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Quinoa (*Chenopodium quinoa* Willd) paste as partial fat replacer in the development of reduced fat cooked meat product type pâté: Effect on quality and safety

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**ABSTRACT**

The aim of this work was to evaluate the effect of partially replacing fat by the addition of three quinoa pastes obtained from white, red and black quinoa on the quality and safety of a cooked meat product such as pork liver pâté. The addition of quinoa paste as fat replacer led to an increase in the moisture, ash and residual nitrite contents, while the fat content decreased with respect to control sample by an average of 8%. The use of quinoa pastes increased the hardness and the gumminess but had no effect on springiness and cohesiveness. The substitution of fat with white, red and black quinoa paste at 10% led to lower oxidation rates than observed in the control. No aerobic bacteria, *Enterobacteriaceae*, moulds and yeasts were found in any sample. The most acceptable sample was the pâté containing red quinoa at 5%.

**KEYWORDS**  
Pasta de quinoa (*Chenopodium quinoa* Willd), moulds and yeasts, Enterobacteriaceae, oxidation.

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oxidation products (Corpet, 2011). One way to improve consumers’ well-being would be to enhance the quality and nutritious value of such products by adding potential functional ingredients with a high content of bioactive compounds (Martín-Sánchez et al., 2013).

Liver pâté is a traditional cooked meat product consumed in numerous countries, principally in Europe (especially in Denmark, France, Germany and Spain). It contains minced liver (pork or duck), fat and meat mixed with water and different additives before being packed in glass containers and submitted to a thermal treatment. As mentioned by Estévez, Ramírez, Ventanas, and Cava (2007), the chemical composition of pâtés (high amounts of saturated fat and low content of natural antioxidants) and the manufacturing process itself (highly susceptible to lipid oxidation) means that consumers are beginning to regard this meat product as an unhealthy food. Therefore, the aim of this work was to evaluate the effect of partially replacing fat by adding quinoa paste obtained from white, red and black quinoa on the quality (chemical composition, physicochemical and sensorial properties) and safety (residual nitrite content, oxidation and microbial quality) of a pork liver pâté.

Material and methods

Plant material

The analyses were performed using three different quinoa seeds obtained from a local market: white Bolivian Real quinoa obtained (WQ), red Bolivian Real quinoa (RQ) and black Bolivian Real quinoa (BQ), all obtained by organic farming. The pre-weighed quinoa seeds were soaked for 20 min in distilled water (1:5 ratio) in a flask at room temperature, covered with a woven cotton towel, left to dry slightly for 10 min and then transferred to a blender, where they were ground for 20 s to obtain the pastes.

Preparation process of cooked meat product

Pork liver pâtés were made following the traditional formula. This original mixture was used as the control sample, and the other pâtés (three formulations) were prepared as shown in Table 1.

The pâtés were prepared in the pilot plant of the IPOA research group following normal industrial processing techniques. Pork dewlap was transferred to the cutter (Höganas, Sweden) with the sodium chloride; then the liver was added to the cutter, and after comminution, the other ingredients and additives were added. The pork backfat was then added. After homogenization, the mixture was stuffed into Fibran-Pack artificial casing (diameter 30 mm; long 150 mm) clipped at both ends and cooked in a water bath. The pâtés were kept in the bath until the coldest point reached 72°C. When the endpoint temperature was achieved, the pâtés were immediately chilled on ice. After reaching room temperature, the product was transferred to the lab in insulated boxes containing ice and stored at 4°C until analysis.

Chemical composition

The fat, ash, moisture and protein contents were determined according to Official Methods (AOAC, 2007). Residual nitrite level (mg NaNO₂/kg sample) was determined according to standards ISO/DIS 2918.26 (ISO, 1975). Lipid oxidation of the pork liver pâtés was assessed by the 2-thiobarbituric acid (TBA) method of Rosmini et al. (1996). Thiobarbituric acid reactive substance (TBARS) values were expressed as mg MA/kg sample.

Physicochemical properties

The pH was measured in a suspension resulting from blending 15 g of the sample with 150 mL deionised water for 3 min using a pH meter (Crismon Instruments, Barcelona, Spain). The water activity (aw) was determined in a Novasina Sprint TH-500 Thermostanter (Pfäffikon, Switzerland) at 25°C.

