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Novel flours from leguminosae (*Neltuma ruscifolia*) pods for technological improvement and nutritional enrichment of wheat bread

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A R T I C L E I N F O

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A B S T R A C T

Wheat bread is widely consumed in many Western cultures (>70 kg/*per capita*/year) despite the fact that the flour milling process reduces the content of dietary fibre, vitamins and minerals resulting in baked goods nutritionally poor. *Vinal* (*Neltuma or Prosopis ruscifolia*) fruit is an American carob that can be grinded to obtain different fractions such as endocarp, seeds, residue and the whole pod flours. The objective of the work was to analyse the chemical compositions, colour and physical, functional and hydration properties of grinding fractions from *vinal* (*Neltuma ruscifolia*); and also, study their application in wheat bread and their effect on rheological, textural and organoleptic characteristics. The obtained flours showed to be a good source of proteins (>30% seed flour) and dietary fibre (>38% endocarp flour), with good physical and functional properties, denoting its suitability as promising novel ingredients for the design and formulation of nutritionally enriched wheat breads. The addition of *vinal* flours (5%) in replacement of wheat flour in a traditional bread significantly affected the rheology, giving as results less extensive doughs. The bread loaf showed a lower specific volume, and firmer and darker colour with brown tone crumbs. Sensory analysis revealed a good degree of acceptance for the enriched breads (with the best values for residue flour) suggesting that these novel flours would be suitable as ingredients for bakery products with good nutritional profile.

1. Introduction

The baked goods represent an essential constituent of the human diet all over the world, being a foodstuff with the largest consumer *per capita*. The new trends in this segment are focused on the development of new functional ingredients that could be able to satisfy the consumers' preference related to healthier diet habits [1,2].

In the production of traditional bread the fundamental raw material is the wheat flour, which type and quantity of gluten proteins as well as other components determine its characteristics [3]. The gluten network gives unique viscoelastic properties and gas

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retention capacity to the dough, having an important role in the texture and final appearance of the product. From a technological point of view, these properties are affected when other ingredients are incorporated, and that is why it is important to study how the replacement of wheat flour by other alternative flours affects the rheological, textural, and sensory characteristics. From a nutritional perspective, one of the challenges to produce functional bakeries is to enrich with alternative flours to enhance the protein profile as well as the bioactive compounds content [2,4]. Some ingredients have already been used to nutritionally enrich wheat bread, showing good sensory acceptance: from the Apiaceae family, cumin *(Cuminum cyminum* L.*)*, caraway *(Carum carvi* L.*)* [5], and fennel *(Foeniculum vulgare* L.*)* [6] for flours from seeds/by-products; from the Lamiaceae family, chia seed (*Salvia hispanica*) powder and defatted cake [7]; and of the Fabaceae family, chickpea *(Cicer arietinum* L.*)*, at 24% with the addition of 16% milk powder [8]. However, it is important to take into account that supplementation of wheat bread with pericarp cereal layers or other raw materials, even in small quantities 1–2%, can have a detrimental effect on dough volume, loaf volume and, therefore, in the good quality of the bread [9]. Legumes are naturally rich in fibre, protein, carbohydrate, B vitamins and minerals. Several anti-nutritional compounds, such as trypsin inhibitor, phenolic compounds, phytates, cyanogenic compounds, lectins and saponins are also found in the legumes; however are susceptible of being improved by simple processing such as dehulling, soaking, cooking, germination and/or fermentation [10]. Although the serving size recommendations for legume consumption varied widely around the world, the consumption of legumes in most countries is below the dietary recommendation, with a low inclusion of varieties in the diet [11]. Therefore, the use of flours from other varieties such as *Prosopis* spp. to enrich wheat bread could be a good strategy to improve consumers' eating habits.

The *Prosopis* genus belongs to the leguminous (*Fabaceae*) family, and the pods are fruits formed of 70–75% pericarp (epicarp, mesocarp, and endocarp) and 25–30% seeds (episperm, endosperm and cotyledons). Actually it has been divided into four new genera: *Anonychium*, *Prosopis*, *Strombocarpa* and *Neltuma* [12]. The *P. ruscifolia* has been included in the latter.

