

Techno-Functional Properties of New Andean Ingredients: Maca (*Lepidium meyenii*) and Amaranth (*Amaranthus caudatus*)[†]

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Abstract: The use of flours derived from Andean products could be an alternative flour. Molecules with a potential beneficial effect on human health have been reported in maca (*Lepidium meyenii*) (dietary fibre, Mg, Ca, K, functional polysaccharides, etc.) and amaranth (*Amaranthus caudatus*) (squalene, linoleic acid, P, Ca, K, Mg, dietary fibre, etc.). However, from an industrial point of view, these new ingredients must be characterized in their techno-functional properties. The objective of this work was to analyze the techno-functional parameters of the amaranth and maca flours (NW) and whole (W) flours, in terms of water holding capacity (WHC, g/g), oil holding capacity (OHC, g/g), swelling capacity (SC, mL/g), foaming capacity (FC, %) and emulsifying capacity (EC, mL). The particle size of flours was also analyzed. The results indicated that the highest values for WHC were obtained in maca flour (NW) with 2.45 g of retained water/g of sample. The highest values of OHC were observed for NW flours (around 1.02 g of absorbed oil/g of sample). Meanwhile, for the variables FC and EC, the highest values were obtained for amaranth (NW) with 16.67% and amaranth (W) with 139.44 mL, respectively. Therefore, the results obtained allow us to consider the incorporation of these types of flours to different food products, knowing their effect on WHC, OHC, EC, and pH, and therefore being able to modify the processes concerning the traditional ones. This is especially interesting in the case of the meat products elaboration process in which these parameters could be critical, with the addition of these type of flours.

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1. Introduction

The Andean highlands are located in native areas over 4000 m altitude where crops show a significant resistance under hostile environmental conditions [1]. However, they have been associated to indigenous local Andean people due to the wisdom and extraordinary nutritional features [1]. Consumption of Andean highlands crops take place, in general, after heat treatment and milled. The most common treatments in amaranth (*Amaranthus caudatus*) and maca (*Lepidium meyenii*) cases are roasting and drying, respectively. However, maca is also consumed as a fresh food either [2,3]. Further, foods as soups, beverages, pasta, jams, puddings, and others have traditional manufacturing methods that

include Andean milled foods as ingredients in the formulations [2,4,5]. The high nutritional value and its contents of bioactive compounds have been demonstrated; this would allow conferring functional properties to the foods in which they are incorporated. Thus, it has been reported that maca has a low level of fat, high level of protein, up to 21%, with the presence of seven out of ten essential amino acids (2.2%), and is a source of minerals (Ca, Mg, K) [6]. It contains dietary fiber in a range of 15.6 to 26% [7]. Further, a wide variety of potential functional molecules included glucosinolates, functional polysaccharides, alkalamides [3,8], and antioxidant and anti-inflammatory compounds have been reported [9].

On the other hand, high amaranth's nutritional value is based mainly on minerals (P, Ca, K, Mg) [10], vitamins (E, B2, C), antioxidant compounds as polyphenols [11], dietary fiber (up to 20%), and protein (16%) levels. Essential amino acids lysine, methionine, and cysteine are contained in their amino acid profile [11,12]. Some studies indicate that amaranth oil contains cholesterol-lowering and anticancer precursors such as squalene (up to 8% of total unsaturated fatty acids) [12] and unsaturated fatty acids with a high $\Omega 6$ content that can range from 40 to 55% of the total unsaturated fatty acids [5]. Therefore, maca and amaranth are potential ingredients to enhance processed food formulations. However, the additional processes could promote different technological challenges, such as physicochemical, textural, sensory, and techno-functional deficiencies. In this context, the evaluation of the techno-functional properties of these potential ingredients is necessary to develop new processed food formulations. The aim of this work was to evaluate, and the main functional properties of wholemeal (W) and nonwholemeal (NW) maca and amaranth flours in terms of their adding processed food aptitude.

2. Materials and Methods

2.1. Plant Materials

Maca (*Lepidium meyenii*) and amaranth (*Amaranthus caudatus*) as wholemeal (W) and nonwholemeal (NW) flours were obtained from local markets in the Valencian community, Spain.

2.2. Techno-Functional Properties

The water holding capacity (WHC) and the oil holding capacity (OHC) were measured following the procedure of Wu et al. [13]. Briefly, 1 g of each flour was mixed with 10 mL of distilled water or oil and the mixture was vortexed for 1 min, allowed to stand for 30 min, and centrifuged at 5000 g for 30 min. Excess liquid was removed, the supernatant was decanted, and the pellet tube was weighed with retained water or oil. The results were expressed as the amount of water or oil retained per one gram of the sample. Both procedures were performed in triplicate for each sample. The solubility index (SI) was obtained by measuring the soluble components in the excess liquid from each WHC test. For this purpose, the samples were first dried at 70 °C (4 h) to avoid liquid projections and then a second drying step at 105 °C to a constant weight. The results were expressed as the amount of soluble compounds per gram of sample. The SI procedure was performed in triplicate for each sample.