The colour was studied in the CIE L*a*b* colour space using a Minolta CM-700 (Minolta Camera Co., Osaka, Japan), with illuminant D₆₅, SCI mode and an observer angle of 10°. The aperture of the instrument for was 11 mm for illumination and 8 mm for measurement. Low reflectance glass (Minolta CR-A51/1829–752)

| Table 1. Formulation of low-fat pork liver pâtés added with different concentrations of white, red and black quinoa seed paste. |  
|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatments (%) | Control | WQ 5% | WQ 10% | BQ 5% | BQ 10% | BQ 5% | BQ 10% | BQ 5% | BQ 10% |
| Pork dewlap | 65 | 62.50 | 60 | 62.50 | 60 | 62.50 | 60 |
| Pork backfat | 10 | 7.50 | 5 | 7.50 | 5 | 7.50 | 5 |
| Pork liver | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| Water | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| Salt | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Caseinate (mg/kg) | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| White quinoa | - | - | 5 | 10 | - | - | - |
| Black quinoa | - | - | - | - | 5 | 10 | - |
| Red quinoa | - | - | - | - | - | - | - |
| Polyphosphates (mg/kg) | 300 | 300 | 300 | 300 | 300 | 300 | 300 |
| Sodium ascorbate (mg/kg) | 500 | 500 | 500 | 500 | 500 | 500 | 500 |
| Sodium nitrite (mg/kg) | 125 | 125 | 125 | 125 | 125 | 125 | 125 |
| Thyme | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| White pepper | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| Nutmeg | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| Garlic powder | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |

Calculated Total Meat equivalent: % pork dewlap + % pork backfat + % pork liver = 100%.
Calculated como equivalentes al total de carne. % de papada de cerdo + % de panceta de cerdo +% de hígado de cerdo = 100%.
was placed between the samples and the equipment. The CIEL*a*b* coordinates determined were: lightness (L*), redness (a*, coordinate red-green), and yellowness (b*, coordinate yellow-blue) and the psychophysical parameters \( h_{ab} \) (hue) and \( C_{ab} \) (chroma), which were calculated as follows:

\[
h_{ab} = \arctg \frac{b^*}{a^*} \quad C_{ab} = \sqrt{a^{*2} + b^{*2}}
\]

Nine replicate measurements (3 x 3) were taken for each sample. For Texture, the texture profile analysis (TPA) was carried out on pork liver pâté samples at 4 ± 1°C using a TA-XT2 Texture Analyzer. For the TPA evaluation, the American Meat Science Association procedure (Claus, 1995) was followed. Pates samples (n = 3) for each treatment group were cut into cubes (1 × 1 × 1 cm) and subjected to a two-cycle compression test. Samples were compressed to 70% of their original height with a cylindrical probe of 10 cm diameter at a compression load of 25 kg, and a cross-head speed of 20 cm/min. The texture profile parameters, hardness, gumminess, springiness and cohesiveness were determined.

**Emulsion stability**

The procedure of Hughes, Cofrades, and Troy (1997) was followed to assess emulsion stability. For this, approximately 10 g of sample was placed in a centrifuge tube (three replicates per formulation) and centrifuged for 1 min at 2500 g. The samples were heated in a water bath for 30 min at 70°C and then centrifuged for 3 min at 2500 g. The supernatants were removed and the centrifuge tubes with the pellets were weighed. The volume of total expressible fluid (TEF) was calculated as follows:

\[
\text{TEF} = \frac{\text{Weight of centrifuge tube and sample}}{-\left(\text{Weight of centrifuge tube and pellet}\right)}
\]

\[
\%\text{TEF} = \left(\frac{\text{TEF}}{\text{sample weight}}\right) \times 100
\]

**Microbial counts**

Microbial analyses of pork liver pâté included determining the number of total aerobic bacteria populations, Enterobacteriaceae, moulds and yeast. For that, samples (25 g) were cut from the interior of pork liver pâté with a sterile scalpel and forceps. Samples were then homogenized with sterile 1.5% peptone water in a Stomacher 400 (Colworth, London, UK) for 1.5 min. Serial dilutions of samples were prepared in sterile peptone water. Total viable counts and Enterobacteriaceae were determined by plating the diluted samples on 3M Petrifilm™ plates and incubating at 35°C for 48 h. Moulds and yeast were determined by plating the diluted samples on 3M Petrifilm™ plates and incubating at 26°C for 48 h.