The underutilised legume *Prosopis* spp. contains a high amount of carbohydrates, mainly fibre and soluble sugars, and proteins [13]. These pods have been also found to be a source of lysine amino acid, and bioactive compounds with antioxidant, anti-inflammatory and antihypertensive activities [2,14]. For instance, the mesquite flour from *P. alba* Griseb (actual *Neltuma alba*) has been studied as a wheat flour replacer (15–35%) in bread making, and in a *"panettone-like"* bread [15,16]. The effect of a commercial carob flour on dough properties has also been analyzed showing a significant effect on specific volume, rheology and texture at initial stages of storage of composite breads [17]. *P. pallida* (actual *Neltuma pallida*) was tested in bread formulation as a partial replacement of wheat flour (0–15%). Its addition increased the nutritional value without changes in hardness crumb of composite breads [18]. The *vinal* or *P. ruscifolia* (actual *Neltuma ruscifolia*) is a very abundant tree in the centre east of South America, and the flours obtained from its pods have an interesting nutritional profile of macro and microcomponents with potential benefits in human health [19]. In addition, other authors reported that no toxic compounds have been detected in the whole fruit or pods of *Prosopis* spp. while it is consumed regionally as traditional foods such as patay (bread), aloja (alcoholic beverage) and añapa (sweet non-alcoholic beverage) since ancient times [20,21]. The seed flour of *vinal* has been studied in a gluten free bread improving the nutritional and sensory characteristics [22]. However, to our knowledge, a complete physicochemical characterization of the flours obtained from *vinal* pods and their application as ingredients in a traditional wheat bread has not been reported so far.

The objective of the present work was to study the physicochemical properties of different grinding *vinal* flours and how the dough characteristics and bread quality are modified by the addition of 5% of these *Neltuma ruscifolia* flours to a traditional wheat bread formulation.

2. Method

2.1. Obtention of vinal flours

Vinal pods were collected in Formosa province (Argentina, 2014). They were washed in chlorine water (1%, v/v- 1 h) and dried at 50 °C for 5 h using a food dehydrator (FA10-MZ, COBOS, Argentina). A laboratory knife mill (HC–1000Y, Arcano, China) was used to obtained the different fractions by sieving: residue flour (RF -containing epicarp and mesocarp) was separate from the seeds with their endocarp, which needed a second milling process obtaining: endocarp flour -EF- and seed flour –SF–. The separation of these latter fractions were manually done. Additionally, the pods were fully grounded to obtain the complete pod flour (PF). All flours were sieved until the granulometry was <840 μm (A S.T.M. N°170, ZONYTEST, Argentina) and, stored at −30 °C until use whithin 30 days. Other materials used were Food Grade and they were obtained in the local market.

2.2. Physicochemical, functional and hydration properties

Crude protein content was determined by the Kjeldahl method (AOAC 984.13, 2005) using the nitrogen to protein conversion factor of 5.75 for vegetable proteins; lipids remaining by Soxhlet method (AOAC 923.05, 2005); total dietary fibre by the gravimetric-enzymatic method (AOAC 992.16, 2005); and ash content in a muffle furnace at 550 °C (AOAC 936.07, 2005). Total non-fibre carbohydrates were determined by difference. The moisture content was determined by drying at 100 °C until constant weight (AOAC 925.10, 2005).

The bulk density (δb) was determined by measuring the volume of a weighted sample in a 15 mL graduated cylinder and the tapped density (δt) was the measurement after a vortex for 1 min. The Hausner ratio (Hr) indicates interparticle friction in powders or cohesiveness, where values close to 1 indicate good fluidity and higher values indicate high interparticle cohesion, which reduces flow properties. Hr is calculated as the ratio between δt and δb. On the other hand, the flowability can be defined by the Carr Index (CI, Eq. (1)) considering the following scale: <15 very good, 15–20 good, 20–35 fair, 35–45 bad, >45 very bad [23].

$$C_I = \frac{(\delta_T - \delta_B)\, x100}{\delta_T} \tag{1}$$

The oil-holding capacity (OHC), and hydration properties such as water holding capacity (WHC) and water retention capacity (WRC) were determined according to Genevois and de Escalada Pla (2021) [24].

2.3. Alveographic parameters and viscoelastic properties

Alveographic determination was done according to ISO 5530–4:1991 using a Chopin alveograph (Chopin, France). A volume (151.7–129.4 mL) of NaCl solution (2.5%) was added to 250 g of flour according to the water content (9–14%). Tenacity (P), extensibility (L), proportional number (P/L), and dough deformation energy (W) were measured in five proves of each flour mixture. For dynamic rheology the doughs were prepared as in the alveograph assay and 50 mm diameter round probes were cut. The oscillatory method was done according to Busch et al. (2018) using a shear control rheometer (PaarPhysica MCR 300, AntonPaarGmbH, Austria) with a 30 mm diameter parallel plates geometry and 2–3 mm gap [25].

