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Tracing chemical and sensory characteristics of baru oil during storage under nitrogen

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ABSTRACT

Chemical and sensory properties of a mechanically extracted, degummed and bleached oil from baru (*Dipteryx alata* Vog.) almonds were traced during storage. Baru oil (BO) was packed with and without nitrogen blanket and stored for 180 days. Each 60 days, fatty acids, peroxide value (PV), iodine value (IV), acidity, sensory profile and acceptance, besides overall liking as salad dressing and viscosity at initial time were evaluated. BO viscosity (65.4 mPa s) resembled peanut and olive oils. Gadoleic acid decreased from 120 days of BO without nitrogen. IV and acidity increased during storage. PV was higher in samples without nitrogen, and decreased between 120 and 180 days. BO showed sensory similarities to samples under nitrogen blanket until 120 days. BO without nitrogen (120 days) presented fishy and soybean oil flavors, besides higher PV, whereas samples at 60 and 180 days associated to baru, peanut, olive oil attributes. BO stored under nitrogen blanket can be a successful oily ingredient in salad dressing.

1. Introduction

The study of plant species from Brazilian savannah is of great interest, since this biome is currently considered one of the most rich savannah biodiversity in the world (Klink & Machado, 2005). The investigation of nutritional, technological and commercial potential of native food raw materials can contribute to environmental sustainability and diet diversification (Stadlmayr et al., 2011; United Nations, 2014).

A prominent fruit from Brazilian savannah is baru (*Dipteryx alata* Vog.). It contains a central elliptical dark brown almond (Fernandes, Freitas, Czeder, & Naves, 2010; Sousa, Fernandes, Alves, Freitas, & Naves, 2011) of approximately 1.5 g. This almond presents about 42 g/100 g of lipids, with a fatty acid profile close to peanut kernels's (Özcan & Seven, 2003) and presents 47.2 g/100 g of oleic acid and 25.5 g/100 g of linoleic acid (Vera et al., 2009).

Besides, baru almonds present contents of total phenolic compounds higher than pines, macadamias, Brazil nuts, cashew nuts, hazelnuts and peanuts (Lemos, Siqueira, Arruda, & Zambiazi, 2012). Studies have shown that the consumption of baru almonds resulted in the decrease of iron-induced oxidative stress in rats (Siqueira et al., 2012) and in the improvement of lipid profile in mildly hypercholesterolemic subjects (Bento, Cominetti, Simões Filho, & Naves, 2014).

However, the potential of baru almonds and their products as ingredients for food and pharmaceutical industries has not been fully established yet. The production of BO is still empirical and in a very small scale. BO is currently sold in Brazilian savannah local markets as cold pressed crude oil and pressed crude oil and it has insufficient stability and shelf-life (Borges, Malheiro, Souza, Casal, & Pereira, 2014). Preliminary studies on the mechanical extraction of BO in our laboratory identified the need for bleaching after degumming to obtain a clear product similar to conventional oils regarding appearance. However, chemical and sensory characteristics of BO after these operations and during storage have not been assessed yet. The application of baru oil cake in flours and cookies

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was reported by Pineli et al. (2015). The goal of this study was to investigate chemical and sensory characteristics of a mechanically extracted, degummed and bleached BO during storage with or without nitrogen blanket.

2. Material and methods

2.1. Processing of BO

2.1.1. Mechanical extraction and refining steps of BO

BO was extracted at the Agro-Energy Laboratory of Embrapa Cerrados. Previously crushed raw and unpeeled almonds (totalizing 49 kg), mixed with rice bran (13 g of rice bran/100 g of almonds) were pressed on a continuous screw press MPE-40R with extraction capacity 40 L of oil/h (Ecirtec, São Paulo, Brazil). The final yield of the process were 24.5 g of crude oil/100 g of almonds and 53.7 g of cake/100 g of almonds, besides losses by clogging in the screw press as reported by Pineli et al. (2015).

Crude oil was filtered through a 1 mm pore size stainless steel screen. The degumming step was performed by addition of 15 mL/100 mL of water to crude oil at room temperature, under constant stirring. The oil was centrifuged at 800 × g for 10 min. Degummed oil was bleached with 5 g/100 g of infusorial earth for 20 min at 25 °C with constant stirring and once more centrifuged for 10 min at 800 × g. The final procedures for degumming and bleaching of BO were determined after several pretests in order to establish satisfactory conditions (data not shown).