**Sensory evaluation**

For a hedonic judgment of the pâtés, 40 people (15 males and 25 females) aged 21–52 years and with no specific formation on the sensory analysis of pâté, were recruited from the staff and students of the Miguel Hernández University. Protocols for sensory analysis were approved by the local Ethics Committee for Clinical Research (ECCR Vega Baja Hospital, Orihuela, Spain). This analysis was performed the day after preparation, under white fluorescent lights in individual booths. Rectangular pieces of approximately 1.5 cm x 2 cm were cut from the centre of slices and served at room temperature. Unsalted crackers and mineral water (room temperature) were provided to clean the palate between samples. The hedonic scale consisted of 7 levels (1: dislike extremely and 7: like extremely), in which the panellists evaluated the different attributes – colour, aroma, hardness, cohesiveness, juiciness and taste-and finally they ordered the samples according to their overall preference.

**Statistical analysis**

For each experiment, three independent samples were examined with three replications per sample. Data obtained for proximate composition, physicochemical analysis and lipid oxidation were analysed by means of a one-way ANOVA test, with the formulation as the main effect. To assess differences between formulations Tukey’s post hoc test was applied for comparisons of means; differences were considered significant at \( P < 0.05 \).

**Results and discussion**

**Chemical composition**

The effects of partially replacing pork dewlap and backfat with different concentrations of quinoa seed paste on the proximate composition of the pâté are given in Table 2. As can be seen, the moisture content was higher in all the experimental samples \( (p < 0.05) \) than in the control, with no statistically significant \( (p > 0.05) \) differences between the samples containing 5% quinoa seed paste and those containing 10% \( (p > 0.05) \). This higher moisture content was probably due to the water retained during the soaking step for removing the saponins since the quinoa seed flours had a water holding capacity of 1.44, 1.50 and 1.80 g water/g sample for red, white and black quinoa seed flours, respectively (Pellegrini et al., 2018). The results obtained agree with those reported by Delgado-Pando, Cofrades, Rodríguez-Salas, and Jiménez-Colmenero (2011), who stated that in their low-fat pork liver pâté samples, obtained by replacing pork backfat with different concentrations of konjac (Amorphophallus konjac) gels, the moisture content increased.

As with moisture, all the pâté samples made with quinoa seed pastes showed a higher \( (p < 0.05) \) ash content (Table 2). The highest values \( (p < 0.05) \) were obtained for the pâté with 10% BQ added followed the pâté with 5% BQ. No statistical differences \( (p > 0.05) \) were found between the RQ5%, RQ10%, WQ5% and WQ10% samples. These higher values could be related to the well documented high calcium, magnesium, iron, copper and zinc contents of quinoa seeds (Vega-Gálvez et al., 2010). As regards the mineral content, the fat replacer used is very important. For example, Choi et al. (2010) reported that partially replacing pork backfat with grape seed oil and rice bran fibre increased the ash content with respect to a control sample.

The two concentrations of quinoa seed pastes used as partial fat replacement for pork backfat and dewlap did not affect the protein content (Table 2), and all the samples (including the control) showed values of between 13.34 and 14.10 g/100 g, with no statistical differences \( (p > 0.05) \) between samples. The fat content (Table 2) of all the pâté
samples formulated with quinoa seed pastes was lower \((p < 0.05)\) compared with the control sample. In WQ5%, RQ5% and BQ5% the average reduction in the fat content was 6%, with no statistical differences \((p > 0.05)\) between them, while in WQ10%, RQ10% and BQ10% the average reduction in the fat content was 10%, with no statistical differences \((p > 0.05)\) between them. These results agree with those of Agostinho dos Santos Alves et al. (2016), who reported a considerable reduction in the fat content of low-fat bologna type sausages using pork skin and green banana flour as fat replacer. It is important to note that the use of quinoa seed paste in the meat product could increase, by a small amount, the samples with polyunsaturated fatty acids (PUFAs), since the majority of the fatty acids detected in red, white and black quinoa seed flours were unsaturated. Approximately, 60% of the total content was polyunsaturated fatty acids and 30% monounsaturated fatty acids, as reported by Pellegrini et al. (2018).

Figure 1 shows the residual nitrite content of samples. As can be seen, all the experimental samples analysed showed higher residual nitrite contents \((p < 0.05)\) than the control sample, except RQ5% which had similar values \((p > 0.05)\). No significant differences were found \((p > 0.05)\) between RQ10% and BQ10% which showed the highest values. This increase in residual nitrite was concentration-dependent: the higher the concentration of quinoa seed pastes added, the higher the nitrite concentration. It is very important to notice that the final values of residual nitrite obtained for pork liver pâtés were below for permitted in this type of product \((100 \text{ mg/kg})\) (EFSA (European Food Safety Agency) Journal, 2003).

