Almond okara as a valuable ingredient in biscuit preparation

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This article has been published as De Angelis, D., Pasqualone, A., Squeo, G., & Summo, C. (2023). Almond okara as a valuable ingredient in biscuit preparation. *Journal of the Science of Food and Agriculture*, *103*(4), 1676-1683. https://doi.org/10.1002/jsfa.12286

Abstract

BACKGROUND: The okara is the water-insoluble residue derived from the production of plant-based beverages, including almond milk. Information on almond okara is scarce, with no scientific references. In this study, the almond okara was characterized, and used to replace wheat flour at 15%, 25% and 35% for biscuit preparation.

RESULTS: The contents of protein, lipid, and dietary fiber of almond okara were 140.08, 421.16 and 407.90 g kg^{-1} dry matter, respectively. The lipid fraction of almond okara showed a content of triacylglycerol oligopolymers and oxidized triacylglycerols of 0.12 and 5.14 g kg^{-1}, respectively, which were significantly lower than the levels observed in the sunflower oil used in the formulation of biscuits. Consequently, the biscuits containing okara showed a content of triacylglycerol oligopolymers lower than control biscuits. The texture analysis revealed that the addition of the okara at 25 and 35% caused a significant increase of biscuit hardness and a reduction of the brittleness, compared to the control. The sensory evaluation confirmed these data, and it highlighted the little impact of the almond okara on the almond odor, taste, and flavor attributes.

CONCLUSION: Almond okara is a valuable by-product that can be easily used as an ingredient for biscuit preparation, exploiting its fiber, protein and lipid content to improve the nutritional value of food, with a limited impact on the sensory properties.

Keywords

By-product; Plant-based beverages; Upcycling; Bakery products; Almond milk

1. Introduction

Plant-based alternatives to animal-derived products are gaining a noticeable interest in the last years, as demonstrated by the rising investments in this sector. [1] Particularly important is the segment of the plant-based beverages developed to substitute the cow's milk, and which are mainly consumed by people suffering of allergies and/or intolerances or by flexitarians, vegetarians, and vegans. Indeed, it is reported that the market of dairy alternatives will grow in the next years at an estimated rate of more than 9.9% by 2025. [2] The most diffused plant-based beverages are produced from soy, almond, oat, coconut and rice; however, other pulses, nuts, seeds, cereals and pseudocereals are also suitable for the preparation of such kind of products. [3]

In particular, the almond milk is one of the most ancient vegetable beverages and it is well diffused and consumed in western countries. [4] For instance, in the United States, the almond milk leads the market of the plant-based beverages, accounting for the 59% of the total category. [1] Almond milk is traditionally consumed in various European countries, so that the label “almond milk” is authorized in European Union due to an amendment to the European Regulation (EC) No 1234/2007. [5]

Almond milk, as well as the other plant-based beverages, is generally produced by soaking almonds, grinding them by a colloidal mill in presence of the proper amount of water, and then filtering the extract to obtain the final product. [6] Consequently, the manufacturing process of all plant-based beverages leads to the production of solid residues which are actually by-products and that are mainly constituted of by insoluble compounds such as dietary fiber, lipids and proteins. With this respect, “Okara” is the term which traditionally defines the soy insoluble residue remaining after the filtration stage during the preparation of soy milk. [7] It is reported that for every kg of soy processed to soy milk, about one kg of fresh okara is produced. [8] It is reasonable to assume that this ratio is similar for the other plant-based beverages. Therefore, considering the growing market trends, it is worth to investigate the strategies to recover these by-products, mitigating the footprint of the productions. This is true for the soy okara, whose composition and properties are well investigated, together with the technological and biotechnological processes to valorize such by-product. [8–10] Instead, the studies on the residues from the production of plant-based beverages, except soy milk, are surprisingly scarce. For example, Lian et al, [11] evaluated the okara derived from a chickpea beverage, and Raghavendra et al., [12] reported the potential use of the dietary fibers derived from the coconut milk production. However, to the best of the authors’ knowledge, there are no references in the scientific literature for almond okara. Therefore, the aim of this paper is to characterize the okara derived from the production of almond milk. Then, from the perspective of promoting the reuse of by-products, the almond okara was proposed as an ingredient for biscuit preparation, exploiting its fiber protein and lipid content to improve the nutritional value of food. Biscuits were chosen on the basis of their characteristics, which are favorable to the incorporation of nutrient-dense upcycled ingredients, [13,14] including soy okara. [15–17]