2.1.2. Storage conditions

For the storage behavior assessment, the bleached BO was packed in hermetic transparent glass bottles of 500 mL, with or without nitrogen blanket. This procedure was achieved by injection of N_2 (99.0 g/100 g purity, White Martins, Rio de Janeiro, Brazil) before hermetic sealing. Bottles were stored for 180 days at room temperature in a cabinet of 1 m^2 with a constant LED lamp (540 lux). To ensure uniform light exposure, positions of the bottles inside the light cabinet were regularly changed throughout storage. The temperature in the cabinet was 22 ± 2 °C. At the end of each experimental period of storage, bottles were stocked at −80 °C and all of them were thawed after 180 days to perform the analyses of all treatments together.

2.2. Evaluation of oil stability

Storage stability was monitored by acidity, peroxide and iodine values and fatty acids' profile. BO viscosity was also compared to other edible oils.

2.2.1. Peroxide value

The BO peroxide values were determined by AOCS Official Method Cd 8-53 (AOCS, 1987).

2.2.2. Iodine value

The BO iodine value was determined by the Wijs method AOCS Cd 1d-1992 (AOCS, 1997a).

2.2.3. Acidity

The BO acidity was assessed according to the method AOCS Cd 8d-63 (1973).

2.2.4. BO fatty acid profile

This analysis was performed according to Christie (1989).

2.2.4.1. Esterification of the samples. Twenty mg of BO samples were esterified with 14 mL/100 mL of boron trifluoride in methanol and the lipid content separated from the methanol phase after addition of saturated NaCl solution and hexane. The supernatant was collected and transferred to a 2 mL aluminum screw-cap septum glass tube and then saturated with nitrogen atmosphere.

2.2.4.2. Chromatographic analysis. The analysis of fatty acid methyl esters (FAME) was performed on a gas chromatograph Shimadzu GC-2010 with MS-QP2010 Plus detector (quadrupole, electron impact) and autoinjector AOC-5000. Separation of FAME was performed using Column RTX (Restek, polydimethylsiloxane) with 30 m of length, 0.25 mm of internal diameter and 0.2 μm of film thickness. Analytical conditions were: column oven temperature of 140 °C, injection temperature of 260 °C and column flow (Helium) of 0.4 mL/min. The volume injected was 0.1 μL. Identification of the peaks was performed by comparison with the retention time of standard 37 FAME mix with known concentrations of each (Supelco, USA) and mass spectra (ratio m/z) – compared to internal database. FAME were quantified by comparison with the peak areas of the standards, and results expressed in g/100 g of total fatty acids.

2.2.5. Viscosity

BO viscosity was assessed by means of a Brookfield viscometer Model RVDV – 1 PRIME and compared with one brand of commercial peanut oil and two brands of other commercial edible oils acquired from local market, with two to six months of shelf-life (olive, corn, soybean, canola and sunflower), two bottles of each, analyzed in triplicates. Refined oils were brands of Bunge Alimentos S.A (producer 1) and Cargill Agricola S.A. (producer 2). Portuguese olive oils were produced by Sovena Portugal Consumer Goods S.A. (producer 1) and Victor Guedes Ind. Com. S.A. (producer 2), whereas peanut oil was processed in Brazil by Pazze Food Industry LTDA (producer 1). Samples of 20 mL were placed in the UL-adapter, which was coupled to the viscometer. The analysis was performed in triplicate, and values of speed and temperature were constant at 6 rpm and 20 °C, respectively, and shear rate of 7.34 s^{-1}. The results were expressed in mPa.s.

2.3. Sensory analyses

Three different sensory tests were carried out in order to assess BO quality: descriptive Free Choice Profile, acceptance test of BO as such, and acceptance test of BO carried as ingredient in a salad dressing.

2.3.1. Free Choice Profile

The sensory profile of BO stored for 180 days, with and without nitrogen blanket, was determined by the method of Free Choice Profile (Williams & Langron, 1984). Nine assessors were recruited among students and staff of University of Brasilia, previously selected according to their schedule availability, medical conditions and skills with descriptive terms and use of intensity scales. For the selection of the panelists, a sequence of five triangular tests was carried out, with two samples of olive oil and a sample of olive oil: sunflower oil (60:40). Paired comparison test was performed with 30 panelists to confirm the existence of the difference among the samples ($p < 0.05$). The selection criterion was at least 40% of correct answers.