Swelling capacity (SC) was determined following the method of Robertson et al. [14] with minor modifications. Briefly, 600 mg were weighted in a graduated tube, excess water was added, and the sample was dispersed with gentle stirring and then allowed to stand for 18 h. Results were calculated by volume sample difference, before and after water added, and expressed as mL/g of sample. The procedure was performed in triplicate for every sample.

Emulsifying capacity (EC) and emulsion stability (ES) were determined following the method of Sathe and Salunkhe [15] with minor modifications. Briefly, 250 mg of sample, 12.5 mL of water, and 1 mL of oil were homogenized with an Ultra-Turrax at the speed of 15,000 rpm/30 s. The oil addition was discontinued when an oil layer was observed de-

spite the mechanical stirring. EC results were expressed as mL of oil emulsified/g of sample. Meanwhile, it was allowed to stand for 24 h and then mL of water released were determined to express the ES (mL of water released/24 h). The SC and ES procedures were performed in triplicate for every sample.

Foaming capacity (FC) and foam stability (FS) were determined following the method of Shevkani et al. [16]. Briefly, the sample suspension (1% *w/v*, 30 mL) at 7.00 pH adjusted in a graduated cylinder was homogenized with an Ultra-Turrax at 15,000 rpm/2 min. FC was expressed as the percentage of increased volume. Meanwhile, it was allowed to stand for 30 min and then FS was determined and expressed as percentage remained foam. The FC and FS procedures were performed in triplicate for every sample.

2.3. Particle Size

Particle size was determined with dry method applied with Mastersizer 2000 equipment. It applies a low angle laser light scattering with a 466 nm length wave for determining the average particle size (D (4,3)). Results were expressed using nm as units. This procedure was performed in triplicate for every sample.

2.4. Statistical Analysis

A completely randomized design was used, and the results were analyzed by using a one-way analyses of variance (One-Way ANOVA). A Tukey's post hoc test was used to determine the differences between the mean values for different variables in each flour ($p < 0.05$). All these analyses were performed using Statgraphics Centurion XVII (Madrid, Spain).

3. Results and Discussion

The Figure 1 shows the results for the hydration-related parameters, water holding capacity (WHC). Solubility index (SI) and swelling capacity (SC) showed significant differences ($p < 0.05$) between all the samples, except for the SC where no significant differences ($p > 0.05$) were observed between the whole meal (W) and nonwhole meal (NW) maca flours samples. For all parameters, maca flours showed higher values than amaranth flours ($p > 0.05$). When comparing W and NW samples, the behavior fluctuated depending on the variable analyzed. For swelling capacity (SC), the values were of the same order in the case of maca samples ($p > 0.05$). For amaranth, the highest values were for W samples.

Values of hydration properties have been reported in different studies for maca and amaranth flours. For amaranth, the values reported were 3.48 (g/g), 5.07 (%), and 3.32 (mL/g) for WHC [17], SI [18], and SC [19], respectively, while for maca values reported were 8.39 (g/g), 20 (%) and 12.33 (mL/g) for WHC [20], SI [13], and SC [19,21], respectively.

The different results obtained in this work may be partially explained by the particle size of flours. Thus, small sizes have been related to an increase in hydration properties. It is due to a bigger surface area and volume pore. The results of particle size indicated that amaranth flours showed the mayor values of particle size, with significant differences ($p < 0.05$) between W flours, with a size of 327.17 ± 17.18 and 157.25 ± 3.57 μm for amaranth and maca, respectively. In contrast, NW flours showed insignificant differences ($p > 0.05$) between them, with size particles of 128.53 ± 1.45 and 128.08 ± 0.90 μm for amaranth and maca, respectively. Hydration variables indicate the interaction between flours and water; they are the result of hydrophilic and hydrophobic groups' balance. WHC has an impact on food formulations because it can be used to eschew syneresis effects, which is very important in meat products. Hence, controlling WHC allows modulating physicochemical properties related to the food texture [13]. In addition, other variables such as pH (5.26 ± 0.02 , 5.30 ± 0.01 , 6.54 ± 0.01 , 6.88 ± 0.02 for NW maca, W maca, NW amaranth, W amaranth, respectively), particle size, pore-volume, etc., weigh on hydration properties.