2.4. Fermentation curves of bread dough and specific volume of loaves

The optimal fermentation time (OFT) was calculated using the Boltzmann sigmoid equation (Eq. 2). The OFT was estimated when the dough reached ¾ of the maximum volume [15].

$$Y = Y_0 + \frac{(Pv - Y_0)}{1 + e^{\frac{(V_{50} - X)}{S}}} \tag{2}$$

where Y represents the increment of dough volume (mL), Y_0 is the minimum sigmoid value (mL), Pv is the maximum sigmoid or volume value (mL), X is the fermentation time (min), S is the curve slope and, V_{50} is a parameter relative to the curvature of the sigmoid. Average and standard deviation of two independent samples are reported in results.

Specific volume (SV) was calculated as the ratio between a bread loaf volume (mL) obtained by displacement of rapeseeds and the bread loaf weight (g) [24].

2.5. Bread making process

A bread traditional recipe was used and the wheat flour was replaced by the 5% of each *vinal* fraction (RF, EF, SF and PF). Solid ingredients were wheat flour (Morixe, Argentina), salt (2%), and fresh yeast (3%). The system with 100% of wheat flour was the control. The water hydration of doughs was performed according to Bigne et al. (2016) (59.1% control system and 58.2% for *Prosopis* spp. dough) [15]. All ingredients were mixed 1 min (stand mixer, Moulinex, Brazil). Dough pieces (~60 g) were fermented at 30 °C and 75% HR in a chamber (Memmert, Germany) according to its OFT (section 2.4.), and finally baked (40 min at 180 °C) in an electric oven (Beta 21, Pauna, Argentina). The loaves were kept 60 min at room temperature and packed in sealed polypropylene bags. Analytical measurements were made within 24 h.

2.6. Texture profile analysis (TPA) of bread

TPA of composite crumb breads was performed using a texturometer (Model 3345, Instron, USA) using the method described by Genevois and de Escalada Pla (2021) [24]. Texture parameters of hardness (N), chewiness (N) and springiness (dimensionless) were calculated from TPA plot Force (N) vs Extension (mm) using the Bluehill Lite software (v 2.4.1, USA).

2.7. Colour

The colour of *vinal* flours and crumb breads were measured using a colorimeter (MiniScan EZ, HunterLab, USA) under the illuminant D65 and with an observer angle of 10°. Results were expressed in the CIEL*a*b* colour space.

2.8. Sensory evaluation

Sensory evaluation of breads with 5% of SF, EF, RF and PF was performed with consumers using a 9-point structured hedonic scale. In accordance with the International Guidelines the informed consent was given prior to sensory evaluation to eighty randomly selected volunteers (n = 80) [26]. A portion of bread slice coded with a three-digit random number was offered to panellists in an individually partitioned booth. They were instructed to rinse their mouths with water, eat a cracker and smell grain coffee between samples to avoid carryover effects. They were guided to evaluate the samples judging the overall acceptance and specific attributes such as colour, texture and odour.

2.9. Statistical analysis

Statistical analysis of results was performed through ANOVA for a level of significance (α) of 0.05 followed by LSD Fisher *post hoc* test to identify significant differences among systems. All statistical analysis and regressions were performed using the Statgraphics Centurion XV software (V 2.15.06, 2007, Statpoint Technologies, Inc., USA).

3. Results and discussion

3.1. Physicochemical, hydration and functional properties of vinal grinding fractions

The grinding of *vinal* pod presented a yield of 61, 31 and 8% for the RF, EF, and SF, respectively. In Table 1 are detailed the macro components contents of *vinal* grinding flours. The carbohydrates represented the major component in all flours, being the RF the fraction with the highest value. The content of proteins and lipids were 2.4 and 1.9 fold-higher in SF, similarly to other *leguminosae*; besides, this fraction has been reported as a good source of essential lysine amino acid and fatty acids, mainly linoleic and oleic acids [27].

The EF presented the highest values of dietary fibre, followed in decreased order by the SF and RF (21.1 ± 0.2g/100 g). The highest content of dietary fibre observed in PF is because this grinding fraction includes the whole pod of *vinal*. It is worth noting that fibre is composed of a variety of components with different physicochemical characteristics. In particular, the *Prosopis* spp. seeds contain 45% of endosperm with galactomann gum, which corresponds to the soluble fibre [28]. While the other flours fractions, the major proportion correspond to the insoluble fibre (data not shown) [18].

Freyre et al. (2003) have studied the macrocomponents in *vinal* grinding fractions [19]. Similarly to the results obtained in this work, they reported a protein content of 33.8% (seed fraction), 12.7% (whole pod) and 10.5% (RF-like pulp fraction) and slightly higher values for lipid content (5.9%, 4.3 and 5.6%, for seed, pod and pulp, respectively). In addition, other authors have studied flours from *P. ruscifolia, P. laevigata* and *P. alba*, whose protein and lipid contents were similar to those obtained here in Refs. [29–31].