2. Material and Methods

2.1 Okara and ingredients for the biscuits preparation

The plain wheat flour (type “00”, Molino Casillo Spa, Corato, Italy), the unrefined cane sugar (Eridania, Bologna, Italy), the sunflower oil (Olearia De Santis, Bitonto, Italy) and the baking powder (sodium bicarbonate and disodium diphosphate) (Cameo S.p.A., Desenzano del Garda, Italy) utilized for the preparation of biscuits were purchased by a local retailer. The fresh almond okara was kindly provided by Equal Time Onlus (Triggiano, Italy), the same day of the production of the almond milk. The fresh almond okara had a moisture content of 75% and a water activity of 0.99, therefore it was immediately lyophilized (LyovaporTM L-200, BÜCHI Labortechnik AG, Flawil, Switzerland). The lyophilized okara was easy to pulverize and it was milled (Realmix 7, G3 Ferrari, Rimini, Italy) and then sieved through an 80-mesh sieve. The okara powder was finally stored at -20°C until the analysis and utilization.

2.2 Biscuit preparation

The formulation of the biscuits, reported in Table 1, was set-up according to preliminary trials. The almond okara was used to replace the wheat flour at three increasing concentrations i.e., 15%, 25% and 35% to produce the O15, O25 and O35 biscuits, respectively. At the same time, considering the lipid content of okara, the oil used in the formulation was reduced accordingly. The ratio of the ingredients was optimized by means of preliminary trials, based on the workability of the dough and the structure after baking. The minimum concentration of okara was set at 15% to reach at least the “high fiber” claim.[18]

The recipe followed our previous studies on biscuits [14] with some modifications. The preparation started by mixing the okara, the flour with the baking powder, and the unrefined sugar for 5 minutes with an electric mixer (Bravomix 550, G3 Ferrari, Rimini, Italy). Then, the oil was added, and the mix was vigorously mixed for 5 minutes. Finally, the water was added, and the dough was mixed for 10 minutes. Then, the dough was rolled out with a rolling pin to a thickness of 6 mm and cut into 6.5 cm diameter disks with the aid of a circular cutter. The disks of dough were placed on a baking tray, following a Latin square design pattern to minimize any effect of the location during baking. Finally, they were baked in an electric oven (Smeg sf64m3pzs, Smeg S.p.A., Guastalia, Italy) at 180 °C for 15 min. Two independent production trials were performed.

2.3 Proximate composition

The official AOAC methods 979.09, 923.03, and 925.10, were used to assess the protein content (total nitrogen × 5.18), ash, and moisture content, respectively. [19] The lipid content was determined by Soxhlet extraction using diethyl ether (Merck KGaA, Darmstadt, Germany) as solvent (AOAC, 2006), in an automatic extractor (SER 148 extraction system, Velp Scientifica srl, Usmate Velate, Italy). The content of total dietary fibre was determined by the enzymatic–gravimetric AOAC method 991.43 [19]. Total carbohydrates were calculated on dry matter as 1000 – (protein, lipids, ash, total dietary fiber). The energy value of the biscuits (expressed as kcal kg^{-1}) was calculated using the Atwater conversion coefficients. [14] Three replicated analyses were carried out.

2.4 Quality of the lipid fraction and oxidative stability

The triacylglycerol oligopolymers (TAGP), oxidized triacylglycerols (ox-TAG), and diacylglycerols (DAG) of the sunflower oil as well as of the lipid fraction extracted from the okara and from the biscuits were determined by High-Performance Size-Exclusion Chromatography (HPSEC) as described by Rodríguez et al. [20] The peroxide value of the sunflower oil and of the lipid fraction of the okara was determined according to the EEC Regulation no. 2568/91.[21]

The oxidative stability of the biscuits was assessed by measuring the Induction time (IT) through the Rapidoxy instrument (Anton Paar GmbH, Graz, Austria). One gram exactly weighed of finely ground sample was subjected to oxidation by increasing temperature and oxygen pressure. The induction time was defined as the time needed to reach a 10% drop of the oxygen pressure under the following conditions: T = 140 °C, P = 700 kPa.