In every step that involved tasting oil, the samples were served of 10 mL at 39 ± 1 °C, heated in 50 mL glass containers capped with glass clock. The evaluation conditions of the samples were taken according to the method described in AOCS Recommended Practice Cg 2-83 Flavor Panel Evaluation of Vegetable Oils (AOCS, 1997b). This project was approved by the Research Ethics Committee of the University of Brasilia, case number 01988112.1.3001.0029.

2.3.1.1. Definition of attributes. In the first session, panelists received samples of baru almonds and other nuts, as well as samples of the most currently consumed refined vegetable oils in Brazil (soybean, sunflower, canola and corn) and crude olive oil, as an exercise or a motivational activity so that the assessors could become familiar with possible sensory stimuli and so they could expand vocabulary. In the second and third sessions, assessors defined individually the attributes to evaluate oil samples using the Repertory Grid method (Kelly, 1955). By triadic elicitation, three samples were used: BO with 0 day of storage, BO stored for 180 days and recently acquired commercial soybean oil, which was included in this step for being the most consumed edible oil in Brazil and is therefore a known sensory reference to Brazilian tasters. Each panelist evaluated the samples noting similarities and differences among them. In the fourth session, assessors elaborated individual evaluation form with unstructured 9 cm scale for each attribute, anchored in the extremities with week and strong. They also provided a definition for each attribute, in order to ensure they knew what they were evaluating. All the attributes evaluated by the panel, as well as the number of panelists that used each attribute, are presented in Table 2.

2.3.1.2. Samples evaluation. Sensory evaluations were conducted in laboratory individual booths. The sample presentation was monadic, in three sessions. In each session, panelists evaluated the 7 samples, with an interval of 20 min between the first four and the last four samples. Samples presentation was randomized. All samples were coded with three-digit numbers and presented at 39 ± 1 °C. Water at 38 °C and cream cracker biscuits were available for the panelists to cleanse the palate between samples.

2.3.2. Affective analyses

2.3.2.1. Acceptance test of BO. Acceptance tests with BO stored samples were performed with 29 untrained panelists, consumers of vegetable and olive oils at least twice a week, in randomized order. The panelists evaluated oils samples with respect to the overall liking, appearance, aroma and flavor attributes using 9 points hedonic scale. Oil samples were served as recommended in the method AOCS Recommended Practice Cg 2-83 Flavor Panel Evaluation of Vegetable Oils (AOCS, 1997b).

2.3.2.2. Acceptance test of BO carried in salad dressing. As edible oils are not usually consumed as such, the acceptance of BO as an ingredient in salad dressing was assessed in a consumer test. A formulation of homemade salad dressing was used to make two sauces, using 90 mL of olive oil or BO. The remaining ingredients were: tomato (40 g), onion (30 g), red wine vinegar (30 mL), fresh basil leaves (10 g), garlic (2 g), salt (3 g) and black pepper (5 g). The emulsions were made in a blender (Mondial, Appliance LTD MK, Brasilia, Brazil). After been selected, washed and sanitized, ingredients were added to the blender and processed homogeneously. The dressings were film capped and stored at 10 °C until the acceptance test, which was carried out 2 h later. The dressings were presented in randomized monadic sequence, in disposable 50 mL cups and at 20 °C, with approximately 5 g of 5 mm strips of lettuce on a white disposable plate so that the dressing was poured over the lettuce at the time of tasting. The untrained assessors (n = 114) were regular consumers of salad dressings (at least once a week), including students and staff of the Catholic University of Brasilia. Samples were evaluated in the Laboratory of Sensory Analysis, in individual booths.

Table 1
Chemical characteristics and fatty acid profile of BO with and without nitrogen blanketing during storage.