Martín-Sánchez et al. (2013) reported that the residual nitrite content in pork liver pâtés with added date palm by-products showed no significant differences with the control, although there was a slight reduction. Hah et al. (2006) evaluated the effect of substituting fat by conjugated linoleic acid on the residual nitrite content in emulsion-type sausage, finding that the concentration of residual nitrite was significantly different between the treatments with the control sample having the highest values.

This higher nitrite content found in the samples with added quinoa seed pastes might be the result of quinoa seed accumulating nitrate in their structure (around 9.92–14.65 mg/100 g) (Gutiérrez-Larrazabal, Soto-Hernández, López-Castañeda, & Mendoza-Martínez et al., 2004), which would be reduced to nitrite in a reaction catalysed by nitrate reductase, as reported Lea and Miflin (2003). Nitrates and nitrites, which were previously considered as inert end

| Sample     | Moisture | Protein | Fat   | Ash   |
|------------|----------|---------|-------|-------|
| CNT        | 49.69 ± 0.018 | 13.85 ± 0.15 | 33.24 ± 0.39 | 2.19 ± 0.01 |
| WQ5%       | 52.93 ± 0.09 | 14.40 ± 0.20 | 26.73 ± 0.44 | 2.28 ± 0.03 |
| WQ10%      | 54.99 ± 0.08 | 13.92 ± 0.36 | 23.33 ± 0.01 | 2.30 ± 0.01 |
| RQ5%       | 52.79 ± 0.01 | 13.74 ± 0.42 | 26.93 ± 0.15 | 2.31 ± 0.01 |
| RQ10%      | 54.77 ± 0.11 | 13.43 ± 0.68 | 22.99 ± 0.25 | 2.32 ± 0.01 |
| BQ5%       | 52.93 ± 0.06 | 13.34 ± 0.49 | 27.54 ± 1.03 | 2.46 ± 0.02 |
| BQ10%      | 54.74 ± 0.08 | 13.81 ± 0.03 | 23.27 ± 0.13 | 2.80 ± 0.01 |

Table 2. Chemical composition of low-fat pork liver pâtés added with different concentrations of white, red and black quinoa seed paste.

| Bar     | CNT       | WQ5%       | WQ10%      | RQ5%       | RQ10%      | BQ5%       | BQ10%      |
|---------|-----------|------------|------------|------------|------------|------------|------------|
| CNT     | d         | c          | b          | d          | a          | c          | a          |
| WQ5%    |          |           |            |            |            |            |            |
| WQ10%   |           |            |            |            |            |            |            |
| RQ5%    |           |            |            |            |            |            |            |
| RQ10%   |           |            |            |            |            |            |            |
| BQ5%    |           |            |            |            |            |            |            |
| BQ10%   |           |            |            |            |            |            |            |

Figure 1. Residual nitrite contents of low-fat pork liver pâtés added with different concentrations of white, red and black quinoa seed paste.

CNT: control pâté; WQ5% and WQ10%: pâté added with 5% and 10% white quinoa, respectively; RQ5% and RQ10%: pâté added with 5% and 10% red quinoa, respectively; BQ5% and BQ10%: pâté added with 5% and 10% black quinoa, respectively. No significant differences were found \((p > 0.05)\) between RQ10% and BQ10% which showed the highest values. This increase in residual nitrite was concentration-dependent: the higher the concentration of quinoa seed pastes added, the higher the nitrite concentration. It is very important to notice that the final values of residual nitrite obtained for pork liver pâtés were below for permitted in this type of product \((100 \text{ mg/kg})\) (EFSA (European Food Safety Agency) Journal, 2003).

Martín-Sánchez et al. (2013) reported that the residual nitrite content in pork liver pâtés with added date palm by-products showed no significant differences with the control, although there was a slight reduction. Hah et al. (2006) evaluated the effect of substituting fat by conjugated linoleic acid on the residual nitrite content in emulsion-type sausage, finding that the concentration of residual nitrite was significantly different between the treatments with the control sample having the highest values.

This higher nitrite content found in the samples with added quinoa seed pastes might be the result of quinoa seed accumulating nitrate in their structure (around 9.92–14.65 mg/100 g) (Gutiérrez-Larrazabal, Soto-Hernández, López-Castañeda, & Mendoza-Martínez et al., 2004), which would be reduced to nitrite in a reaction catalysed by nitrate reductase, as reported Lea and Miflin (2003). Nitrates and nitrites, which were previously considered as inert end
products of nitric oxide (NO) metabolism or undesired residues in food, are now being viewed as storage pools for NO like bioactivity completing NOS-dependent NO production (McNally, Griffin, & Roberts, 2016).