2.5 Physicochemical properties and texture analysis

The bulk density (BD), the water absorption capacity (WAC) and the oil absorption capacity (OAC) were determined on the wheat flour and on the okara according to the procedures reported in De Angelis et al.[22]

The baking induced variations of the diameter, thickness and spread ratio (diameter/thickness), and of the weight loss were determined with the methods described in Pasqualone et al.[14]

The instrumental color determination was carried out by CM-600d spectrophotometer (Konica Minolta, Tokyo, Japan). The Whiteness Index (WI) was calculated as: $WI = 100 - [(100 - L^*)\ 2 + a^{*2} + b^{*2}]^{1/2}$. [16] The true color difference was calculated as follows: $\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$.

The textural properties were evaluated by a 3-points bending test, according to Pasqualone et al., [14] using a. ZI.0 TN texture analyzer (ZwickRoell GmbH & Co. KG, Ulm, Germany), equipped with 1 kN load-cell. The biscuits were placed on the analyzer support with their top surface down. The distance between the support bars was 4 cm. The fracture force (N/mm^2) and the deformation until the rupture i.e., the brittleness (mm) were determined by breaking the biscuit with the probe at the speed of 5 mm s^{-1}. Four replicates were considered for each thesis.

The milk absorption of the biscuits was determined as in Moriano et al. [23]

For all the analyses four replicates were considered.

2.5 Sensory analysis

The Quantitative Descriptive Analysis (QDA) of biscuits was performed by a trained sensory panel of eleven people, following the ethical guidelines of the laboratory of Food Science and Technology of the Department of Soil, Plant and Food Science (Di.S.S.P.A., University of Bari, Italy). The panelists already had experience with sensory analysis of biscuits [14] and they were regular consumers of biscuits and almonds and did not suffer from any food intolerances or allergies. They were informed about the study aims and signed an individual written informed consent. The descriptors (reported in Table 2) were identified according to Pasqualone et al., [14] with some modifications. The evaluation was carried out in duplicate.

2.6 Statistical Analysis

Data obtained for biscuits were subjected to one-way analysis of variance ANOVA followed by Tukey HSD (Honestly Significant Differences) test for multiple comparisons at a significance level α=0.05 by using the Minitab 19 Statistical Software (Minitab Inc., State College, PA, USA). The t-test was performed to detect significant differences between the okara and the wheat flour, and between the okara lipid fraction and the sunflower oil.

3. Results and Discussion

3.1 Chemical and nutritional characterization of the Almond Okara

The composition of the wheat flour and of the almond okara is reported in Table 3. The protein content of the okara was significantly higher than that of the wheat flour. Moreover, the almond okara showed a total dietary fiber content of about 407.90 g kg^{-1} which is a very high value, similar or even higher than other fibrous ingredients that can be used in biscuit preparation, such as wheat and oat bran. [24] This result involves that the almond okara, even added in a small amount, allows to reach a dietary fiber content able to meet the requirements of the nutritional claims “source of fiber” and “high in fiber”. [18] The lipid content was similar to that of the whole almond seeds. [25] However, during the production of the almond milk, most of the insoluble compounds do not migrate in the water phase and are retained in the okara after the filtration phase. Indeed, also the soy okara has been reported to have a dietary fiber content similar to the almond okara, but with a lower content of lipids and a higher content of proteins. [7,26] However, these differences can be explained by the compositional differences existing between the soy and almond.