Oil holding capacity is the ability of powder ingredients for remaining oil while a gravity force can affect the flavor sensation and the mouthfeel. Furthermore, it depends on nonpolar groups' presence in terms of quantity and their interaction with fat [13]. This

parameter is related to other properties as the emulsifying capacity and its stability. Figure 2 shows that OHC values were higher ($p < 0.05$) for NW flours with respect to W ($p < 0.05$). These results agree with studies that point out the refined process as a cause of the increase of OHC [17,20,21]. Thus, NW maca flours with fiber-rich fractions and NW amaranth flour with protein-rich fraction presented OHC values 3.91 and 6.40 g/g, respectively. However, the results obtained in this work are similar to OHC values reported for other Andean flours, such as quinoa, with a range from 0.89 to 1.2 g/g depending on the variety plant [20–22].

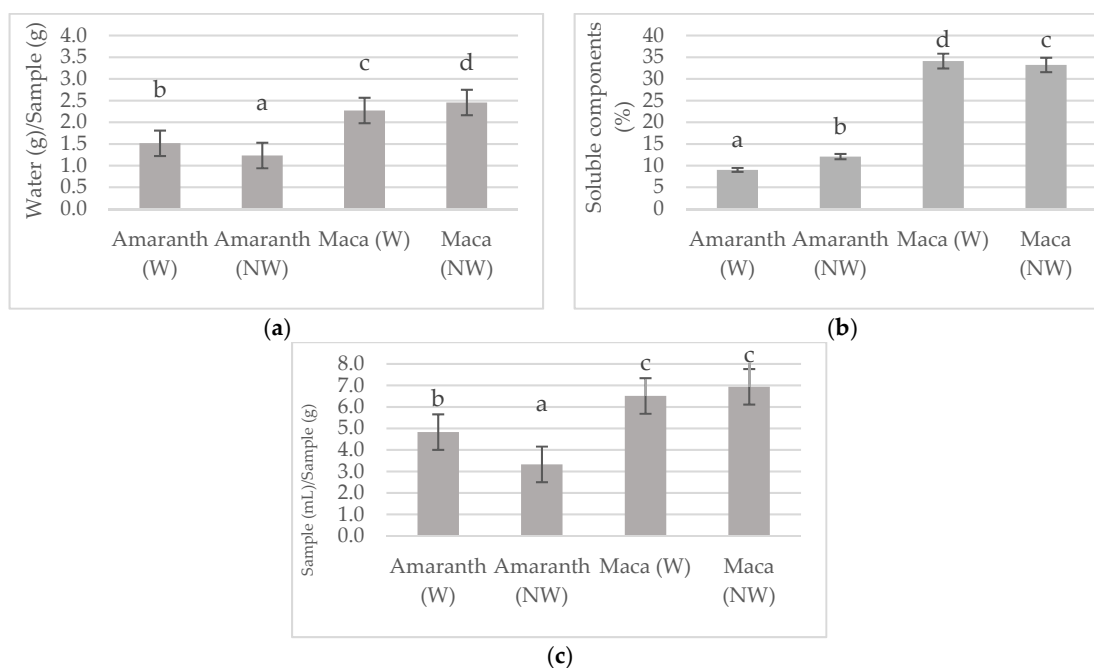


Figure 1. (a) Water holding capacity (WHC), (b) solubility index (SI) and (c) swelling capacity (SC) values of whole meal (W) and nonwhole meal (NW) maca and amaranth flours. * Means with the same letter do not differ significantly ($p > 0.05$).

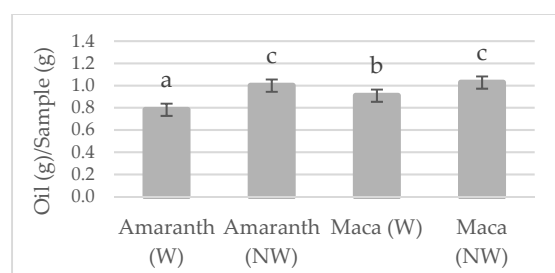


Figure 2. Oil holding capacity (OHC) values of W and NW maca and amaranth flours. * Means with the same letter do not differ significantly ($p > 0.05$). The results of the emulsion properties of studied flours are shown in Figure 3.

