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FOOD TECHNOLOGY

Enhancement of oat cereal bars with added *Araucaria angustifolia* flour: seed, almond or bark

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ABSTRACT: The feasibility of enhancing oat cereal bars, widely recognized for their health benefits, was investigated by replacing up to 5% oats with whole seed, almond, or steam-cooked pinhão husk flour. Pinhão contributes with resistant starch, antioxidant compounds, and minerals. The control oat bar (30.5% of the mixture), without pinhão flours but containing brown sugar (25.5%), raisins (15.0%), glucose (15.0%), coconut oil (3.0%), gelatin (0.5%), and water (10.0%), provides 75.53 kcal, with 15.66% carbohydrates (on a dry basis), 2.88% insoluble fiber, 0.70% soluble fiber, 1.82% protein, 0.62% lipids, and 0.32% minerals. Bars replacing up to 5% of oats with almond, husk, or whole seed flour showed statistically similar compositions, except for lipids, few minerals, phenolic compounds, and antioxidant activity. Concerning daily recommendations, a 22 g bar offers low energy (3.78%, Brasil, 1998) and proportionally high mineral content, including potassium (34.64%), zinc (81.58%), magnesium (108.55%), iron (421.18%), copper (192.98%), calcium (395.13%), and manganese (1,027.00%). Additionally, they exhibit a significant content of total phenolic compounds (8.66 mg GAE/g) and antioxidant capacity (24.43 mg Trolox/g). These innovative bars were well-received in sensory evaluations and demonstrated good commercial potential. Notably, a bar that replaced 5% oats with husk flour could be a viable option for microenterprises due to simplified technology, contributing to waste valorization and encouraging the preservation of the Araucaria Forest.
Key words: oat cereal bars, functional foods, sensory evaluation, market potential, sustainable food production.

Aprimoramento de barras de cereais de aveia com adição de farinha de *Araucaria angustifolia*: semente, amêndoa ou casca

RESUMO: A viabilidade de aprimorar barras de cereal de aveia, produtos amplamente reconhecidos por seus benefícios à saúde, foi investigada pela substituição até 5% da aveia por farinha de semente inteira, da amêndoa ou da casca do pinhão cozido a vapor. O pinhão pode contribuir com amido resistente, compostos antioxidantes e minerais. A barra controle de aveia (30,5% da mistura), sem farinhas de pinhão, contendo açúcar mascavo (25,5%), passas (15,0%), glicose (15,0%), óleo de coco (3,0%), gelatina (0,5%) e água (10,0%) disponibiliza 75,53 kcal, com 15,66% de carboidratos (base seca), 2,88% de fibras insolúveis, 0,70% de fibras solúveis, 1,82% de proteínas, 0,62% de lipídios e 0,32% de minerais. Barras substituindo até 5% de aveia por farinha de amêndoa, casca ou semente integral apresentaram geralmente composição estatisticamente similar, exceto para lipídeos, alguns minerais, compostos fenólicos e atividade antioxidante. Quanto a demanda diária, uma barra de 22g fornece baixa energia (3,78%) e proporcionalmente altos teores de minerais, como potássio (34,64%), zinco (81,58%), magnésio (108,55%), ferro (421,18%), cobre (192,98%), cálcio (395,13%) e manganês (1.027,00%). Além disso, essa barra exibe conteúdo relevante de compostos fenólicos totais (8,66 mg GAE/g) e capacidade antioxidante (24,43 mg Trolox/g). Essas barras inovadoras foram bem-aceitas sensorialmente e mostraram bom potencial comercial. Notavelmente, uma barra que substituiu 5% da aveia por farinha de casca pode ser uma opção viável para microempresas devido a tecnologia simplificada, contribuindo para a valorização deste resíduo e incentivando a preservação da Floresta com Araucárias.
Palavras-chave: barras de cereais de aveia, alimentos funcionais, avaliação sensorial, potencial de mercado, produção sustentável de alimentos.

INTRODUCTION

Cereal bars, those composed of oats (*Avena sativa* L.), are increasingly popular as an energy source and are strongly associated with health food trending in the contemporary food industry. Oats are recognized for their energy-providing properties, owing to the presence of biodegradable carbohydrates, as well as soluble dietary fiber (β-glucan) which contributes to the reduction of total cholesterol, very low-density lipoprotein, and low-density lipoprotein cholesterol. Additionally, combining oat-enriched diets, hypocaloric regimens, or docosahexaenoic acid supplementation has shown the potential to reduce triglyceride levels significantly (AMERIZADEH et al., 2022). Oat bars also receive brown sugar, raisins, coconut oil, and fruits as bioactive ingredients (KLERKS et al., 2022; VINHAL et al., 2022).

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Innovative strategies involving the partial replacement of oats from cereal bars with vegetable dietary fiber flours, such as husk (shell or coat) of Araucaria seed (pinhão) bark flour, have emerged as a promising approach (TIMM et al., 2020). In this context, the incorporation of flour derived from the whole pinhão, specifically the steamed pinhão (Integral), its shell (Husk), or its almond, has become a novel additive. The Pinheiro-do-Paraná (*Araucaria angustifolia*) is a tree of cultural and ecological significance, recognized for its almond extensively used in southern Brazilian cuisine. Despite its cultural and social importance, the cutting of this tree is legally restricted, as this pine is misclassified as vulnerable regarding the risk of extinction. A more attractive market would promote nutrition and marketing by rural producers, promote cultivation, and automatically discourage illegality (PERALTA et al., 2016). In this context, the utilization of pinhão has been extensively studied globally due to its functional attributes for food, pharmaceutical, and cosmetics manufacturing (CASTRILLON et al., 2023).