**Physicochemical properties**

Table 3 shows the pH values of low-fat pork liver pâtés with different concentrations of white, red and black quinoa seeds added as fat replacers. WQ5% and RQ10% showed the highest (p < 0.05) values with no statistical differences between them while the control sample had the lowest (p < 0.05) values. The water activity values (Table 3) did not differ (p > 0.05) between the control pâté and any of the pâtés containing WQ, RQ and BQ pastes, with values ranging between 0.926 and 0.936. Because of these high pH and water activity values, the low-fat pork liver pâtés containing different concentrations of white, red and black quinoa seeds must have kept under refrigeration conditions in the same way as the control formulation.

Reducing the fat content normally affects the colour of meat and meat products, which is further influenced by the approach used (Choi, Park, Kim, & Hwang et al., 2013). The results for colour (L*, a*, b*, C_ab* and h_ab*) parameters are present in Table 3. Luminosity (L*) was not affected by the replacement of backfat and dewlap by white, red and black quinoa pastes, and no statistical differences (p > 0.05) were found between the control pâté and pâtés containing WQ, RQ and BQ. These might be explained by the fact that quinoa pastes are structurally composed of macromolecules that are rehydrated and which remain inside the meat matrix, where they do not affect lightness. For the redness value (a*) of samples (Table 3), the use of WQ, RQ and BQ led to a decrease in redness with significant differences with respect to the control (p < 0.05). In the case of the yellowness value (b*) of samples (Table 3), the replacement of backfat and dewlap by white, red and black quinoa pastes decreased its value with respect to the control value (p < 0.05), with no statistically significant differences (p > 0.05) between the different quinoa pastes. Chroma (C_ab*), a measure of colour saturation, is proportional to the colour strength, and decreases when a* and/or b* decrease. In our case, quinoa paste addition (Table 3) significantly (p < 0.05) affected C_ab* values, and all the samples containing WQ, RQ and BQ pastes had lower C_ab* values than the control. Hue (h_ab) indicates the degree of change of the colour from red (low hue values) to yellow (high hue values). No statistically significant differences (p > 0.05) were found (Table 3) between the control sample and the WQ5%, WQ10%, RQ5% and BQ10% samples, although RQ10% and BQ5% had higher hue values, with no statistical differences (p < 0.05) between them.

Table 3 shows the effect of white, red and black quinoa seeds used as fat replacers on the textural properties of low-fat pork liver pâtés. The results obtained (Table 3) showed that the addition of quinoa paste affected hardness (p < 0.05) in a concentration-dependent manner. The control sample showed the lowest (p < 0.05) values, while WQ10%, RQ10% and BQ10% had the highest (p < 0.05) values for the same parameter, with no statistical differences (p < 0.05) between them. Similar results were obtained by Choe, Kim, Lee, Kim, and Kim (2013) for low-fat frankfurter-type sausage made using pork skin and wheat fibre. The reduction in fat increases the hardness due to the tighter connections among the meat particles and denser structure of the gel and pork skin, while Choi et al. (2009) reported that neither parameter was affected in low-fat meat emulsion in which pork back fat was replaced by vegetable oils and rice bran fibre.

**Lipid oxidation**

Lipid oxidation can have undesirable effects on the properties of meat and meat products since the process can alter sensory attributes such as colour, texture, odour and flavour as well as nutritional quality. Figure 2 shows the lipid oxidation values of low-fat pork liver pâtés with different concentrations of the quinoa pastes added as fat replacers. The TBARS values obtained for all samples analysed were within levels permitted for oxidative rancidity. Values over 1 mg MAD/kg sample indicate oxidative rancidity. The control sample showed the highest (p < 0.05) oxidation values with no statistical differences (p > 0.05) between WQ5% and RQ5%. For their part, WQ10%, RQ10%, BQ5% and BQ10% samples showed lower oxidation values than the control sample with no statistically significant differences (p > 0.05) between them. The lipid oxidation stability could be explained by the use of sodium ascorbate and sodium nitrite in the formulation of pâtés. Thus, the strong antioxidant effect of nitrite in cooked meat products is well known. Further, the decrease in TBARS values with increasing concentration of quinoa pastes might be due to the antioxidant activity of this quinoa flours by the effect of the bioactive compounds, such as phenolic acids, flavonoids and carotenoids present in their composition (Pellegrini et al., 2018). There are several scientific works which reported that the proteins from some legumes (soy, lentils and beans, amongst others) have antioxidant properties (Zou, Chang, Gu, & Qian, 2011).