Oil	Iodine value (g I_2/100 g oil)	Peroxide value (meq/kg)	Acidity (mgKOH/g)	Fatty acids (g/100 g of total fatty acids) C16:0	C18:0	C18:1	C18:2	C18:3	C20:0	C20:1	C22:0	C24:0
BO[A] Control	97.68 ± 0.41^{d}	4.33 ± 0.23^{f}	0.44 ± 0.01^{e}	5.51 ± 0.38^{a}	3.59 ± 0.20^{ab}	37.48 ± 0.61^{b}	39.40 ± 0.27^{a}	ND	0.97 ± 0.08^{a}	4.27 ± 0.18^{ab}	3.76 ± 0.12^{ab}	5.02 ± 0.23^{a}
BO–60	100.86 ± 0.75^{c}	4.98 ± 0.22^{d}	0.55 ± 0.01^{c}	5.13 ± 0.31^{ab}	3.55 ± 0.29^{ab}	38.18 ± 1.09^{ab}	39.38 ± 0.68^{a}	ND	0.93 ± 0.13^{a}	3.98 ± 0.14^{bcd}	3.75 ± 0.36^{ab}	5.35 ± 0.4a
BON[B]–60	102.47 ± 0.74^{c}	4.20 ± 0.11^{f}	0.52 ± 0.01^{d}	5.54 ± 0.31^{a}	3.89 ± 0.21^{a}	37.41 ± 1.20^{b}	39.95 ± 0.94^{a}	ND	1.08 ± 0.05^{a}	4.43 ± 0.18^{a}	4.14 ± 0.37a	5.20 ± 0.32^{a}
BO–120	110.71 ± 0.69^{b}	6.53 ± 0.19^{a}	0.78 ± 0.02^{b}	5.59 ± 0.05^{a}	3.52 ± 0.17^{ab}	38.85 ± 0.65^{a}	38.72 ± 0.38^{a}	ND	0.94 ± 0.06^{a}	3.76 ± 0.32^{d}	3.80 ± 0.23^{ab}	5.11 ± 0.54^{a}
BON–120	110.98 ± 0.49^{ba}	6.08 ± 0.11^{b}	0.76 ± 0.01^{b}	4.77 ± 0.42^{b}	3.42 ± 0.11^{b}	39.05 ± 0.96^{a}	38.68 ± 0.42^{a}	ND	0.97 ± 0.01^{a}	4.11 ± 0.05^{bc}	3.91 ± 0.31^{ab}	5.29 ± 0.52^{a}
BO–180	113.10 ± 2.97^{ba}	5.38 ± 0.19^{c}	0.93 ± 0.02^{a}	5.45 ± 0.25^{a}	3.72 ± 0.25^{ab}	38.83 ± 0.72^{a}	38.81 ± 0.55^{a}	ND	0.98 ± 0.09^{a}	3.82 ± 0.08^{cd}	3.64 ± 0.27^{b}	4.82 ± 0.17^{a}
BON–180	113.74 ± 2.60^{a}	4.68 ± 0.11^{e}	0.91 ± 0.01^{a}	5.51 ± 0.11^{a}	3.78 ± 0.33^{ab}	38.60 ± 2.46^{ab}	38.50 ± 0.41^{a}	ND	1.02 ± 0.14^{a}	4.17 ± 0.01^{ab}	3.78 ± 0.28^{ab}	5.03 ± 0.19^{a}
Virgin olive oil[C]	75–94	≤10	≤2.0	7.5–20.0	0.5–5.0	55.0–83.0	3.5–21.0	ND-0.9	0.0–0.6	0.0–0.4	0.0–0.2	0.0–0.2
Peanut oil grade 1[D]	86–107	≤12	≤1.0	8.0–14.0	1.0–4.5	35.0–67.0	13.0–43.0	ND-0.3	1.0–2.0	0.7–1.7	1.5–4.5	0.5–2.5

[A]BO–baru oil and [B]BON–baru oil with nitrogen blanketing, stored for 60, 120 and 180 days. [C]Virgin olive oil standard–Codex Alimentarius (2013), [D]Peanut oil grade 1 standard–Branson et al. (2004). ND–not determined.
In columns, means followed by the same letters do not differ according to Fisher Test ($p < 0.05$).

Table 2
Viscosity (20 °C) of baru oil and other commercial edible oils.

Oil	Producer	Age (months)	Viscosity (mPa s)	Viscosity (20 °C) according to literature (mPa s)
Baru	Experiment	2	76.8ab ± 3.5	–
Peanut	1	5	78.8ab ± 2.4	68–77[b]
Olive	1	5	73.8b ± 4.5	75–80[a]
Olive	2	6	79.7a ± 3.1	
Canola	1	2	64.8cde ± 6.4	72–82[c]
Canola	2	2	68.2c ± 2.6	
Corn	1	5	65.3cd ± 3.9	
Corn	2	6	61.4def ± 5.7	
Soybean	1	3	60.2ef ± 3.6	59–62[a]
Soybean	2	2	64.9cd ± 3.3	
Sunflower	1	2	55.4g ± 3.5	68[a]
Sunflower	2	2	59.2fg ± 5.6	51–57[b]

Analyzes of two samples in triplicate. Means followed by the same letter do not differ by Fisher test ($p < 0.05$).
[a] Shahidi. (2005) Bailey's Industrial Oil and Fat Products, 6 Volume Set, 6th Edition.
[b] Karleskind (1992) Manuel des Corps Gras, Verlag: Lavoisier, Tec. & Doc, 1st Edition.
[c] Data reported as rapeseed oil erucic acid excl. by Karleskind (1992).