Notably, pinhão almond from fertilized seed (KOEHNLEIN et al., 2012), comprising approximately 76% (on a dry basis) of gluten-free starch (ZORTÉA-GUIDOLIN et al., 2017), has found its way into various products including cakes (IKEDA et al., 2018), bread (POLET et al., 2019), and cereal bars (CONTO et al., 2015), enhancing attributes such as the provision of slowly assimilated carbohydrates (ZORTÉA-GUIDOLIN et al., 2017), minerals, and bioactive compounds (CASTRILLON et al., 2023; LIMA et al., 2020). Combining almonds or husk components of cooked pinhão, immersed in water, offers an opportunity to produce oat cereal bars. Ground pinhão, cooked in water, can replace up to 20% oats without compromising sensory appeal or purchase intent. This approach not only adds nutritional value (BRASIL, 1998) but also offers an income-generating opportunity for small-scale farmers during the pinhão off-season (CONTO et al., 2015; QUINTEIRO et al., 2019), with simple production methods.

When it comes to preparing the pinhão almond for consumption, the traditional method involves cooking it in water (CONTO et al., 2015). Cooking facilitates the separation of the almond from the shell and increases the resistant and slowly digestible starch content (ZORTÉA-GUIDOLIN et al., 2017), but causes a small loss of starch, a complete loss of amylose and total soluble sugars in the almonds. It allows the transfer of polyphenols from the shell to the almond, which is beneficial as will be detailed below, but is also beneficial to the cooking water. (CORDENUNSI et al., 2004; CASTRILLON et al. (2023). In this sense, the steam cooking technique can represent an innovative approach to avoid loss of phenolic and carbohydrate compounds from the seed, while still being viable for implementation in kitchens and small businesses.

Highlighting the value of the husk (shell, peel, bark, or coat) and unfertilized seeds ("chocho") of pinhão harbor various bioactive components with potential health benefits, such as high molecular weight condensed tannins (KOEHNLEIN et al., 2012), phenolic compounds with antioxidant properties, and essential minerals (CASTRILLON et al., 2023). These components have the potential to mitigate glycemic spikes (LIMA et al., 2020), regulate serum triglyceride and cholesterol levels (OLIVEIRA et al., 2015; LIMA et al., 2020), and promote healthy weight management (LIMA et al., 2020). However, incorporating the peel into cereal bars requires emulsification to minimize its astringent effect on the food (TIMM et al., 2020), which requires more sophisticated technology.

From a broader perspective, maximizing the utilization of *Araucaria angustifolia* seeds to produce flours, including steamed pinhão-based flours (Integral, Almond, or Husk), through straightforward technology that traditional communities can implement, serves to prevent the extinction of this invaluable pine tree.

Considering these contexts, this study focuses on the development of three innovative cereal bars using simple technology to replace up to 5.00% of oats with steamed pinhão-based flours, intending to increase its nutritional value and/or provide protection against damage caused by free radicals and at the same time maintaining high acceptability and purchase intention.

MATERIAL AND METHODS

Production of three flours and cereal bar

Three pinhão flours were produced: integral flour (IPF), almond flour (PAF) and husk flour (PHF). The cones were collected at EMBRAPA - Florestas (Colombo, Paraná, Brazil) to select fertilized pinhão (Figure 1). The mature feminine strobilus or cone consists of seeds (full pinhão), unfertilized pinhão ("chocho"), and bracts (flaws) (CASTRILLON et al., 2023). Fertilized pinhão were washed and steamed (120 ºC) for 30 min in an autoclave (Fabbe, model 103, Brazil). Fifty seeds were peeled, and the husk and almond contents were determined (dry basis). A portion of unpeeled pinhão (IP) was dried in an oven (Fanem, model 002 CB, Brazil) with

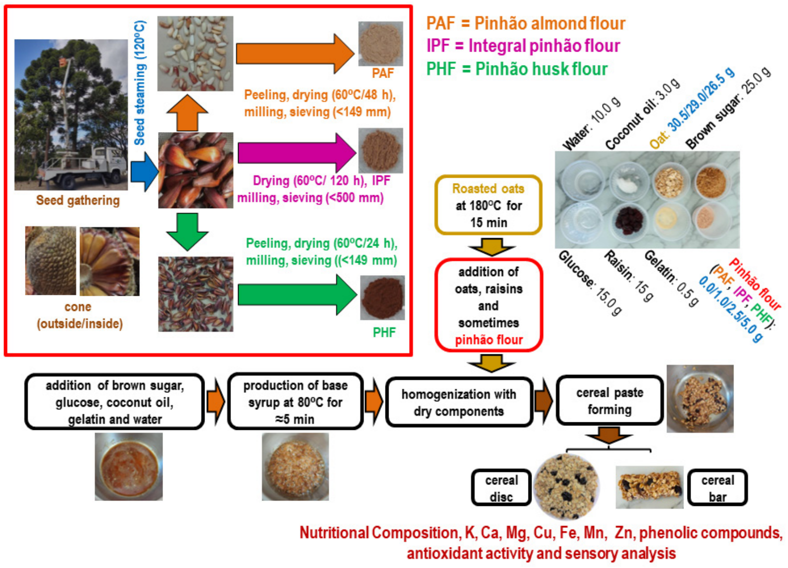

Figure 1 - Production process of whole meal, husk and almond flour (above left) and visual diagram of cereal bar production (bottom right).

air circulation at 60 ºC for 120 h, and ground in a knife mill (Fortinox, model star FT4G, Brazil). Sequentially, the fraction passed through a 100 mesh (<149 mm) sieve was called IPF. Alternatively, another amount of steamed pinhão was peeled, and the nut and the husk were dried separately in an oven with air circulation at 60 °C for 48 h and 24 h, respectively. Both portions were milled separately, and the portion that passed through a 35-mesh sieve (<500 mm) generated the PAF, while the portion that passed through a 100-mesh sieve (<149 mm) generated the PHF, respectively. All flours were stored in airtight vacuum packs.