In Table 1 are also shown the hydration, functional and physical properties. The WRC and WHC represent the proportion of water retained in the capillary structures of the fibre, strongly or weakly linked, respectively [24]. As shown in Table 1 the EF and RF were the flours with the highest WRC and WHC, possibly due to the fibre content (Table 1). De Gusmão et al. (2016) have reported a good water binding capacity of *P. juliflora* flour similarly to *vinal* flours [32]. The SF presented the lowest values of WRC and WHC, probably due to its different type of fibre that could lead to a different dough behaviour [33]. The EF, RF and PF fractions presented slight but significant variations in the OHC. As regards the CI, although there are some differences, all flours have good flowability with values < 1.5. Hr values close to 1.0 indicate that these flours have low cohesiveness and consequently good fluidity. Between them, RF has better flow properties, lower CI and Hr.

The physicochemical properties of novel flours provide information about its applications as food ingredients or additives, being of great interest for the food industry. Besides, they may be associated with benefits in health consumers [24].

3.2. Optimal fermentation times of bread dough added with vinal and loaf specific volume

Fig. 1 shows the fermentation curves of doughs with 5% of *vinal* fractions. The Boltzmann sigmoidal parameters (R2>96.7) showed some differences between flours. S (curve slope) values were: 12 ± 1 (control), 26 ± 2 (SF), 15 ± 0.4 (EF, PF), and 21 ± 4 (RF); and the

Table 1
Macro components composition, and Hydration, Functional and Physical Properties of *vinal* (*Neltuma ruscifolia*) grinding fractions.

	SF	EF	RF	PF
Chemical Composition				
Carbohydrates	35 ± 2^{c}	35 ± 3 ^{bc}	53 ± 4^{a}	41 ± 5^{b}
Proteins	30.6 ± 0.7^{a}	11.8 ± 0.3^{b}	10.2 ± 0.2^{c}	12.8 ± 0.7^{d}
Lipids	4.6 ± 0.1^{a}	2.1 ± 0.1^{b}	2.4 ± 0.1^{c}	2.4 ± 0.1^{c}
Total Dietary Fibre	20.9 ± 0.1^{a}	38.6 ± 0.4^{c}	21.2 ± 0.1^{a}	31.1 ± 0.1^{b}
Ash	3.2 ± 0.1^{c}	3.9 ± 0.2^{b}	4.5 ± 0.4^{a}	4.1 ± 0.3^{a}
Water	5.9 ± 0.3^{b}	8.9 ± 0.1^{a}	8.9 ± 0.4^{a}	8.7 ± 0.4^{a}
Hydration Properties				
WHC	4.8 ± 0.1^{d}	8. 0 ± 0.1^{b}	8.4 ± 0.3^{a}	6.2 ± 0.2^{c}
WRC	4.4 ± 0.1^{d}	8.6 ± 0.1^{a}	6.7 ± 0.1^{b}	5.3 ± 0.2^{c}
Functional Properties				
OHC	0.67 ± 0.01^{d}	1.42 ± 0.04^{b}	1.35 ± 0.01^{c}	1.49 ± 0.02^{a}
Physical Properties				
Hr	1.20 ± 0.04^{b}	1.20 ± 0.07^{a}	1.10 ± 0.06^{c}	1.10 ± 0.03^{c}
CI	12.9 ± 0.6^{b}	14.3 ± 0.6^{a}	9.1 ± 0.6^{c}	13.0 ± 0.6^{b}

SF: seed flour; EF: endocarp flour; RF: residue flour; PF: pod flour.
WHC: water holding capacity; WRC: water retention capacity; OHC: oil holding capacity; Hr: Hausner ratio; CI: Carr Index.
Mean values ± standard deviation are expressed as percentage (n = 2).
Different letters mean significant differences between flours (p < 0.05).

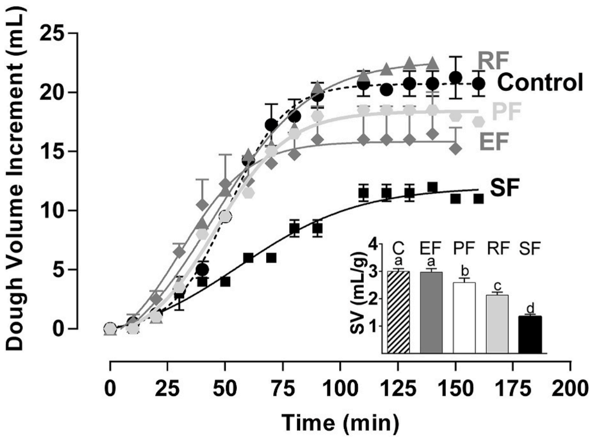

Fig. 1. Fermentations curves of doughs with wheat flour (control) and with 5% of *vinal* (*Neltuma ruscifolia*) milling fractions. Inset: Specific volume of loaves.
SF: Seed Flour; EF: Endocarp Flour; RF: Residue Flour; PF: Pods Flour.