2.4. Experimental design

The experimental design was completely randomized with the factors nitrogen blanket in headspace (with or without) and storage time (0, 60, 120 and 180 days), resulting in eight treatments with three replicates each. The instrumental data and acceptance data of BO samples were analyzed by ANOVA and when significant, Fisher test ($p < 0.05$) was applied. Free Choice Profile data were analyzed by Generalized Procrustes Analysis (GPA), with Euclidean transformations of the data by rotation, translation and auto scaling, followed by Principal Component Analysis (PCA) of the consensus configuration, with 5% significance.

3. Results and discussion

3.1. Physical and chemical properties of BO during storage

The effect of physical conditions of storage as time period and presence or absence of nitrogen blanket on BO fatty acids is shown on Table 1. The fatty acid profile of BO presents high linoleic acid (38.92 g/100 g) and oleic acid (38.34 g/100 g), in very similar proportions. In minor proportions, and in decreasing order, palmitic acid (5.36 g/100 g), lignoceric acid (5.11 g/100 g), gadoleic acid (4.07 g/100 g), behenic acid (3.83 g/100 g), stearic acid (3.64 g/100 g) and arachidic acid (0.98 g/100 g) were found. Linolenic acid was not detected in any sample. This profile differs from that reported by Vera et al. (2009) for baru almonds, and from Borges et al. (2014) for crude baru oil, because of the lower proportions of oleic and stearic acids, besides higher proportions of linoleic and gadoleic acids of our BO, indicating a higher degree of unsaturation. It is worth noting that the conditions of solvent extraction or cold pressing without refining steps of the oils for analysis in the reported works differ from physical extraction followed by degumming and bleaching of BO in our work and is one possible source of variation between the fatty acid profiles of baru almond and BO. Furthermore, studies focusing on the effect of climatic conditions on fatty acid profiles of baru almonds, should be carried out. Onemli (2012) studied three cultivars of peanuts during three years and found that oleic acid decreased and linoleic acid increased at lower temperatures post anthesis. Indeed, the effect of lower temperatures on the synthesis of unsaturated fatty acids of plants is well established (Bansal Satija, & Ahuja, 1993; Canvin, 1965; Grosso, Lamarque, Maestri, Zygadlo, & Guzman, 1994; Upchurch, 2008).

The variations of fatty acids proportion during storage and between treatments with and without nitrogen blanket were slight. Among the unsaturated fatty acids, it was not observed any change in the proportions of linoleic acid, contrary to the expected from the greater susceptibility to oxidation brought about in linoleic acid by the presence of the two double bonds. However, significant decrease was observed in gadoleic acid at 120 days of BO storage without nitrogen blanket. This decrease may result in positive variations in the proportion of the other fatty acids, as observed for oleic acid. Slight changes in the proportions of unsaturated fatty acids reported can be related to the presence in the oil of natural antioxidants from baru almonds (Lemos et al., 2012).

The iodine value (IV) is an index of the oil's global degree of unsaturation. The IV of BO was in the range usually found for peanut oils until 60 days, but slightly higher for 120 days of storage (Branson, Xinping, & Bugang, 2004) and was above the range stated for olive oil according to Codex Alimentarius (2013). The IV of BO increased with storage time but no significant differences were found between samples with or without nitrogen blanket at the same storage time. The increasing of IV during storage diverges from current literature of edible oils (Al-Bachir, 2015; Anwar Chatha & Hussain, 2007). Generally, a decrease in IV is expected because of the lowering of polyunsaturated fatty acids content due to time dependent oxidation. One possible explanation is that, once it was observed a slight significant decrease in the monounsaturated gadoleic acid, the proportions of other acids, such as linoleic and oleic acids increase slightly resulting on a small increase in IV. The acidity of BO also increased gradually until 180 days of storage, achieving a difference of 2.1-fold between the initial time and the end of storage. BO presented acidity lower than 1.0 g/100 g for all samples and thus could be rated on the same criteria of virgin olive oil (Codex Alimentarius, 2013) and of the grade 1 pressed finished peanut oil (Branson et al., 2004).