The results obtained disagree with the scientific literature. Therefore, Zapata and De La Pava (2018) analysed the influence of quinoa flour on the oxidative stability of cooked meat product made with red tilapia fillet. These authors reported that the lipid oxidation was significantly affected by the concentration of quinoa flour. Thus, the lipid oxidation significantly increased with the addition of quinoa flour and the increase showed a steady trend. The samples containing 20 g/kg quinoa flour showed more lipid oxidation than those with 10 g/kg quinoa flour and the control sausages. On the other hand, Martín-Sánchez et al. (2013) studied the use of different levels of date palm in the formulation of pork liver pâtés, finding that the TBARS values in samples were date palm was added were lower than in control sample.

**Emulsion stability**

The percentage of total expressible fluid (TEF) measures the mixture of water and fat separated from the supernatant, to evaluate the possibility of exudates. Therefore, a higher TEF
### Table 3. Physicochemical properties of low-fat pork liver pâtés added with different concentrations of white, red and black quinoa seed pastes.

| Sample   | pH      | aw       | L*  | a*  | b*  | hab   | C<sub>ab</sub>  |
|----------|---------|----------|-----|-----|-----|-------|---------------|
| CNT      | 6.52 ± 0.02<sup>a</sup> | 0.928 ± 0.001<sup>a</sup> | 59.30 ± 1.25<sup>a</sup> | 7.51 ± 0.29<sup>a</sup> | 12.81 ± 0.43<sup>a</sup> | 59.61 ± 1.02<sup>a</sup> | 14.85 ± 0.44<sup>a</sup> |
| WQ5%     | 6.72 ± 0.04<sup>a</sup> | 0.935 ± 0.006<sup>a</sup> | 58.72 ± 0.95<sup>a</sup> | 6.99 ± 0.58<sup>a</sup> | 11.34 ± 0.38<sup>a</sup> | 58.34 ± 2.60<sup>a</sup> | 13.32 ± 0.12<sup>a</sup> |
| WQ10%    | 6.59 ± 0.01<sup>b</sup> | 0.931 ± 0.001<sup>a</sup> | 59.00 ± 0.92<sup>b</sup> | 6.92 ± 0.41<sup>b</sup> | 11.72 ± 0.44<sup>b</sup> | 59.44 ± 1.64<sup>b</sup> | 13.62 ± 0.49<sup>b</sup> |
| RQ5%     | 6.59 ± 0.01<sup>b</sup> | 0.936 ± 0.007<sup>a</sup> | 59.52 ± 0.92<sup>b</sup> | 5.26 ± 0.41<sup>b</sup> | 11.46 ± 0.44<sup>b</sup> | 65.34 ± 1.64<sup>b</sup> | 12.61 ± 0.49<sup>b</sup> |
| RQ10%    | 6.68 ± 0.01<sup>b</sup> | 0.936 ± 0.002<sup>a</sup> | 59.55 ± 1.15<sup>d</sup> | 5.27 ± 0.50<sup>c</sup> | 11.52 ± 0.71<sup>b</sup> | 65.41 ± 1.12<sup>b</sup> | 12.67 ± 0.83<sup>b</sup> |
| BQ5%     | 6.61 ± 0.02<sup>d</sup> | 0.927 ± 0.001<sup>a</sup> | 59.87 ± 1.11<sup>a</sup> | 6.61 ± 0.31<sup>a</sup> | 11.19 ± 0.56<sup>a</sup> | 59.42 ± 1.45<sup>b</sup> | 13.00 ± 0.55<sup>c</sup> |
| BQ10%    | 6.56 ± 0.01<sup>d</sup> | 0.926 ± 0.004<sup>a</sup> | 59.87 ± 1.11<sup>a</sup> | 6.61 ± 0.31<sup>a</sup> | 11.19 ± 0.56<sup>a</sup> | 59.42 ± 1.45<sup>b</sup> | 13.00 ± 0.55<sup>c</sup> |