As for the main physicochemical properties (Table 3), the powdered almond okara had a significantly lower bulk density compared to the wheat flour, indicating that it was constituted of by small and light particles. Previously, it was reported that the lyophilization can confer a porous structure to the okara [27], which can be related to the low bulk density. Moreover, the almond okara was characterized by a five-time higher water absorption capacity than the wheat flour, probably due to the high fiber content of okara. [27,28] The water absorption capacity is also related to other hydrophilic macromolecules such as proteins. [27] Therefore, the higher water absorption capacity of the okara may be also explained by its higher protein content compared to the wheat flour. The oil absorption capacity was also higher in almond okara compared to the wheat flour, suggesting a good attitude in the formulation of bakery products where the oil incorporation is required, whereas the high water absorption is important to increase the dough yield after mixing.[29]

Owing to its high lipid content, the almond okara can be used as a fat replacer in the preparation of biscuits, with the advantage of being untreated, e.g. not subjected to any refining or thermal treatment. In particular, considering the quality of the lipid fraction (Table 3), the sunflower oil and the okara lipid fraction showed a similar peroxide value. The latter is an index of primary oxidation of lipids which, however, is usually lowered during the oil refining process, namely in the decolorization step. Okara showed a lower content of polar compounds compared to the sunflower oil. These compounds, having a higher polarity than the unaltered triacyclglycerols, derive from the secondary oxidation of lipids and include the triacylglycerol oligopolymers (TAGP) and the oxidized triglycerides (ox-TAG). They also include the diacylglycerols (DAG), derived from hydrolytic degradations of triacylglycerols. [20] The TAGP are indices of the oxidative degradation level and their value significantly increases during the refining process of the oil, [30] which explains the highest content of TAGP found in the sunflower oil compared to the okara. The ox-TAG are related to the beginning of the oxidative process, while the DAG are related to the extent of hydrolytic alterations. [30] The content of such compounds is influenced by the type of the oil considered, and it generally increases during thermal processing such as baking. [31]

Fat is one of the key ingredients in the preparation of biscuits due to its strong influence on texture. [32] Moreover, improving the quality of the lipid fraction could lead to health benefits for the consumers. [33]

3.2 Proximate composition of biscuits and quality of the lipid fraction

The proximate composition of the examined biscuits is reported in Table 4. Owing to the differences observed in the raw materials, the addition of increasing concentrations of almond okara to the formulation of biscuits led to a significantly higher protein content compared to the control. The ash content progressively and significantly increases with the addition of okara, due to a higher concentration of minerals in the enriched biscuits compared to the control. The biscuits incorporated with 15% of almond okara were characterized by a sufficient total dietary fiber content to labelled as "source of fiber", whereas the O25 and O35 biscuits showed a dietary fiber content higher than 60 g kg^{-1} and could be labelled as "high in fiber". [18] Total carbohydrates progressively and significantly decreased due to the addition of increasing amounts of okara. The same trend was previously reported by other authors. [16] The energy value of biscuits was similar to the one reported by Ostermnan-Porcel et al., [16] and it showed no significant differences among the trials, although a decreasing trend was observed.

The lipid content was kept constant in all the formulations because the increase of the okara was compensated by the reduction of the amount of sunflower oil used. Indeed, all the trials showed a similar lipid content of about 200 g kg^{-1}. However, the incorporation of the almond okara led to an improvement of the quality of the lipid fraction by reducing the TAGP, which showed a significant decrease in O25 and O35, the latter showing the lowest value. By contrast, no significant differences were identified in the ox-TAG and DAG values. Overall, the content of polar compounds was lower than the content previously found in other commercial biscuits. [34]

Finally, the induction time, i.e. the time needed to oxidize biscuits under forced conditions, was near 50 minutes in all the trials, indicating that the addition of okara did not change the oxidative stability of the product.