Cereal bars were produced using common ingredients on the market (Figure 1). The oats were roasted in a preheated oven at 180 °C for 15 min to provide a crispy texture (TIMM et al., 2020). The water, coconut oil, brown sugar, glucose, and gelatin were heated at 80 °C for 5 min to form the caramelized base syrup. Then, raisins, oats, and eventually PAF, PHF, or IPF (1.0 to 5.0 g) to partially replace the oats, were incorporated (Table 1). After homogenization, the mixture was compacted on parchment paper to produce disks or cereal bars of approximately 22 g.

Physicochemical analyses

Moisture (M), ash (A), protein (P, factor 6.25), and lipid (L) contents were determined according to the protocols of (AOAC, 2016). Soluble dietary fiber (SF%) and insoluble dietary fiber (IF%) were determined by the enzymatic-

Table 1 - Formulation to produce control cereal bars or with up to 5.0% of one of the flours produced: whole meal (IPF), almond (PAF), and husk (PHF).

Material	1.0%	2.5%	5.0%	Control
Oats	30.5	29.0	26.5	31.5
Brown sugar	25.0	25.0	25.0	25.0
Raisins	15.0	15.0	15.0	15.0
Glucose	15.0	15.0	15.0	15.0
Coconut oil	3.0	3.0	3.0	3.0
Gelatin	0.5	0.5	0.5	0.5
Water	10.0	10.0	10.0	10.0
Functional flour*	1.0	2.5	5.0	0.0

gravimetric method using the Total Dietary Fiber Kit (Megazyme, Ireland). Carbohydrates (Carb%) were calculated according to the difference: 100% -A% -P% -L% -SF% -IF%. The caloric value (kcal/100 g) was calculated by the sum of P%$_*$4 +L%$_*$9 +Carb%$_*$4 (PÁDUA et al., 2004). The mineral components were determined after digestion with nitroperchloric acid. K was analyzed by flame photometry (Quimis Q398M2, Brazil) and Ca, Mg, Cu, Fe, Mn, and Zn by atomic absorption spectrometry (Perkin Elmer AA200, England) (AOAC, 1955, 2000, 2016). The phenolic compounds were determined using the Folin Ciocalteu method (YOON et al., 2015). Antioxidant activity was determined by inhibiting the ABTS•+ radical (YIM et al., 2013). The mean and standard deviation of triplicates (duplicates for dietary fibers) are expressed on a dry basis, except for moisture (wet basis). Eventual outliers were eliminated by the Q test ($P < 0.05$). Analysis of variance (ANOVA) and Tukey’s method were performed ($P < 0.05$) using Statistica13.2 software (StatSoft, USA).

Sensory analysis and flash profile

The microbiological biosafety of the bars has been proven against molds, yeasts, *Escherichia coli*, and *Salmonella* sp. (BRASIL, 2019). Sensory analysis was approved by the ethics committee (Plataforma Brasil; CAAE 26152919.9.0000.0102; approval opinion number 4045223). Fifty healthy volunteers and consumers of cereal bars belonging to the department of the higher education institution were used. The bars were cut (1.0 x 2.5 x 2.5 cm) and placed in disposable containers coded by three random digits (Figure 2). After signing the Informed Consent Form, the 10 bars at room temperature were presented in individual booths for a 9-point hedonic analysis (1: disliked very much – 9: like a lot) for appearance, color, odor, flavor, texture, and overall acceptability. Purchase intention was assessed using a 3-point scale (definitely would buy, might buy, and certainly would not buy). Water and crackers were used to neutralize aftertastes between sample evaluations (MONTANUCI et al., 2015). For the Flash Profile, 15 tasters were considered able to write spontaneous descriptors (odor, flavor, texture, and color) for bars without addition (control) or adding 5% PAF, PIF, or PHF. For the Grid method (ISO 13299, 2016), the evaluators classified the intensity of the sample descriptors on an unstructured scale (10 cm line) delimited by limits with terms “weak” and “strong” (ALBERT et al., 2011). Generalized Procrustes Analysis (GPA), a multivariate exploratory technique that involves transformations (i.e., translation, rotation, reflection, isotropic

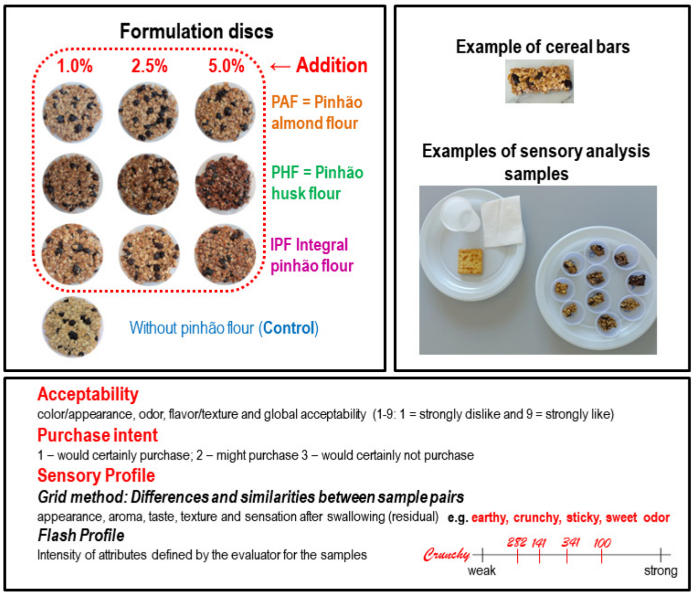

Figure 2 - Visual appearance of the control cereal bar production masses and with the addition of one of the three flours produced (above left) and samples used (above right) in the sensory analysis and purchase intention techniques (below).