Peroxide value (PV) of BO stored for 60 days under nitrogen blanket was similar to that of BO at initial time (BO-control), which confirms the efficacy of nitrogen to control oxidation of BO in early storage time. Although the increase of PV occurred during storage for all samples, it was always higher in samples without nitrogen blanket. PV rose from 4.20 meq/kg to 6.53 meq/kg, in nitrogen free samples stored for 120 days. Subsequently, there was a decrease in the values at 180 days. This decrease is probably caused by the degradation and polymerization reactions of hydroperoxides, generating oxidative rancidity products (Frankel, 1998, chap. 2). For all samples, PV of BO met the standard requirements for virgin olive oil and grade 1 pressed finished peanut oil.

The viscosity of BO was similar to that of peanut and olive oils, and more viscous than the most common refined frying oils from Brazilian market (Table 2). It was also slightly higher than the viscosity reported by Karleskind (1992) for hazelnut oil (66–76 mPa s). Some viscosity data differ to a small degree from the literature. Peanut oil viscosity was slightly higher than the range of 68–77 mPa s reported by Karleskind (1992), whereas the viscosity of olive oil of producer 1 was slightly lower than the range of 75–80 mPa s reported by Shahidi (2005). The viscosity of canola oil was in average 16% lower in relation to rapeseed oil with erucic acid exclusion (Karleskind, 1992), and viscosity of soybean oil of producer 2 was slightly higher than the range of 59–62 mPa s reported by Shahidi (2005). Some variation in viscosity can also be found within the literature. The viscosity of sunflower oil and cottonseed oil was, respectively, 68 mPa s and 80 mPa s according to Shahidi (2005) and 51–57 mPa s and 65–69 mPa s according to Karleskind (1992). Viscosity is influenced by the size of molecules, which decreases with higher fatty acids unsaturation degree

(Fountain, Jennings, McKie, Oakman, & Fetterolf, 1997). Variations in fatty acids unsaturation degree can be expected if we consider genetic variability (Pali & Mehta, 2014), genetic improvement (Abbadi et al., 2004), environmental factors (Onemli, 2012) and partial hydrogenation to improve oil stability (Schmidt & Schomacker, 2007), among other factors.

The fatty acid profile of BO with those of olive and peanut oils standards were compared, due to their technological similarities regarding extraction, post extraction operations and food application. The proportion of stearic acid (18:0) in BO is within the expected range for the peanut and olive oils (Branson et al., 2004; Codex Alimentarius, 2013) whereas the palmitic acid (16:0) proportion is lower. Gadoleic acid (20:1), and lignoceric acid (24:0) are higher in BO. Oleic acid (18:1), the main fatty acid of olive oil, is in a smaller proportion in BO, which is comparable to that expected for peanut oil. On the other hand, linoleic acid (18:2) and behenic acid (22:0) were within the range for peanut oil and above the range for olive oil. The arachidic acid (20:0) is in lower proportion than the usually observed for peanut oil standard, but in greater proportion than the expected for olive oil.

3.2. Free Choice Profile

The panelists elicited 5 attributes of appearance, 10 of aroma, 13 of flavor and 3 of texture (Table 3). Regarding appearance, 8 assessors indicated yellow color whereas one panelist cited the descriptor color of olive oil. Transparency or translucency were indicated by five assessors. Shiny was elicited by one assessor. The odors of peanuts, nuts, baru, Brazil nuts and almonds were cited by 7 of 9 panelists. Some assessors also cited the odors of olive oil, fishy, soybeans and of frying oil. The flavors related to peanuts, almonds, nuts, baru and Brazil nuts were perceived by seven panelists, whereas five assessors identified flavors of oil or edible oil or soybean oil. The bitter taste was elicited by two assessors and astringency by one panelist. Other flavor attributes evaluated by only one assessor were flavor of olive oil, fish and sunflower seed. The raised texture attributes were viscosity (7 assessors), velvety (3 assessors) and oiliness (2 assessors).

Table 3
Frequency of elicited descriptors.