V_{50} (curvature of the sigmoid) values were: 52 (control, SF), 31 (EF), and 48 (RF, PF). In general, *vina*l reduced the Pv in a range of 43–12% with respect to the control system (Pv values were 21, 12, 16, 22.7 and 18.4 mL; for control, SF, EF, RF and PF, respectively). In consequence, a significant increase in the OFT for the SF (88 min), RF (73 min) and PF (67.3 min) was observed; possibly due to the presence of fibre components that interrupt either the gas cell distribution and retention, or the gluten network formation [18]. In the case of EF, although a reduction in Pv was observed, the OFT (OFT EF = 49.9 min) was lower than the control system (OFT control = 65.0 min) possibly due to changes in dough matrix produced by other components that could produce more extensibility and gas retention in less time [18,34] (Bravo et al., 1998; Gonzales-Barron et al., 2020). As a consequence of the lower Pv of the doughs, the SV of the breads was also reduced when adding vinal flours, except for EF (with the worst effect for SF) (inset Fig. 1). This could be explained by the presence of other components that interfere giving a weak network that could not retain carbon dioxide during proofing and baking [24,35] (Autio, 2006; Genevois and de Escalada Pla, 2021). Similar results have been reported by Ref. [15] Bigne et al. (2016) in wheat-mesquite (*Prosopis alba*) mixtures at different levels of wheat replacement (15–35%) in bread making.

3.3. Viscoelastic properties and alveographic parameters of dough

Comparing the mechanical spectra obtained by means of frequency sweep tests it can be seen as mainly solid viscoelastic and the typical weak gel behaviour was confirmed in all doughs (data not shown). Comparing the different elastic modulus for different flours at 10.7 Hz, the SF showed higher values (G' = 50 ± 20 kPa) than the other *vinal* flours and the control (G' = 4.8 ± 0.7 kPa). This solid character increase could be associated with the presence of high molecular weight polymers in the seed endosperm [28]. Other authors have shown that hydrocolloids modify dough rheology [33]. Considering commercial carob, the 30% *Prosopis* spp.-wheat mixture also showed a higher solid character in dough [17].

Table 2 shows alveographic parameters. In all cases, the addition of *vinal* decreased the L parameter. It was observed that only SF increased the P and the W. This may be related to the more solid character of the dough observed in the oscillatory assay and the high gum content in SF [28]. This gum would provide to the gluten network additional consistency and strength. Kim et al. (2008) reported an increase in P and stability of wheat dough containing hydrocolloids [36]. In all *vinal* flours L was reduced and P/L was higher than the control. These vinal-wheat-mixtures would be classified as high tenacity flours (P/L > 1.2). Other authors have already reported that the addition of fibre causes a decrease in L and, consequently, an increase in P/L [37]. These changes are generally related with the decrease in gluten content and interruption of protein network by the fibre. Nevertheless, Ribota et al. (2005) proposed that the gluten

Table 2
Alveograph parameters of wheat flour (control), and of 95% wheat flour with 5% of SF, EF, RF and PF (*Neltuma ruscifolia* grinding fractions).

Systems	$P_{(mm\ H2O)}$	$L_{(mm)}$	P/L	W_{10}^{-4}
Control	136 ± 9 ^{bc}	110 ± 7^{a}	1.2 ± 0.1^{d}	500 ± 30^{b}
SF	203 ± 13^{a}	85 ± 5^{b}	2.4 ± 0.1^{c}	605 ± 36^{a}
EF	145 ± 9 ^{bc}	43 ± 3^{c}	3.4 ± 0.2^{a}	245 ± 15^{d}
RF	127 ± 8^{c}	45 ± 3^{c}	2.8 ± 0.2^{b}	259 ± 16 ^{cd}
PF	138 ± 10^{b}	48 ± 4^{c}	2.9 ± 0.2^{b}	284 ± 17^{c}

SF: seed flour; EF: endocarp flour; RF: residue flour; PF: pod flour.
Tenacity (P), extensibility (L), proportional number (P/L), and dough deformation energy (W) are informed.
Mean values ± standard deviation are expressed as percentage (n = 4).
Different letters mean significant differences between systems ($p < 0.05$).

proteins compete for the hydration water with other proteins or interact with them making them less available [38]. This could be the case of SF wich protein content is high (30.6 ± 0.7). When comparing *P. ruscifolia* flours with *P. juliflora* (hole pod flour) a 5% of addition showed similar values for P (127 ± 1.4mmH_2O) and slightly lower L and W (38 ± 5.7 mm, and 211 ± 16±10^{-4} J, respectively) [32].