rescaling) of individual data matrices to provide optimal comparability, was used for the multivariate calibration of the Sensory Profile using the XLSTAT® 2016 software (Addinsoft™) with 500 interactions, 22 configurations, 6 lines and 163 columns of data (Method: Commandeur, biplot type: Correlation biplot/ Coefficient= Automatic) to generate the GPA biplot graph. The Shapiro-Wilk test ($P > 0.05$) was used to verify normality, and the Bartlett test to verify homoscedasticity. ANOVA ($P < 0.05$) was applied according to Kruskal-Wallis for non-parametric data. The difference in means with the control sample was evaluated using the Duncan test and without the control sample using the Tukey test. Results were expressed as mean ± standard deviation. The percentage of each response assessed purchase intent. Tests, GPA graphs, and mathematical modeling were generated using R®Studio12.5 software and ChemoStat®V2 software.

RESULTS AND DISCUSSION

Production of three flours and cereal bar

The drying time to ensure complete dehydration was shorter for shells than for almonds. Seeds require even more time. These differences were attributed to mass transfer limitations along the water trajectory and specific to the biological tissue of the plant seeds. Seed flour (IPF) or shell flour (PHF) form smaller particles than almond flour (PAF). The PAF was lighter and the PHF was darker, as expected due to the higher content of starch and lignocellulosic material (CASTRILLON et al., 2023), respectively (Figure 1). The production of the bars was simple and there were no different requirements for different flours to replace up to 5% of the oats. The control cereal dough disc became lighter and the PHF disc became darker, being directly proportional to the added flour content (Figure 2).

Physicochemical analyses

The bars with or without additive produced did not show a significant difference ($P > 0.05$) on a dry basis for protein, insoluble dietary fiber, and soluble dietary fiber for the ten formulations, regardless of the addition (from 1.0 to 5.0%) or not of functional pine nut flours (Table 2). The difference in humidity may be due to the empirical selection of the endpoint of the preparation of the dough to produce bars (Figure 1). The quantification of lipids uses a more complex methodology than for the other parameters (PÁDUA et al. 2004) and their low proportion may explain the difference ($P > 0.05$). Thus, the original cereal bar (22 g) or with up to 5.0% IPF, PAF, or PHF would have 1.67 g of protein, 3.63 g of dietary fiber (0.74% soluble), 16.12 g of carbohydrates and 0.34 g of lipids (average admitted; although, it varied statistically).

This cereal bar showed essential mineral contents (Cu, Fe, Mn, and Zn), being statistically ($P > 0.05$) different for a few minerals for bars with the addition of at least one of the proposed flours. Additional studies are necessary to resolve the

Table 2 - Centesimal composition (g/100 g) and total caloric value (kcal/100 g) of the control cereal bars or with 1.0%, 2.5%, or 5.0% of one of the flours produced: whole meal (IPF), almond (PAF) and husk (PHF).

Sample	Moisture	Ash*	Proteins*	Lipids*	IDF*	SDF*	Carbohydrates*	TCV
PAF 1.0%	$13.51^{abc}\pm0.22$	$1.35^{a}\pm0.09$	$7.52^{a}\pm0.01$	$0.73^{c}\pm0.04$	$13.12^{a}\pm1.20$	$3.38^{a}\pm0.33$	73.90	332.25
PAF 2.5%	$14.30^{a}\pm0.39$	$1.37^{a}\pm0.03$	$8.43^{a}\pm0.62$	$1.66^{abc}\pm0.09$	$10.61^{a}\pm0.08$	$3.21^{a}\pm0.09$	74.72	347.54
PAF 5.0%	$12.67^{cd}\pm0.12$	$1.39^{a}\pm0.04$	$7.26^{a}\pm0.33$	$1.52^{abc}\pm0.22$	$11.81^{a}\pm0.46$	$4.05^{a}\pm<0.00$	73.97	338.60
PHF 1.0%	$11.01^{e}\pm0.29$	$1.35^{a}\pm0.09$	$7.93^{a}\pm0.55$	$2.02^{ab}\pm0.12$	$15.21^{a}\pm0.01$	$3.79^{a}\pm2.39$	69.70	328.70
PHF 2.5%	$13.94^{abc}\pm0.50$	$1.47^{a}\pm0.04$	$7.12^{a}\pm0.50$	$1.76^{ab}\pm0.05$	$15.75^{a}\pm1.09$	$2.71^{a}\pm0.56$	71.19	329.08
PHF 5.0%	$14.90^{a}\pm0.23$	$1.36^{a}\pm0.01$	$6.66^{a}\pm0.36$	$2.26^{ab}\pm0.21$	$15.97^{a}\pm1.85$	$3.05^{a}\pm0.16$	70.70	329.78
IPF 1.0%	$13.24^{bc}\pm0.31$	$1.34^{a}\pm0.10$	$8.33^{a}\pm0.21$	$1.70^{abc}\pm0.11$	$13.93^{a}\pm2.52$	$4.85^{a}\pm0.38$	70.45	330.42
IPF 2.5%	$14.49^{ab}\pm0.28$	$1.28^{a}\pm0.01$	$7.8^{a}\pm0.12$	$1.61^{abc}\pm0.09$	$10.58^{a}\pm1.59$	$2.79^{a}\pm0.20$	77.21	354.53
IPF 5.0%	$14.25^{ab}\pm0.15$	$1.27^{a}\pm0.06$	$7.90^{a}\pm0.02$	$0.85^{bc}\pm0.09$	$11.02^{a}\pm3.68$	$2.59^{a}\pm0.39$	77.63	349.77
Control	$11.72^{de}\pm0.43$	$1.24^{a}\pm0.07$	$8.27^{a}\pm0.05$	$2.83^{a}\pm0.31$	$13.07^{a}\pm0.52$	$3.20^{a}\pm0.11$	72.62	349.03