3.3 Physicochemical properties and texture of biscuits

The physicochemical properties of the biscuits are reported in Table 5. The instrumental evaluation of color highlighted that the biscuits supplemented with almond okara had highest Lightness (L^*) and yellowness ($b*$), but similar redness ($a*$) compared to the control. Overall, the biscuits appeared whiter, as explained by the whiteness index values which progressively and significantly increased in the trials formulated with almond okara, with the highest values in O25 and O35. The overall differences between the almond okara supplemented biscuits and the control are described by the ΔE, which progressively and significantly increased as the concentration of almond okara increased in the formulation. Particularly relevant were the ΔE in O25 and O35 biscuits, with values which indicated clearly observable differences. Indeed, it was previously reported that with values higher than 3.5 a clear difference in color is noticed. [35] Regarding this aspect, Li et al., [36] reported that a lighter color of biscuits was preferred by panelists during the sensory analysis, suggesting that hypothetically, the biscuits supplemented with the highest okara concentration could be more appreciated by consumers. In contrast with our results, Lee et al., [17] and Ostermann-Porcel et al., [16] previously reported a decrease in $L*$ as the concentration of soy okara in the product increased, explaining that the soy okara used in their study had a high content of the precursors of the Maillard's reaction which led to an easier browning during cooking. [17] By contrast, our results suggest that almond okara could have lower content of reducing sugars and free amino groups responsible of the color formation during cooking. Moreover, the lyophilized okara appears as a white fine powder, which keeps its color when mixed with water. Therefore, this can explain the highest whiteness index of the biscuits containing okara.

The weight loss after baking was not affected by the addition of almond okara, whereas it seems to inhibit the expansion in diameter and thickness of the biscuits. Indeed, the variation in thickness and in diameter recorded after baking progressively and significantly diminished as the concentration of okara increased (Table 5). This result indicates that the control was significantly thicker and larger in diameter compared to the other trials.

Finally, the spread ratio was higher in O25 and O35 because these biscuits increased more in diameter than in thickness, compared to the control. These results corroborate with those reported by Lee et al., [17] who formulated biscuits with soy okara. They explained that the high water absorption capacity of the okara gave a lower elasticity to the dough and a tighter structure, which reduced the expansion during cooking. [17] A higher spread ratio is desirable in biscuits because it is an index of the overall acceptability of the product [16,37] and, thus, okara could have a positive influence on biscuit acceptability.

The milk absorption capacity of the biscuits formulated with almond okara was significantly lower compared to the control, without any significant effect of the concentration. This result can be explained by the lower expansion (recorded also by the analysis of the dimensional indices) of okara enriched biscuits, which led to the formation of a more compact structure that inhibited the absorption of milk.

The analysis of the fracture force (N/mm^2) and of the brittleness (mm) of biscuits revealed that the incorporation of almond okara led to a hard-to-break biscuit characterized by a loss of brittleness, because the distance to break the biscuits increased. This effect was significant when the concentration of almond okara was higher than 25%, because the biscuits prepared with 15% of substitution did not show any significant difference compared to the control. The brittleness or friability if a key feature of the biscuits, therefore a less friable product could be less appreciated by consumers. [38] In a previous work, the addition of soy okara caused a significant increase of both the hardness and the brittleness, [17] observing the same behavior found for other fibrous ingredients. [14] As for the variation of the dimensional indices, the decrease of the brittleness could be related to the very high water absorption capacity of the okara, which gave a more elastic and consistent dough matrix.

3.4 Sensory analysis

The sensory properties were significantly different in terms of general aspect, odor, taste and flavor, as reported in Figure 1. In particular, the color of the biscuits containing almond okara at 25 and 35% was perceived lighter compared to the control, according also to the instrumental evaluation of the same parameter. The friability of the O25 and O35 biscuits was lower than the control, meaning that the panelists evaluated the biscuits as harder to break, confirming the data of the texture analysis. The overall intensity of the odor notes did not show any significant differences among the trials, and the typical odor of biscuits and a caramel note were the main sensations perceived by the panelists. The almond odor was significantly more perceived in the biscuits containing almond okara compared to the control. However, the score was near/below 2, meaning a very low perception (Table 2). The addition of almond okara determined a the presence of almond odor in the enriched biscuits, but without any significant dose-effect.