**Textual parameters**

| Sample   | Hardness (kg) | Gumminess (g) | Cohesiveness | Springiness (mm) |
|----------|---------------|---------------|--------------|------------------|
| CNT      | 0.99 ± 0.08<sup>a</sup> | 78.20 ± 1.82<sup>a</sup> | 0.25 ± 0.03<sup>a</sup> | 3.08 ± 0.12<sup>a</sup> |
| WQ5%     | 1.96 ± 0.26<sup>a</sup> | 77.61 ± 1.73<sup>a</sup> | 0.25 ± 0.02<sup>a</sup> | 3.21 ± 0.09<sup>a</sup> |
| WQ10%    | 2.44 ± 0.08<sup>a</sup> | 77.30 ± 2.01<sup>a</sup> | 0.27 ± 0.01<sup>a</sup> | 3.25 ± 0.05<sup>a</sup> |
| RQ5%     | 1.82 ± 0.04<sup>b</sup> | 92.41 ± 5.10<sup>a</sup> | 0.26 ± 0.01<sup>a</sup> | 3.27 ± 0.06<sup>a</sup> |
| RQ10%    | 2.52 ± 0.29<sup>b</sup> | 99.81 ± 9.31<sup>a</sup> | 0.23 ± 0.02<sup>a</sup> | 3.29 ± 0.07<sup>a</sup> |
| BQ5%     | 1.81 ± 0.18<sup>b</sup> | 81.50 ± 2.80<sup>a</sup> | 0.21 ± 0.03<sup>a</sup> | 3.20 ± 0.06<sup>a</sup> |
| BQ10%    | 2.25 ± 0.02<sup>b</sup> | 86.30 ± 2.10<sup>a</sup> | 0.22 ± 0.01<sup>a</sup> | 3.27 ± 0.04<sup>a</sup> |

CNT: control pâté; WQ5% and WQ10%: pâté added with 5% and 10% white quinoa, respectively; RQ5% and RQ10%: pâté added with 5% and 10% red quinoa, respectively; BQ5% and BQ10%: pâté added with 5% and 10% black quinoa, respectively.

L*: lightness; a*: red-green coordinate; b*: yellow-blue coordinate; C<sub>ab</sub>*: Chroma; h<sub>ab</sub>: Hue.

Values followed by the same letter in the same column did not show statistically significant differences according to Tukey’s HSD post-hoc test (p > 0.05).
values means that emulsion stability is lower. The addition of quinoa seed paste at different concentrations in pork liver pâté had a significant ($p < 0.05$) effect on emulsion stability, as shown in Figure 3. The control sample containing pork dewlap and backfat and no quinoa seed pastes added had the highest ($p < 0.05$) %TEF values, followed by the samples in which part of the fat was replaced with black quinoa at 5% and 10%, with no statistical differences ($p > 0.05$) between them. The sample with WQ10% had the lowest ($p < 0.05$) %TEF values. The effect of quinoa paste could be due to retain more water, increasing pâté viscosity, reducing the expressible fluid. These results agree with those that reported by Choi et al. (2009), who found that a control batter elaborated with pork back fat and no added rice bran fibre resulted in higher %TEF than samples to which rice bran fibre had been added. Pereira, Zhou, and Zhang (2016) stated that the addition of rice flour at 4% and 6% improved the emulsion stability of emulsified sausages.

Figure 2. TBA values of low-fat pork liver pâtés added with different concentrations of white, red and black quinoa seed paste.
CNT: control pâté; WQ5% and WQ10%: pâté added with 5% and 10% white quinoa, respectively; RQ5% and RQ10%: pâté added with 5% and 10% red quinoa, respectively; BQ5% and BQ10%: pâté added with 5% and 10% black quinoa, respectively. Bars with different low case letters are statistically different according to Tukey’s HSD post-hoc test ($p < 0.05$).

Figura 2. Valores de TBA de los pâtés de hígado de cerdo bajo en grasas adicionados con diferentes concentraciones de pasta de semilla de quinoa blanca, roja y negra.
CNT: pâté control; WQ5% y WQ10%: pâté adicionado con 5% y 10% respectivamente de quinoa blanca; RQ5% y RQ10%: pâté adicionado con 5% y 10% respectivamente de quinoa roja; BQ5% y BQ10%: pâté adicionado con 5% y 10% respectivamente de quinoa negra.
Barras con diferentes letras minúsculas son estadísticamente diferentes de acuerdo con el test de Tukey ($p < 0.05$).

Figure 3. Emulsion stability of low-fat pork liver pâtés added with different concentrations of white, red and black quinoa seed paste. Values expressed as total expressible fluid percentage (TEF%).
CNT: control pâté; WQ5% and WQ10%: pâté added with 5% and 10% white quinoa, respectively; RQ5% and RQ10%: pâté added with 5% and 10% red quinoa, respectively; BQ5% and BQ10%: pâté added with 5% and 10% black quinoa, respectively. Bars followed by different low case letters are statistically different according to Tukey’s HSD post-hoc test ($p < 0.05$).