IDF = Insoluble Dietary Fibers, SDF = Soluble Dietary Fibers and TCV = Total Caloric Value. * Dry base.
Different letters in the same column demonstrate a significant difference ($P < 0.05$) between the means by Tukey's test (ANOVA).

observed variations, as a pattern of predictability has not been determined. Even so (Table 3), the consumption of a bar added with pinhão flour provides generally more minerals than energy (3.71%, this is the average for all added bars) concerning the daily recommendation. It would have proportionally more Mn (>691.60%), Fe (>270.56%), Ca (>258.89%), Cu (>178.81%), being deficient for Mg (only 92.39%), K (only 66.50%) and Zn (only 62.07%). Brazilian legislation (Portaria do Ministério da Saúde nº 27, of January 13, 1998) classifies food as a source and rich in minerals when it has at least 15% (* in Table 3) and 30% (** in Table 3) of the Dietary Reference Intakes (Brasil, 1998; DRI, 2001) to consumption of 100 g, respectively. Therefore, the pinhão flour bars are rich in Ca, Cu, and Fe, and sources of Mg and Mn (Table 3) according to the daily recommendation of intake of these compounds for men and women, which revealed to be applied as special foods. For example, Manganese (Mn) is an essential trace element for bone growth. For example, its deficiency in broiler chickens has increased the possibility of tibial dyschondroplasia (WANG et al., 2021). Also, Mn and Cu have indirect antioxidant activity, since they act as cofactors for several enzymatic reactions that neutralize free radicals (TURECK et al., 2013), that is, they inhibit damage to the biological system that could lead to the development of a large series of serious pathologies (BARBOSA et al., 2010).

The bars with and without additives with one of the flours presented compounds that protect human health, whether total phenolic compounds (expressed as Gallic Acid Equivalent GAE), as well as antioxidant activity (ABTS or 2,2'-azino-bis(3-ethylbenzothiazoline) 6-sulfonic acid expressed as equivalent to Trolox) (Table 4). The control oat bar exhibited a substantial content of 39.36 mg GAE in terms of total phenolic compounds (TPC), alongside 111.03 mg Trolox. Notably, these figures significantly surpass the modest 0.51 mg GAE/g observed in a quinoa-based cereal bar (KAUR et al., 2018). The incorporation of seed (IPF), husk (PHF), or almond (PAF) flour significantly amplifies ($P < 0.05$) the presence of phenolic compounds (Table 4). Although, not mandatory, there was a good correlation between ABTS and TPC ($ABTS=0.6679_{*}TPC+67.631$; $R^2 = 0{,}8278$), which suggested that the antioxidant activity of the Araucaria seed, as well as the almond and the husk, is mostly due to phenolic compounds. This substantiates the heightened concentration of phenolic compounds in cereal bars containing IPF, followed by those with PHF. The remarkable abundance of phenolic compounds in the bark is as expected, considering its predominantly lignocellulosic

Table 3 - Mineral composition (mg in 100g) of the control cereal bars or with 1.0%, 2.5%, or 5.0% of one of the flours produced: whole meal (IPF), almond (PAF) and husk (PHF).

Sample	K	Ca*	Mg	Cu**	Fe**	Mn*	Zn
PAF 1.0%	381.67^{a}±3,86	602,50^{c}±2.50	67.50^{bc}±2.50	0.35^{b}±0.05	4.86^{e}±0.06	2.89^{h}±<0.00	1.23^{ef}±0.02
PAF 2.5%	325.00^{b}±5.00	510.00^{f}±5.00	60.00^{d}±2.00	0.25^{d}±0.05	4.50^{e}±0.30	3.23^{g}±<0.00	1.28^{de}±0.05
PAF 5.0%	390.00^{a}±5.00	520.00^{f}±5.00	63.33^{cd}± 2.36	0.40^{a}±<0.00	5.22^{d}±0.06	3.61^{e}±0.04	1.11^{g}±<0.00
PHF 1.0%	335.00^{b}±5.00	617.50^{b}±22.50	70.00^{b}±2.00	0.40^{a}±<0.00	5.52^{c}±0.02	3.87^{d}±0.13	1.20^{f}±0.04
PHF 2.5%	300.00^{c}±10.00	700.00^{a}±15.00	70.00^{b}±2.00	0.40^{a}±<0.00	5.76^{b}±0.02	4.21^{b}±0.04	1.25^{e}±<0.00
PHF 5.0%	265.00^{c}±25.00	570.00^{d}±5.00	65.00^{c}±1.00	0.40^{a}±<0.00	5.28^{d}±0.01	3.49^{f}±<0.00	1.35^{c}±<0.00
IPF 1.0%	290.00^{c}±<0.00	556.67^{e}±4.71	70.00^{b}± 2.00	0.40^{a}±<0.00	5.46^{c}±0.06	4.17^{bc}±0.09	1.25^{e}±<0.00
IPF 2.5%	273.33^{c}±17.00	580.00^{d}±10.00	75.00^{a}±1.00	0.40^{a}±<0.00	5.88^{a}±0.01	4.38^{a}±0.04	1.33^{cd}±0.03
IPF 5.0%	285.00^{c}±5.00	675.00^{a}±15.00	65.00^{c}± 2.00	0.40^{a}±<0.00	5.22^{d}±0.06	3.66^{de}±0.09	1.40^{b}±<0.00
Control	210.00^{d}±9.00	682.50^{a}±12.50	75.00^{ab}±3.00	0.30^{c}±<0.00	5.82^{a}±0.06	4.08^{c}±<0.00	1.55^{a}±<0.00
DRI_{man} #, ##	3510	1000	400	0.900	8	2.3	11
DRI_{woman} #,##	3510	1000	310	0.900	18	1.8	8

*Source (>15%) and **Rich (>30%) of this mineral concerning the Dietary Reference Intakes (Brasil, 1998; DRI, 2001) for consumption of 100 g of bar.