Attributes	Abbreviation	Number of assessors[a]
Yellowness	Yel	8
Color of olive oil	Olv-clr	1
Transparency	Transp	2
Translucency	Transl	3
Shiny	Shn	1
Soy odor	Sb-odr	2
Peanut odor	Pnut-odr	1
Brazil nut odor	Bznut-odr	1
Baru odor	Br-odr	1
Edible oil odor	Edboil-odr	3
Nut odor	Nut-odr	2
Olive oil odor	OLV-odr	1
Frying odor	Fry-odr	1
Almonds odor	Alm-odr	2
Fish odor	Fsh-odr	1
Baru flavor	Br-flv	2
Flavor of sunflower seeds	Sflw-seed	1
Nut flavor	nut-flv	2
Bitterness	Bit	2
Oil flavor	oil-flv	1
Olive oil flavor	OLV-flv	1
Adstringency	Adst	1
Edible oil flavor	Edboil-flv	1
Soybean oil flavor	Sboil-flv	3
Peanut flavor	Pnut-flv	1
Brazil nut flavor	Bznut-flv	1
Almond flavor	Alm-flv	1
Fish flavor	Fsh-flv	1
Viscosity	Visc	7
Velvety	Velv	3
Oiliness	Oil-txt	2

[a] Total of respondents: 9 assessors.

The Principal Component Analysis (PCA) of the consensus configuration (Fig. 1) of BO revealed three groups with distinct characteristics, so that the control and the samples stored for 60 and 120 days under nitrogen blanket differ from samples stored for 120 days without nitrogen blanket, which also differ from samples stored for 180 days or for 60 days without nitrogen. The positive side of the first dimension (F1), where the first group of samples are located, is correlated with the attributes nut odor, nut flavor, and sunflower seed flavor. The negative side of F1, where the other treatments are located, correlates with the attributes peanut odor, Brazil nut odor, baru flavor, oil flavor, olive oil flavor and viscosity. It is worth noting that nuts and almonds' flavors are also present in olive oils sensory profiles (Valli, Bendini, Popp, & Bongartzc, 2014), revealing some sensory similarity between olive oils and those made with oily seeds. In the second dimension (F2), BO without nitrogen blanket stored for 120 days is differentiated from the other samples, mainly those with 60 or 180 days of storage. The negative side of F2, where the samples BO-120 are located, correlates positively with the attributes soybean oil odor, soybean oil flavor and fishy flavor and negatively with yellow and olive colors, translucency, Brazil nut odor, baru odor, edible oil odor, almond odor, peanut flavor and Brazil nut flavor. These same samples chemically differed from the others by its higher peroxide value.

3.3. Acceptance

The acceptance of BO was assessed as pure oil and as ingredient of a salad dressing (Table 4). The acceptance of pure BO was high, with means around seven and eight points, and it did not change with time of storage or nitrogen blanket. The acceptance found for BO is satisfactory when the scores of acceptance of olive oil reported by Asensio, Nepote, and Grosso (2013) Recchia, Monteleone, and Tuorila (2012) are considered as references. Although sensory descriptive and chemical analysis have indicated changes in oils during storage, acceptance was not negatively affected by those changes. The acceptance of BO salad dressing was close to that of a regular olive oil salad dressing, which suggests the applicability of this oil for culinary purposes. New salad dressings are currently studied once they are products that enhance the attractiveness and tastiness of salads (Ma, Boye, Fortin, Simpson, & Prasher, 2013). The fatty acid profile of BO makes it more interesting than soybean oil, the currently major oil ingredient in salad dressings due to its lower cost (Lee, Lee, Min, & Pascall, 2014). Costs and chemical stability regarding the replacement of olive oil by BO in formulations of salad dressing are aspects that deserve further attention and research.

4. Conclusion

The chemical and physical characteristics of BO are close to those of peanut oil and olive oils. The changes in fatty acids profile during storage and between treatments with and without nitrogen blanket were slight. Significant decrease was observed in gadoleic acid after 120 days of storage of BO without nitrogen blanket. Iodine value and acidity of BO increased with storage time. BO stored under nitrogen blanket showed lower peroxide values. BO viscosity resembled peanut and olive oils. Regarding sensory analysis, BO at initial time showed more sensory similarities to samples under nitrogen blanket until 120 days of storage. Samples