3.4. Colour and texture parameters of dough bread added with vinal

The CIELab* colour parameters of *vinal* flours are shown in Fig. 2a. As it can be seen SF was the most luminous (L*) fraction and the RF was the darkest fraction. The RF contains the epicarp which is the first external barrier rich in polyphenol compounds explaining in part its darker colour. Other authors already related the darker colour to a higher content of polyphenols (*P. nigra,* [28] Díaz-Batalla et al., 2018; *P. laevigata,* [39]. The EF, RF and PF showed positive values for a* (red) and b* (yellow), presenting brownish tones. The SF showed the lowest values of a* and b*, and the highest value of luminosity, indicating a significant difference in colour from the rest of the flours. Fig. 2b shows the colour parameters of the crumb breads with the addition of *vinal* (loaves and slices images can be seen at Fig. 4b). In general, the presence of these flours lead to crumb with darker colour (lower values of L*). Particularly, there was a significant increase in ~~the values of parameter~~ a* with the addition of RF and PF.

It is worthy to note that this change is not only due to *vinal* flour colours but to flours components: a higher carbohydrate content in RF and PF could promoted a non-enzymatic browning during baking [40] (Table 1). Similar colour changes were also reported in a traditional bread with the addition of *P. alba* [15].

Fig. 3 shows the texture of breads with addition of 5% of *vinal* recording the hardness, chewiness and springiness from TPA. The maximum force that occurs during the first compression of a bit represents the hardness of the bread crumb, and it was not modified ($p > 0.05$) by the addition of EF, RF or PF, presenting similar values to the control system (27±3 N). Nevertheless, the bread with SF presented a hardness 2 fold-higher than the rest of the systems. The behaviour of SF confirmed the particularity of this flour already observed by a higher P and a more solid character, in the alveographic and oscillatory rheology studies, respectively. Some authors proposed that for baking processes with long fermentation times and in order to gain strength it could be desirable to use components (as those present in the SF) as dough fortifiers [33].

As expected no changes were observed in the chewiness of breads added with EF, RF and PF. Then, the 5% of these *vinal* flours used to replace wheat flour in the present study would not modify the crumb texture of breads. On the other hand, and in agreement with the changes observed in hardness when SF was added, the chewiness increased. Furthermore, the springiness (related to the loaf freshness) was reduced when SF was included in the formulation. Meanwhile, the EF, RF and PF presented springiness values similar to the control system.

The substitution of wheat flour by mesquite flour (*Prosopis* spp.*)* in bread making has already shown differences in texture behaviour [15,17,18]. These differences reported could be possibly due to the presence of galactomannan gum, and the binding water

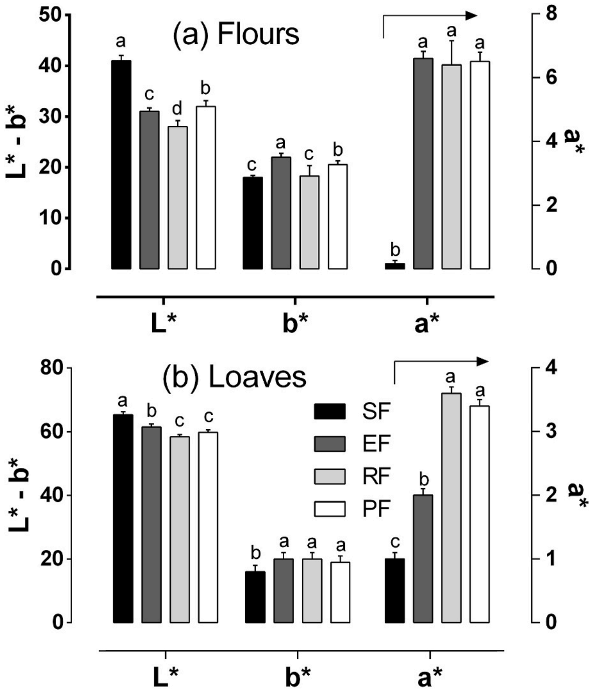

Fig. 2. CIELab* colour parameters for flours (a) and loaves with 5% of *vinal* flours (b): Seed Flour (SF-black), Endocarp Flour (EF-dark gray), Residue Flour (RF-light gray), Pods Flour (PF-white).