#DRI. Dietary Reference Intakes for vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, nickel, silicon, vanadium, and zinc; Standing Committee on the Scientific Evaluation of Dietary Reference Intake, Food and Nutrition Board, Institute of Medicine, 2001. ##for 19 to 50 years of age.

Different letters in the same column demonstrate a significant difference (P < 0.05) between the means by Tukey's test (ANOVA).

Table 4 - Total phenolic compounds and antioxidant activity of the control cereal bars or with 1.0%, 2.5%, or 5.0% of one of the flours produced: whole meal (IPF), almond (PAF), and husk (PHF).

Sample	Total phenolic compounds[1] (mg GAE/g)	ABTS[2] (mg Trolox/g)
PAF 1.0%	52.15^{h}±0.46	96.35^{g}±0.72
PAF 2.5%	62.33^{e}±<0.00	106.45^{e}±<0.00
PAF 5.0%	56.36^{g}±0.46	103.13^{f}±1.26
PHF 1.0%	47.04^{i}±0.45	104.49^{f}±0.26
PHF 2.5%	64.01^{d}±<0.00	114.33^{c}±1.78
PHF 5.0%	88.90^{b}±2.80	120.33^{b}±0.78
IPF 1.0%	61.59^{f}±<0.00	112.58^{d}±0.79
IPF 2.5%	75.68^{c}±0.93	116.43^{c}±1.57
IPF 5.0%	94.88^{a}±0.47	137.31^{a}±<0.00
Control	39.36^{j}±3.15	111.03^{e}±0.26

Total phenolic compounds: Gallic Acid Equivalent (GAE); ABTS antioxidant activity = Trolox (6-hydroxy-2,5,7,8-tetramethylchrome-2-carboxylic acid) equivalent. Different letters in the same column demonstrate a significant difference ($P < 0.05$) between the means by Tukey's test (ANOVA).

composition. Furthermore, the elevated levels of phenolic compounds in PAF (Table 4) prove that steam cooking allows their migration from the shell to the almond (CORDENUNSI et al., 2004), but prevents their loss in the cooking water, as the seeds are not immersed as in usual cooking (CASTRILLON et al., 2023). The benefits of these compounds open the prospect of extracting them from unfertilized seeds ("chocho") to produce food additives. For example, tannins (e.g., catechin at 140.6±2.86 mg/100 g bark and epicatechin at 41.3±2.73 mg/100 g bark), alongside flavonoids such as quercetin (23.2±0.06 mg/100 g peel) and apigenin (0.6±0.06 mg/100 g peel), can be successfully extracted to form an aqueous extract (SOUZA et al., 2014). Still, the production of a hydroalcoholic bark extract (ranging from 19 to 71 mg GAE/g) opens doors to various technological possibilities. Importantly, tannins are known to have weight loss properties, combat obesity (PERALTA et al., 2016), and maintain cellular homeostasis redox levels (SOUZA et al., 2014). Additionally, flavonoids have demonstrated favorable effects against conditions like cancer, cardiovascular diseases, and neurodegenerative disorders (ASENSI et al., 2011; OBRENOVICH et al., 2011). Conversely, the direct use of husk flour or whole meal flour is cheaper and viable for small businesses. It is noteworthy that phenolic compounds can influence taste, odor, color, and shelf life while being closely correlated with antioxidant capacity (OLIVEIRA et al., 2014). Consequently, the observed physicochemical characteristics collectively suggested that this product possesses a favorable shelf life, providing a source of dietary fiber and phenolic compounds (CORDENUNSI et al., 2004; SANT'ANNA et al., 2016 This stark contrast underscores the valuable contribution of incorporating the unique husk component to enhance the nutritional profile (BRASIL, 1998) and biosecurity of cereal bars. The antioxidant activity was also reinforced (from 32.49% to 141.06% more) by the addition of one of the flours (Table 4), which proves other health benefits for consumers of the proposed products.

Sensory analysis and flash profile

The bars with the addition of 5.0% IPF, PAF, or PHF or not (control) microbiologically safe (BRASIL, 2019) were evaluated by a hedonic scale by 50 untrained consumers between 23 and 55 years old, predominantly women (86%). The Grid method revealed differences between sample pairs for descriptors such as color (light and dark tones), sweet, sticky/firm or soft flavor and aroma, and earthy texture (Figure 3). The most cited descriptors were sweet, sticky flavor, sweet aroma, firm, light color, and dark color. The sweet taste was associated with the Control bar due to fewer phenolic compounds (Table 4) and slightly less for the bar with 5.0% PAF (Figure 3), this flavor is partially masked by the astringency of the peel (TIMM et al., 2020). Stickiness was more related to the bar with 5.0% PAF, which is compatible with the texture of this almond. The dark color was more associated with the bar with 5.0% PHF (Figure 2) and the light color was attributed to 5.0% IPF (≈24% peeling), which is logical.

