in the experimental work.

*Sanchez-Vega Rogelio*: He participated in the experimental design and planning the research.

*Chavez-Martínez América*: She was the leader of the project, and she contributed with the revision of the manuscript.

#### DATA AVAILABILITY STATEMENT

All datasets generated during and/or analyzed during the current study is available from the corresponding author on reasonable request.

#### CONFLICT OF INTEREST

There is no conflict of interest among the authors.

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