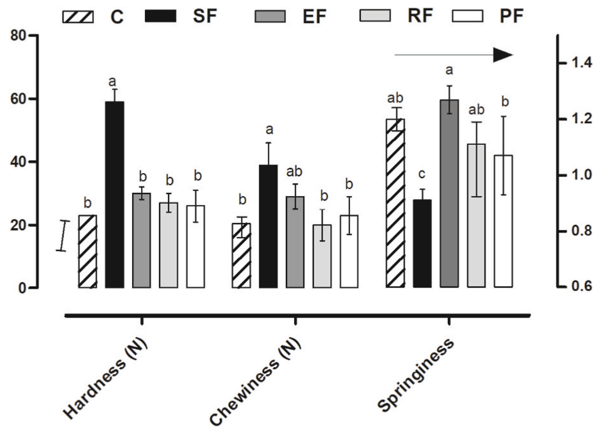

Fig. 3. Texture Profile Analysis parameters of crumb breads with wheat flour (control) and with 5% of vinal (*Neltuma ruscifolia*) grinding fractions. C: control; SF: Seed Flour; EF: Endocarp Flour; RF: Residue Flour; PF: Pods Flour.

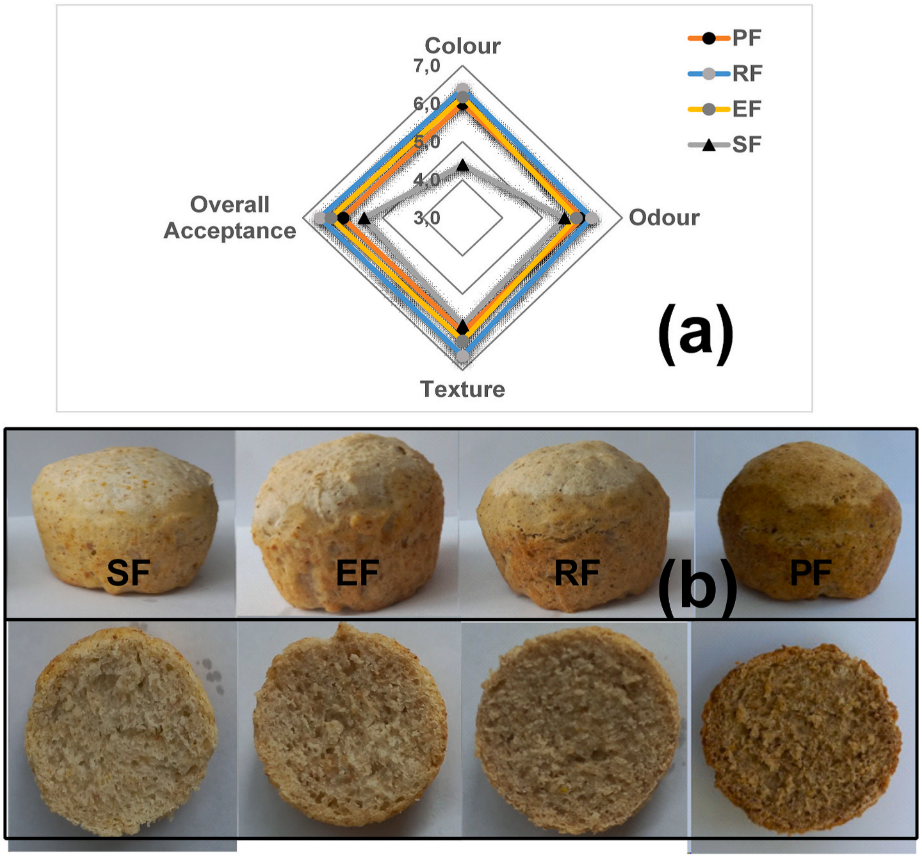

Fig. 4. Sensory evaluation (a) and loaves and slices images (b) of breads with 5% of vinal flours (Neltuma ruscifolia). In the sensory evaluation, a 9-point structured hedonic scale was used (the range 3–7 is shown, Fig. 4a.).
SF: Seed Flour; EF: Endocarp Flour; RF: Residue Flour; PF: Pods Flour.

capacity of some compounds from fibre [24,41,42]. To our knowledge, no reports have been found about the effect of *vinal* grinding fractions on bread texture.