No statistically significant differences were observed ($P < 0.05$) in sensory attributes such as odor, flavor/texture, and overall acceptability (Table 5). However, the darker color/appearance of the 5.0% PAF variant may present a potential limitation for certain consumers, leading to increased variability in preference. Aggregate scores ranged between 5.76 (indicative of 'indifference') and 7.32 (representing 'moderate likeness'), indicating that the inclusion of PHF up to 5.0% is viable. Notably, cereal bars enriched with quinoa seeds achieved a similar score of 7 (SILVA et al., 2011).

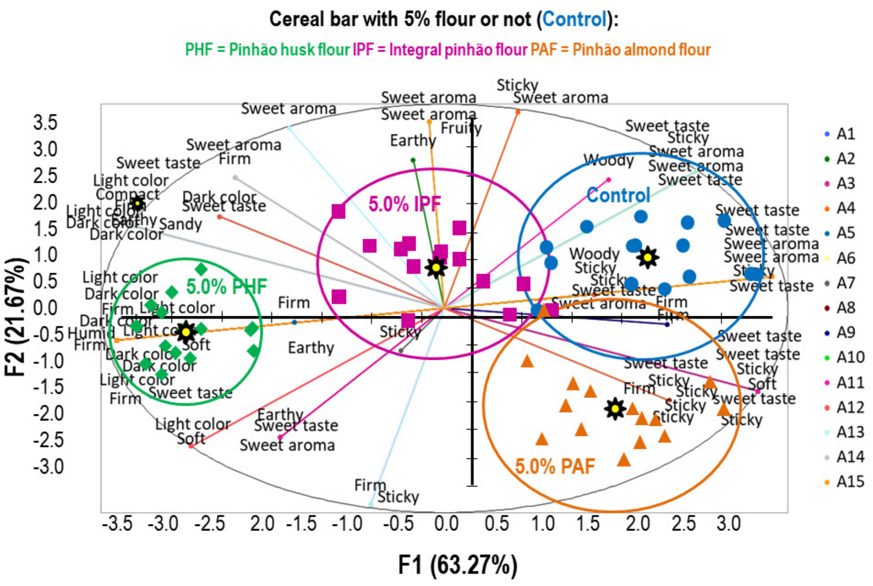

Figure 3 - Generalized Procrustes Analysis (GPA), the spatial distribution of terminology compiled in the plane (2D), and its relationship with control cereal bars (without addition) or with addition (5.0%) of one of the three flours produced.

This supposition finds support in the low rejection rates (8-20%) - signifying 'certainly would not buy' - except for PAF 1.0% (36%) and IPF 2.5% (24%), while the control bar recorded a rejection rate of 24%. Thus, it can be inferred that there exists an 86% potential market for the sale of these enriched cereal bars. Consequently, oats could be substituted by up to 5.0% PHF or PIF in the production of specialized foods, whether whole-grain or augmented with whole-grain flours (IKEDA et al., 2018; POLET et al., 2019).

While the hedonic evaluation did not yield variances among the four bars, the Generalized Procrustes Analysis (GPA), employing descriptors with correlation coefficients of 0.60 or higher as recommended (MAMED; BENASSI, 2016) from 15 evaluators,

Table 5 - 9-Point hedonic evaluation of color/appearance, odor, flavor/texture and overall acceptability of the of cereal bars control or with 1.0%, 2.5% or 5.0% of one of the flours produced: almond (PAF), husk (PHF) and whole meal (IPF).

Sample	Color/Appearance	Odor	Flavor/Texture	Overall acceptability
PAF 1.0%	7.00^{a}±1.73	6.50^{a}±1.50	6.96^{a}±1.64	7.06^{a}±1.37
PAF 2.5%	6.98^{a}±1.83	6.50^{a}±1.43	6.96^{a}±1.39	6.94^{a}±1.49
PAF 5.0%	6.84^{ab}±1.90	6.46^{a}±1.34	7.02^{a}±1.75	7.12^{a}±1.54
PHF 1.0%	6.76^{ab}±1.33	6.82^{a}±1.30	7.14^{a}±1.56	7.30a±1.32
PHF 2.5%	6.50^{ab}±1.60	6.62^{a}±1.38	7.20^{a}±1.96	7.10^{a}±1.71
PHF 5.0%	5.76^{b}±2.02	6.42^{a}±1.38	7.32^{a}±1.47	7.10^{a}±1.37
IPF 1.0%	6.22^{ab}±2.03	6.60^{a}±1.27	7.18^{a}±1.52	7.02^{a}±1.31
IPF 2.5%	6.98^{a}±1.22	6.58^{a}±1.10	7.10^{a}±1.74	7.08^{a}±1.60
IPF 5.0%	6.44^{ab}±1.71	6.58^{a}±1.21	7.22^{a}±1.32	7.18^{a}±1.32
Control	6.10^{ab}±1.91	6.62^{a}±1.27	6.94^{a}±1.77	6.92^{a}±1.54

Scale for organoleptic characteristics and overall acceptability: 1 - Strongly dislike to 9 - strongly like. Different letters in the same column indicate a significant difference ($P < 0.05$).

demonstrated no discernible distinction between the 15 samples of the same cereal bar (as depicted within the ellipses in figure 3). Notably, variations were evident between different bar types, distinguished by their respective color-coded data points.

This attribute survey marks a novel approach in the context of cereal bar analysis. The descriptors and their intensities account for 84.94% (F1) and 63.27% (F2) of the variance, respectively, as depicted in the GPA Biplot graph (Figure 3). The statistical test, indicating $P < 0.0001$ ($\alpha=0.05$) between F1 and F2, reaffirmed the effective differentiation among the samples.