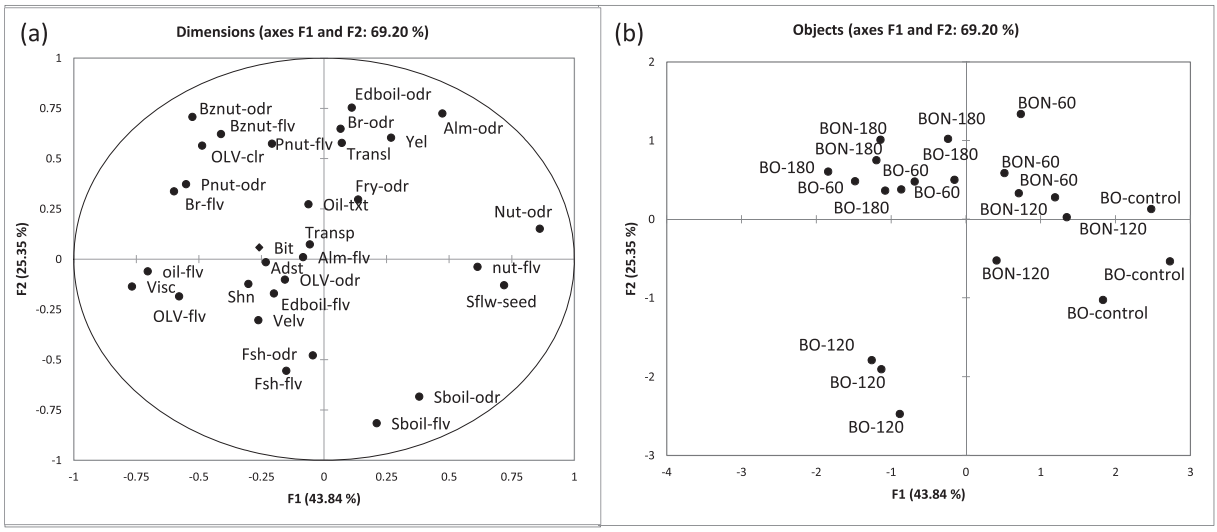

Fig. 1. Principal Component Analysis of consensus configuration data from GPA. a) Configuration of sensory variables (variable names in Table 2) b) Configuration of treatments. BO—baru oil and BON—baru oil under nitrogen blanket in the headspace, stored for 0 (control), 60, 120 and 180 days.

Table 4
Acceptance of pure baru oil with and without nitrogen blanket and overall acceptance of baru oil carried as ingredient in salad dressing.

	Overall impression	Appearance	Color	Odor	Flavor
Baru oil acceptance (n = 29 consumers)					
BO[A] control	7.1 ± 1.6a	7.9 ± 1.6a	8.1 ± 1.1a	6.9 ± 1.9a	7.4 ± 1.8a
BO—60	7.6 ± 1.4a	8.2 ± 0.9a	8.2 ± 0.9a	7.4 ± 1.6a	7.2 ± 1.7a
BON[B]—60	7.5 ± 1.3a	7.8 ± 1.4a	7.9 ± 1.1a	7.0 ± 1.9a	6.8 ± 2.1a
BO—120	7.6 ± 1.3a	8.0 ± 1.1a	8.1 ± 1.0a	7.2 ± 1.5a	7.6 ± 1.3a
BON—120	7.6 ± 1.4a	7.8 ± 1.4a	8.1 ± 1.0a	7.2 ± 1.6a	6.7 ± 2.0a
BO—180	7.4 ± 1.4a	8.2 ± 1.0a	8.2 ± 0.8a	7.6 ± 1.6a	7.1 ± 1.8a
BON—180	7.4 ± 1.6a	8.1 ± 1.0a	8.1 ± 1.1a	7.3 ± 1.2a	7.4 ± 1.2a
Salad dressing overall consumer acceptance (n = 114 consumers)					
BO control	6.9 ± 2.0				
Olive oil[a]	6.4 ± 1.9				

[A]BO—baru oil and [B]BON—baru oil with nitrogen blanketing, stored for 60, 120 and 180 days. In columns, means followed by the same letter dot not differ by Fisher Test ($p < 0.05$) for oils.

[a] Salad dressing made with olive oil was also evaluated as a reference for a mean of acceptance of the regular salad dressing.

stored without nitrogen blanket presented fishy and soybean oil flavors, besides higher peroxide value. However, samples with 60 and 180 days of storage showed more descriptive attributes related to baru, peanut and Brazil nut, olive oil and viscosity. Although sensory descriptive and chemical analysis have indicated changes in oils during storage, acceptance was not negatively affected by those changes in BO. Peroxide and acidity values were acceptable after 180 days of storage for all samples, indicating that BO can be commercialized with a shelf life of six months. The impact of nitrogen blanket was significant from the descriptive standpoint so that the cost-benefit of this step should be taken into consideration for a higher sensory quality, in spite of not being mandatory for the processing and marketing of BO in the evaluated period of time. BO can be applied in salad dressings with satisfactory acceptance. Further studies are necessary to assess antioxidants and volatile compounds and their changes during storage, as well as their relation with sensory profile of BO.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.lwt.2015.02.015.

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