Overall, the taste was characterized by the predominance of sweetness, which was the highest in the control biscuits. The reduction of sweetness in the biscuits containing soy okara was previously reported and it was related to the presence of bitter peptides. [17,36] The addition of almond okara slightly impacted the taste and flavor of the products as it emerged by evaluating the intensity of the almond taste attribute. However, as the concentration of almond okara increased in the formulation, the biscuits were perceived significantly more astringent, though with a score lower than 1 in all the trials. The panelists did not perceive any off-taste during the sensory evaluation. Previously, the incorporation of 40% soy okara in biscuit formulation led to a not acceptable product due to a low sweetness and a beany flavor. [17]

During tasting, the biscuits containing almond okara were perceived significantly harder compared to the control and consequently more difficult to chew, as also explained by the results of the 3-points bending test. Moreover, the addition of okara led to a lower graininess with respect to the control, reflecting the instrumentally determined textural data. These characteristics were related to the less expanded structure of the biscuits containing the almond okara, which gave a denser network, and this trend was previously observed in biscuits formulated with soy okara. [17]

Overall, it should be highlighted the small impact of the almond okara on the sensory properties, especially on the odor and taste. Probably, most of the volatile compounds, including those responsible of the almond flavor, migrated in the almond milk during its preparation, leading to the smooth sensory properties of the almond okara. This aspect is particularly important from the perspective of promoting the utilization of this by-product in biscuits, as well as in other bakery products, and it is an advantage compared to the soy okara which, instead, is characterized by a marked beany flavor. [15,17]

4. Conclusion

The almond okara is a valuable ingredient that can be used to improve the nutritional features of food. It is characterized by a high lipid content (421.16 g kg^{-1}) and by a very high dietary fiber content (407.90 g kg^{-1}). Moreover, almond okara showed a good water and oil absorption capacities (respectively, 5.01 and 2.88 g absorbed per g of okara flour) which makes almond okara suitable in all the formulations requiring the incorporation of water and oil.

The biscuits formulated with almond okara showed a lower content of TAGP, i.e. a better lipid quality compared to the control containing sunflower oil. However, the addition of the okara affected the texture of biscuits causing an increase of hardness and a reduction of brittleness, which is related to a less expanded structure compared to the control. These data were also confirmed by the sensory evaluation which also highlighted the little impact of the almond okara on the odor notes and on the flavor of the products (with scores always lower than 2 out of 9). This is particularly important from the perspective of an easy utilization of the okara as ingredient in food.

Acknowledgments

This research was carried out within the project “Almond Management Innovations (Approcci per una Mandorlicoltura biologica Innovativa)" AMÌ - CUP: B99J20000110009” supported by the Misura 16 Cooperazione – Sottomisura 16.2 "Sostegno a progetti pilota e allo sviluppo di nuovi prodotti, pratiche, processi e tecnologie" D.d.S. n. 94250025148

The authors would like to thank the Equal Time Onlus (Triggiano, Italy) for providing the okara used in this study.

Declaration of interest

None.

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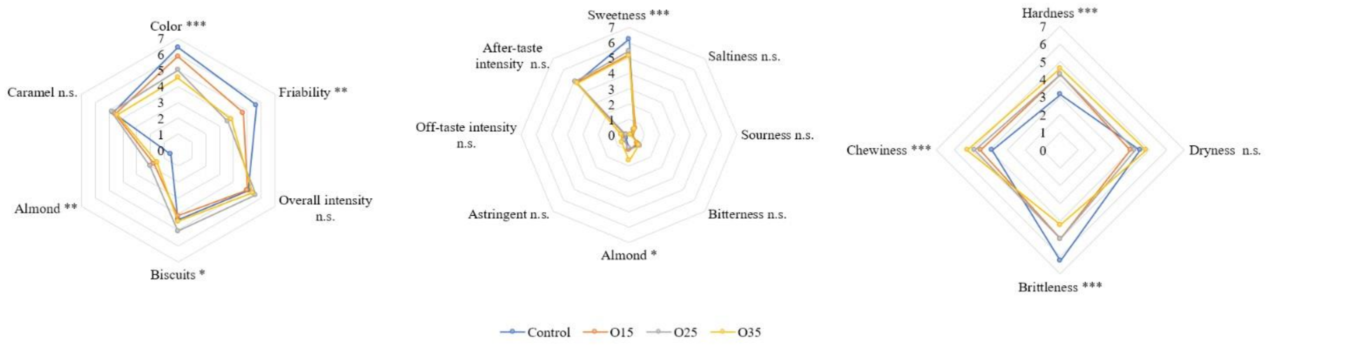
FIGURE LEGEND:

Figure 1. Quantitative descriptive analysis of the biscuits. From the left to the right, according to the descriptor classes in Table 2: Appearance (visual/tactile) and odor; Taste; Texture. Control: biscuits without okara; O15, O25 and O35: biscuits prepared with 15%, 25% and 35% of almond okara respectively. According to the One-way ANOVA (α=0.05): *n.s.*: $p > 0.05$; * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$.