F1 primarily correlates with attributes such as stickiness, sweetness, earthy flavor, aroma, and both light and dark tones, while F2 is associated with sugary and earthy textures, firmness, and stickiness. These factors relate to color and flavor/texture aspects. Flavor/texture has also been described for mapping of 8 granola bars, as bitter, fruity, sweet, and sour typical of berry-type fruits and texture characteristic of nuts and granola bars (KENNEDY, 2010). Color descriptors (light/dark) were frequently cited for the 4 bars evaluated in the present study (Table 6) and contributed to the correlation of factors in the multivariate analysis ($r>0.90$), composing the descriptors: flavor and sweet aroma, light colors and dark, moist, sticky, fruity, soft and compact. These descriptors are not necessarily negative, which reinforces the good hedonic evaluation and promising purchase intention (86%), but it is necessary to conduct complementary optimization of the formulation.

Thus, adding one of the three *Araucaria angustifolia* seed flours up to 5% in cereal bar-based formulations can be considered promising. Steamed pinhão flour or its parts can also be applied in the production of expanded extruded food, beer, films, cake, bread, and nanosuspension (CONFORTI & LUPANO, 2008; ZORTÉA-GUIDOLIN et al., 2017; JORGE et al., 2018; DAUDT et al., 2017; IKEDA et al., 2018; POLET et al., 2019). The value of pinhão husk, including the unfertilized seed ("chocho"), can also be used as an input for the preparation of pharmaceutical excipients, bactericides, and biocomposites and to compose nanosuspensions for various applications (DAUDT et al., 2014; TROJAIKE et al., 2019; ENGEL et al., 2020; LIMA et al., 2020).

The socio-environmental impact of producing cereal bars with additives using simple, cost-effective technology holds promise for small-scale entrepreneurs. This approach facilitates year-round income generation, countering the limited availability of seeds that typically allows income generation for only about one-third of the year. Additionally, considering that the pinhão husk constitutes approximately a

Table 6 - Attributes best correlated with the dimensions 1 and 2 by the evaluator in the Flash Profile ($|r|>0.60$ as related by MAMED; BENASSI, 2016). of the cereal bars control or with 1.0%, 2.5% or 5.0% of one of the flours produced: whole meal (IPF), almond (PAF) and husk (PHF).

Evaluator	F1	F2
1A	(-0.913) light color; (-0.954) firm	(0.960) sweet aroma
2A	(0.913) sweet flavor; (-0.913) firm; (-0.913) compact	-
3A	(0.954) sweet flavor	-
4A	(0.913) sweet flavor; (-0.954) dark color; (0.737) sweet aroma	(0.960) sticky
5A	(-0.954) light color	-
6A	(-0.954) light color	-
7A	(0.954) sweet flavor; (-0.954) dark color	(-0.960) firm; (0.917) sweet aroma
8A	(-0.954) sweet flavor; (-0.954) dark color; (-0.954) moist	-
9A	(0.913) sweet flavor; (-0.913) dark color; (0.954) sweet aroma; (0.913) sticky	-
10A	(-0.954) dark color; (0.913) soft	-
11A	(-0.954) light color; (-0.954) soft; (0.913) sticky	-
12A	(-0.913) dark color	-
13A	(-0.913) light color; (-0.913) sandy	(0.882) sweet aroma; (-0.960) sticky
14A	(0.954) sweet flavor; (-0.913) earthy	(0.917) fruity
15A	(0.954) sweet flavor; (-0.954) light color; (-0.954) firm; (0.954) sticky	(0.917) sweet aroma

quarter of the seed's mass, its utilization prevents wastage, provides supplementary income, and reduces environmental impact.

Moreover, promoting the comprehensive utilization of the seed encourages the conservation and cultivation of the Araucaria tree, potentially averting its endangered status. This holistic approach to seed utilization not only fosters economic sustainability but also contributes to the preservation of the Araucaria species.

CONCLUSION

Whole meal, almond, and husk flours can be easily manufactured through a series of uncomplicated steps: collection, selection, steam cooking, shelling (or not), drying at 60 ºC, grinding, and sieving. Notably, the husks, constituting approximately 24% of the seed's dry mass, are particularly intriguing to produce oat cereal bars. The entire process, encompassing the creation of a base syrup, the addition of solid components, mass production, compaction, and cutting, remains straightforward. Oat cereal bars are recognized for their functional properties due to oats and other components. Substituting up to 5.0% with Pinhão Almond Flour (PAF), Pinhão Husk Flour (FHP), or Full Pinhão Flour (FIP) does not induce significant alterations in the bar's composition. Consequently, these bars offer rapid energy primarily sourced from biodegradable carbohydrates, accompanied by insoluble and soluble dietary fiber. Furthermore, they deliver substantial quantities of essential minerals, including manganese, copper, iron, calcium, and magnesium. These bars are also rich in total phenolic compounds, which are its main antioxidant compounds. It is noteworthy that steam cooking does not cause the loss of these compounds in the cooking water through immersion. The favorable results obtained from hedonic sensory evaluations and purchase intentions underscore the significant potential for these bars to become successful commercial products. The introduction of diverse Pinhão flours imparts distinct characteristics to the bars, rendering them promising candidates in the market. This technology can be readily adopted by micro-entrepreneurs, including family businesses, and may contribute to the preservation of the Araucaria Forest, thereby mitigating its decline.

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DECLARATION OF CONFLICT OF INTEREST

We have no conflict of interest to declare.

AUTHORS' CONTRIBUTIONS

All authors contributed equally to the design and writing of the manuscript. All authors critically reviewed the manuscript and approved the final version.

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