With respect to emulsifying capacity (EC), no significant differences were detected between NW amaranth and W maca ($p < 0.05$). W Amaranth flour presented the highest values, and NW maca presented the lowest. For the emulsion stability properties (ES), insignificant differences were detected between maca samples and amaranth W sample, in all cases, with values around 40 mL (water released at 24 h). On the other hand, ES values of amaranth NW were much lower. The values of the emulsion variables indicate the ability of the ingredients to reduce surface tension and facilitate the creation of stable structures over time, avoiding phenomena such as coalescence. Studies with flour and protein concentrate of *Phaseolus vulgaris* L. indicate values of EC of 39.6 and 72.6 mL of emulsified oil/g of sample and values of ES of 26 mL of released water/g, whereas with

protein concentrate the release of water was of 0 mL/g [15]. In this case, W amaranth flour showed higher values for EC than legume flours, whereas W and NW maca and amaranth NW flours display similar and lower values. Regarding ES, analyzed samples presented values higher than those indicated for legume flours, except NW amaranth whose values were slightly lower.

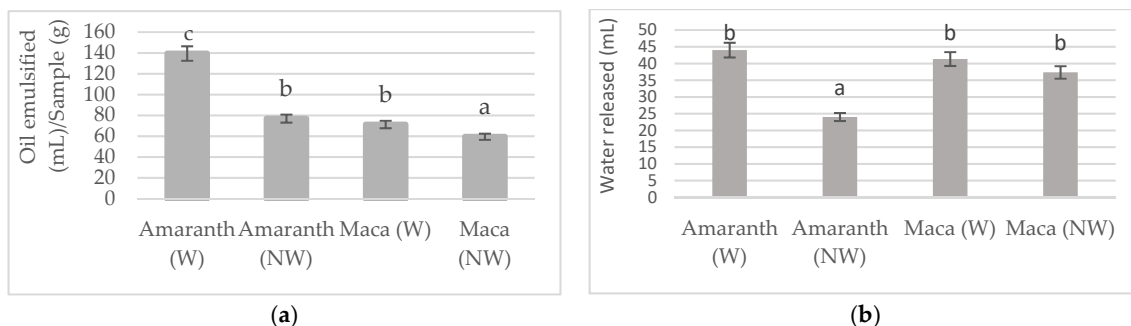


Figure 3. (a) Emulsifying capacity (EC) and (b) emulsion stability at 24 h (ES) values of whole meal (W) and non whole meal (NW) maca and amaranth flours. * Means with the same letter do not differ significantly ($p > 0.05$).

The results of foaming capacity (FC) and stability (FS) are shown in Figure 4. NW amaranth flour obtained the highest values for both properties with significant differences ($p < 0.05$), while for both properties the W and NW maca flours did not show significant differences ($p > 0.05$). The results observed for the FC variable in maca flours were similar to those mentioned for quinoa flour with values of the order of 9% FC. In the case of amaranth flour, these were somewhat lower. Regarding the variable FS, the values obtained differ from those mentioned for the quinoa (4%) [23]. However, quinoa flour has been suggested as a substitute for wheat flour in milkshakes due to its FC [24]. Therefore, the results obtained would allow considering the use of maca and amaranth flours W and NW in this type of products. In any case, it will be necessary to evaluate how the addition of amaranth and maca could modify a processed food since reformulations can change the appearance and other variables related to consumer expectations of a known food.

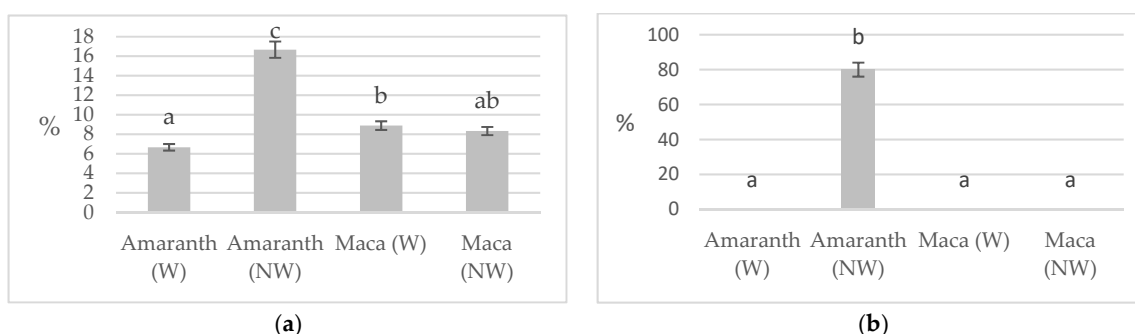


Figure 4. (a) Foaming capacity (FC) and (b) foam stability at 30 min (FS) values of W and NW maca and amaranth flours. * Means with the same letter do not differ significantly ($p > 0.05$).

4. Conclusions

The results obtained allow us to consider incorporating these types of flours to different food products, knowing their effect on WHC, OHC, and EC, and therefore being able to modify the processes concerning the traditional ones. This is especially interesting in the case of the meat products elaboration process in which these parameters could be critical, with the addition of these types of flours.

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