Supplementary material S1. Biscuits formulated with almond okara. From the left to the right: control, O15, O25, O35.

Table 1. Ingredient composition of the biscuits. Control: biscuits without okara; O15, O25 and O35: biscuits prepared with 15%, 25% and 35% of almond okara.

	CTRL	O15	O25	O35
Plain wheat flour (g)	100	85	75	65
Almond Okara (g)	-	15	25	35
Unrefined cane sugar (g)	35	35	35	35
Sunflower oil (g)	30	24	20	16
Water (g)	30	30	30	30
Baking powder (g)	3	3	3	3

Table 2. Sensory attributes, definition, and scale anchors for biscuits (scale 0–9).

	Attribute	Definition	Scale anchors (0-9)
Appearance (visual/tactile)	Color	Perceived color tone on the surface	0: pale yellow – 3: beige - 6: light brown - 9: dark brown
	Friability	Hardness perceived by breaking by hands	0: very hard – 3: fairly hard; 6: friable; 9: very friable
Odor	Overall intensity	Overall odor intensity of the sample	0: not perceived – 3: poorly perceived – 6: clearly perceived – 9: highly perceived
	Biscuits	Typical biscuit's odor	
	Almond	Typical almond odor	
	Caramel	Typical caramel odor	
	Off-odor intensity	Non-characteristic odors (chemical, rancid, metallic, etc.)	
Taste	Sweetness	Association with sucrose	0: not perceived – 3: poorly perceived – 6: clearly perceived – 9: highly perceived
	Saltiness	Association with sodium chloride	
	Sourness	Association with citric acid	
	Bitterness	Association with caffeine	
	Almond	Association with almond	
	Astringent	Puckering sensation in mouth/tongue	
	Off-taste intensity	Non-characteristic tastes (chemical, rancid, metallic, etc.)	
	After-taste intensity	Intensity 5 seconds after swallowing the sample	
Texture	Hardness	The force required to compress the sample using teeth	0: almost not effort required – 3: easy compressible – 6: moderately compressible – 9: hardly compressible
	Dryness	Dryness perceived during chewing	0: moist – 3: slightly dry – 6: moderately dry – 9: completely dry
	Brittleness	Amount of particles released during 5 chews	0: no particle perceived – 3: few and small particles – 9: a lot of particles with various dimensions
	Chewiness	Effort required to chew the sample until it can be swallowed	0: no chews needed – 3 easy to chew – 6: moderately hard to chew – 9: hardly to chew

Table 3. Nutritional composition (g kg^{-1} of dry matter), physicochemical properties and quality of the lipid fraction of the ingredients used for the formulation of biscuits. BD: bulk density; WAC: water absorption capacity; OAC: oil absorption capacity; TAGP: triacylglycerol oligopolymers; ox-TAG: oxidized triacylglycerols; DAG: diacylglycerols.

	Wheat Flour	Almond Okara	Sunflower oil
Protein	92.02±4.03^{b}	140.08±7.01^{a}	
Lipids	10.00±1.04^{b}	421.16±12.09^{a}	
Ash	5.51±0.52^{b}	30.86±4.13^{a}	
Total Dietary Fibers	18.03±11.00^{b}	407.90±35.89^{a}	
BD (g mL^{-1})	0.82±0.02^{a}	0.24±0.00^{b}	
WAC (g water g^{-1} flour)	0.78±0.04^{b}	5.01±0.02^{a}	
OAC (g oil g^{-1} flour)	0.82±0.01^{b}	2.88±0.07^{a}	
Peroxide value (meq O_2 kg^{-1} oil)		3.28±0.58^{a}	3.97±0.98^{a}
TAGP (g kg^{-1})		0.12±0.00^{b}	2.42±0.02^{a}
Ox-TAG (g kg^{-1})		5.14±0.01^{b}	9.89±1.05^{a}
DAG (g kg^{-1})		14.91±0.04^{a}	14.61±0.02^{b}

Data reported as mean±standard deviation. Different letters in the same row indicate significant differences according to the *t*-test (α=0.05).