3.5. Sensory acceptance of breads added with vinal

There is a diversity of alternative raw materials that could be considered as healthy novel ingredients and could be an interesting solution to enrich nutritionally baked goods. However, their organoleptic characteristics should be accepted for consumers. In Fig. 4a are present the results of overall acceptance and specific attributes as colour, odour and texture, obtained from Hedonic Test in regular consumers. The colour of breads with 5% of PF, RF and EF *vinal* flours were similarly appreciated by panellists receiving a punctuation >6 in a 9-point hedonic scale. However, the addition of SF reduced ($p > 0.05$) the punctuation received in this parameter (4 ± 2 in a 9-point hedonic scale). The odour, texture and overall acceptance of breads with *vinal* showed a similar tendency, having better classification the RF, PF, and EF ("like slightly") with respect to the SF ("dislike slightly").

3.6. Nutritional considerations

The present study showed that replacement of wheat flour by 5% of different *vinal* grinding flours in bread formulation, in general, did not modify the texture, but significantly change the colour resulting in a colourful, with good odour and sensory acceptance. From a nutritional view point, the addition of 5% *vinal* SF, EF, RF and PF in a traditional wheat bread recipe would provide 4.2, 4.7, 4.2 and 4.5 g of dietary fibre per two serving size (100 g), respectively (wheat bread 3.5 g fibre/100 g). In addition, SF, EF, RF and PF breads would contribute with 51.3, 40.7, 52.0 and 51.6 (52.3 g carbohydrates/100 g control bread); 2.1, 1.7, 2.1, and 2.1 (2.1 g lipids/100 g control bread) and 8.6, 7.9, 7.8 and 7.9 (7.8 g proteins/100 g control bread) for 100 g. Therefore, the consumption of two serving size (100 g) would contribute 16.8–18.8% and 11.0–12.4% of the daily dietary fibre intake in women and men, respectively, aged 18–50 years [43]. It is interesting to note that *leguminosae* proteins such as those from *Neltuma ruscifolia* have higher biological value than the lysine deficient cereal ones. This dietary fibre and protein contribution to the diet is poorer in the counterpart wheat bread (control bread).

4. Conclusion

This first report evaluates the applicability of these novel flours in the formulation of wheat-5% *vinal* bread. It is important to highlight that each *vinal* grinding fraction showed some differences that could be exploited: RF had darker colour, high carbohydrates content (53%) and the best fluidity properties; SF had higher protein (30.6%), and it modified the rheology and texture, interesting characteristics for long fermentation doughs; EF showed higher total dietary fibre content (38.5%) keeping loaf volume and texture characteristics and, PF had good colour and the easiest grinding process. However, there are some limitations of the present study since more studies would be necessary for a greater *vinal* flour addition, different bread formulations or a different genetic/geographical origin of the raw material. It can be concluded that the incorporation of *vinal* flours led to a bread of good nutritional, textural and sensory quality. In addition, as each of the obtained flours presented particularities, depending on the industrial or consumer requirements, one or another fraction can be chosen, or combined, to design a specific wheat-vinal. Moreover, the *vinal* flours studied in the present work showed an interesting alternative to improve the nutritional value of high-consumption cereal products such as wheat bread (4.2–4.7 g of dietary fibre per 100 g with 5% *vinal*). These innovative ingredients with good acceptance by consumers expand and diversify the offer in the food market to satisfy the needs of consumers.

Author contribution statement

Lourdes Ojeda: Performed the experiments; Analyzed and interpreted the data.

Carolina Elizabeth Genevois, Veronica Maria Busch: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Data availability statement

Data associated with this study has been deposited at https://drive.google.com/drive/folders/1lW4VPne28TpNHTDrEjFlCkVbjwTdzCK5?usp=sharing.

Ethic Committee

Considering the Sensory evaluation carried out in the "Novel flours from leguminosae (*Neltuma ruscifolia*) pods grinding for technological improvement and nutritional enrichment of wheat bread" research work we want to take in consideration the following:

The approval statement through an Ethical Committee is not applicable in this case because in our country sensory tests doesn't require ethical approval. Besides, there were neither children nor elderly subjects among the panellists and there was no risk assessment. In addition, all panellists were volunteers and the informed consent was gave prior to its participation in the sensorial sessions as recommended by international guidelines (https://www.ifst.org/membership/networks-and-communities/special-interest-groups/sensory-science-group/ifst-guidelines).

On the other hand in the institution where the sensory evaluation was carried out (Facultad de Bromatologia, Universidad Nacional de Entre Ríos), the Ethic Committee is being formed and does not yet have elected members or activities. We hope that in future evaluations we can count on the advice and approval of an established Ethic Committee.

Declaration of competing interest

The authors do not declare any competing interests.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e17774.

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