Figura 3. Estabilidad de la emulsión de los pâtés de hígado de cerdo bajo en grasas adicionados con diferentes concentraciones de pasta de semilla de quinoa blanca, roja y negra.
Valores expresados como porcentaje de fluido expresable (TEF%).
CNT: pâté control; WQ5% y WQ10%: pâté adicionado con 5% y 10% respectivamente de quinoa blanca; RQ5% y RQ10%: pâté adicionado con 5% y 10% respectivamente de quinoa roja; BQ5% y BQ10%: pâté adicionado con 5% y 10% respectivamente de quinoa negra.
Barras con diferentes letras minúsculas son estadísticamente diferentes de acuerdo con el test de Tukey ($p < 0.05$).
The scientific literature contains a high number of contributions dealing with the effect of potential functional ingredients such as fibre-rich products on emulsion stability of meat products. For example, Choi et al. (2010) informed that these ingredients increase the hydration properties and the fat holding capacity, reducing the fat and water losses whilst increasing the emulsion stability. In the same way, Wang, Wang, Li, Adhikari, and Shi (2011) described how the possible interactions that occur during processing between proteins and carbohydrates can also help to increase the stability of the emulsion. Furthermore, some polyphenolic compounds present in functional ingredients could react with some proteins and so stabilize the emulsion structure.

**Microbial counts**

No aerobic bacteria, *Enterobacteriaceae*, moulds and yeast were found in any of the treatments (control, WQ5%; WQ10%; RQ5%; RQ10%; BQ5%; BQ10%) probably due to the effectiveness of the cooking and the packing conditions during the storage time. It should be emphasised that the addition of quinoa seed pastes as partial fat replacer had no effect on the microbial counts. Thus, according to the microbial counts, in the given experimental conditions, the pork liver pâtés developed were safe and fit for consumption from a microbiological standpoint.
### Sensory evaluation

The results obtained for sensory evaluation of low-fat pork liver pâtés are shown in Figure 4a. No significant differences \( p > 0.05 \) were observed between the sensorial qualities of low-fat pork liver pâtés as regards rancidity, particle detection, cohesiveness, greasiness, salty and bitterness when compared with the control sample. For colour intensity, BQ10% and RQ5% had the highest \( p < 0.05 \) scores followed by WQ10% and the control sample, with no statistical differences \( p > 0.05 \) between them. WQ5% had the lowest values \( p < 0.05 \) for this descriptor. As regards brightness, BQ5%, WQ5% and RQ10% had the highest values \( p < 0.05 \) with no statistical differences \( p > 0.05 \) between them. There were differences between the appreciation of this property as measured by panellists and instrumental means, the panellists detecting higher brightness in these samples, while the instrumental measurement of \( L^* \) showed similar values for all the samples. In reference to aroma intensity, BQ10% RQ10% and the control sample showed the lowest \( p < 0.05 \) scores, with no statistical differences \( p > 0.05 \) between them. The panellists found RQ10% to be the hardest \( p < 0.05 \) sample, in agreement with the instrumental test, although their evaluations did not coincide with the instrumental values for the rest of the samples analysed. Thus, for the panellists, the softest \( p < 0.05 \) samples were the control and BQ10%, followed by WQ5% and RQ5%. For juiciness, RQ10% was perceived as the most juicy \( p < 0.05 \), while for the rest of the samples no statistical differences were found \( p > 0.05 \). These values obtained for juiciness indicated that the quinoa seed pastes retained the right amount of moisture and fat to ensure a juicy product.

Regarding general acceptance (Figure 4b), the lowest values were obtained for BQ5%, RQ10% and control sample with no statistical differences \( p < 0.05 \) between them. On the other hand, among the low-fat pork liver pâtés analysed, the most acceptable sample \( p < 0.05 \) was RQ5%.

### Conclusions

The use of plant-based flours, such as white, red and black quinoa pastes, is a good alternative in the development of reduced fat meat products. In particular, the substitution of pork fat with quinoa paste increased the healthiness of the product, reduced fat content and improved fibre content.

The use of quinoa pastes as novel ingredient appears to be a viable alternative in the meat processing industry due to (i) increased stability of the product because reduced the lipid oxidation and (ii) higher emulsion stability was obtained in samples with quinoa.

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