Table 4. Nutritional composition (g kg^{-1} of dry matter) and quality of the lipid fraction of the biscuits. Control: biscuits without okara; O15, O25 and O35: biscuits prepared with 15%, 25% and 35% of almond okara respectively.

	Control	O15	O25	O35
Proteins	58.01±0.72^{c}	63.85±0.15^{b}	74.59±3.03^{a}	78.66±1.43^{a}
Lipids	208.30±19.9^{a}	221.87±11.03^{a}	218.99±10.43^{a}	227.02±7.70^{a}
Ash	14.99±0.16^{d}	17.99±0.31^{c}	20.58±0.01^{b}	24.31±0.01^{a}
Total Dietary Fiber	10.61±1.51^{d}	46.63±3.69^{c}	71.90±5.40^{b}	98.27±5.02^{a}
Carbohydrates	708.10±18.30^{a}	649.66±14.08^{b}	613.94±5.78^{c}	571.74±11.88^{d}
Energy value (kcal kg^{-1})	4960±101.64^{a}	4944±50.40^{a}	4869±60.79^{a}	4841±28.70^{a}
TAGP (g kg^{-1})	1.87±0.09^{a}	1.73±0.07^{a}	1.3±0.01^{b}	1.13±0.03^{c}
Ox-TAG (g kg^{-1})	10.27±1.38^{a}	10.12±0.14^{a}	10.88±1.17^{a}	8.51±0.42^{a}
DAG (g kg^{-1})	15.79±0.65^{a}	15.51±0.60^{a}	15.64±0.11^{a}	16.07±0.18^{a}
Induction time (min)	51.91±0.31^{b}	50.22±0.64^{c}	53.76±0.25^{a}	50.63±0.80^{bc}

Data reported as mean±standard deviation. Different letters in the same row indicate significant differences according to the Tukey's HSD Test (α=0.05).

Table 5. Physicochemical properties of biscuits. Control: biscuits without okara; O15, O25 and O35: biscuits prepared with 15%, 25% and 35% of almond okara respectively.

	Control	O15	O25	O35
*L**	47.37±2.18^{c}	50.47±2.04^{b}	53.60±0.87^{a}	54.93±2.31^{a}
*a**	12.79±0.94^{a}	13.14±0.52^{a}	13.16±0.23^{a}	12.79±0.37^{a}
*b**	28.58±1.75^{b}	30.26±1.00^{a}	31.39±0.48^{a}	31.42±0.67^{a}
Whiteness Index	38.70±1.13^{c}	40.47±1.35^{b}	42.45±0.55^{a}	43.57±1.73^{a}
ΔE vs Control		3.54	6.85	8.08
Fracture Force (N/mm^2)	21.42±1.12^{b}	20.56±2.41^{b}	28.67±3.60^{a}	32.11±4.28^{a}
Brittleness (mm)	2.54±0.20^{b}	2.90±0.170^{b}	4.45±0.28^{a}	4.12±0.52^{a}
Diameter variation (%)	9.66±1.11^{a}	5.77±0.88^{b}	2.26±0.77^{c}	1.61±1.61^{c}
Thickness variation (%)	81.94±1.39^{a}	56.55±6.27^{b}	44.05±1.19^{c}	30.56±2.48^{d}
Spread ratio (D/T)	6.55±0.09^{b}	5.88±0.13^{c}	7.11±0.39^{a}	7.18±0.07^{a}
Weight loss (%)	16.87±0.88^{a}	16.13±1.01^{a}	17.27±0.24^{a}	17.66±0.82^{a}
Milk absorption (%)	6.93±0.07^{a}	3.75±0.16^{b}	3.73±0.23^{b}	3.77±0.25^{b}

Data reported as mean±standard deviation. Different letters in the same row indicate significant differences according to the Tukey's HSD Test (α=0.05).