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Effect of baru (*Dipteryx alata* Vog.) addition on the composition and nutritional quality of cookies

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Abstract

The use of the defatted baru almond (*Dipteryx alata* Vog.) prevents the production of waste residues after extraction of its oil (partially defatted baru flour), representing a process of interest from an environmental point of view. The aim of this study was to prepare oat cookies with functional properties, replacing 100% soy oil for baru oil and 30% wheat flour for partially defatted baru flour (baru cookie). Baru cookies presented a higher moisture (7.80%), probably due to the high content of dietary fiber (3.78%), resulting in a lower calorie content (457.46 kcal.100 g^{-1}), compared to traditional oat cookies. Changing the formulation resulted in the enrichment of a number of microelements, including phosphorus (~ 197.90 mg.100 g^{-1}) and iron (~ 21.56 mg.100 g^{-1}). Baru oil increased the concentration of unsaturated fatty acids (~ 76.11%), consisting of approximately 50.37% monounsaturated (MUFA), and 25.74% polyunsaturated fatty acids (PUFA). The total phenolic compound content was approximately doubled in the baru cookie. As such, the baru cookie presents an interesting composition from a nutritional point of view, having a high protein and dietary fiber content, in addition to presenting substantial concentrations of iron and oleic acid, and may be used as part of a healthy diet.

Keywords: baru; unsaturated fatty acids; whole utilization of foods; food composition; dietary fibers.

Practical Application: The use of baru in cookies increases their protein content, iron and monounsaturated fatty acids, such as oleic acid.

1 Introduction

The baru almond (*Dipteryx alata* Vog.) is an edible seed from the fruit of the "barueiro" tree, which is native to the Cerrado biome. The barueiro fruit is of the drupe type and, therefore, has a fibrous pulp with a hardened center containing a single edible oleaginous seed (Lorenzi, 2002). The tree is native to the Brazilian Cerrado, belongs to the Leguminosae family, and has an average height of 15 meters. It flowers from October to January and its fruits ripen between March and August, producing on average of 2000-6000 fruits per plant (Pio Corrêa, 1984; Sano et al., 2006).

The tree's seed or baru almond contains approximately 38.20% lipids, consisting predominantly of unsaturated fatty acids; 23.90% protein; 15.80% carbohydrates; 13.40% dietary fiber, of which 2.50% are soluble fibers and 10.90% are insoluble fibers (Pineli et al., 2015a). The baru almond also has a high mineral content, especially of calcium, iron, magnesium, potassium, phosphorus and zinc (Sousa et al., 2011; Siqueira et al., 2012; Takemoto et al., 2001).

Soybean oil is the most widely-consumed vegetable oil in Brazil, mainly due to its cost; however, the demand for vegetable oils with differentiated chemical compositions is currently increasing (Pedreiro, 2007; Santos et al., 2013). Some oils, such as baru oil, stand out due to their high contents of α-tocopherol (5 mg / 100 g) and peanut oil-like fatty acid composition (50.40% oleic acid and 28.0% linoleic acid) (Takemoto et al., 2001; Santos et al., 2013).

The inclusion of 20g baru almond in the diet of subjects with mild hypercholesterolemia (Bento et al., 2014) significantly reduced serum total cholesterol (TC), low-density lipoprotein (LDL-c) and non-high-density lipoprotein (non-HDL-c) (Bento et al., 2014). Animals fed for two months with a high-fat diet and 15% baru almond lipids showed a reduction in lipid peroxidation and an improvement in serum lipids (Fernandes, 2011). Additionally, Siqueira et al. (2012) reported that the feeding of iron-supplemented rats on diets with 10% baru almond for 17 days protected them against tissue damage and lipid oxidation caused by iron-induced oxidative stress (Siqueira et al., 2012).

Due to its nutritional composition and promising study results, the baru almond has been amply explored, particularly with a view to developing foods with added baru almond and/or its by-products (Soares et al., 2007; Rocha & Cardoso Santiago, 2009; Santos et al., 2012; Pineli et al., 2015a, b). It has been shown that cookies developed with different partially defatted baru flour (PDBF) concentrations in substitution of wheat flour (WF) and cassava starch (CS) (Soares et al., 2007) present

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increases in protein, lipids, iron, calcium and fiber, as well as improved nutritional quality. The addition of 8.0% PDBF to the cookie does not affect the sensory preferences of consumers (Soares et al., 2007).

As such, the use of baru derivatives in different types of food can contribute to the utilization of alternative regional products, contributing to the conservation and sustainable development of native Cerrado (Soares et al., 2007; Pineli et al., 2015a). Furthermore, use of the whole baru almond, employing baru almond oil and PDBF in cookies, presents an interesting alternative from an economic and nutritional point of view.

2 Material and methods

2.1 Obtaining the sample (baru almonds)

Baru almonds were obtained from the municipal market of Goiânia (GO, Brazil) and originated from the Cerrado of the Midwest region. Other ingredients used for making cookies were of known brands and acquired in local shops (SP, Brazil).

2.2 Baru oil extraction

The extraction of baru almonds oil was carried out using a cold press type expeller, with processing of 40 to 60kg/h raw material, at the Institute of Food Technology (ITAL), in Campinas (SP, Brazil). To improve the baru oil extraction performance, baru almonds were initially subjected to mechanical disintegration without heating (coarse grinding) to break the original almond structure (which is wrapped by epicarp) to facilitate the release of the oil. The almonds were placed in the expeller for pressing; the duration of each batch pressing was 10 minutes on average. The crude oil yield was calculated by the ratio of the mass of oil obtained in the press to the initial mass of oil in the grain. The partially deffated baru flour yield was calculated using the ratio of the mass of partially deffated baru flour obtained from the pressing to the initial grain mass.

After the extraction process, the baru oil was obtained, as well as partially deffated baru flour (PDBF) as a by-product. The oil obtained was stored in an amber bottle at –20 °C for later use, and the PDBF was subjected to the autoclaving process for inhibiting antinutritional factors.

2.3 Inactivation of the trypsin inhibitor

The PDBF obtained after oil extraction was autoclaved to inactive antinutritional factors, using the following conditions: 120 °C for 20 minutes under a pressure of 1kgf/m^2, according to Siqueira et al. (2015).

2.4 Cookie development

Initially, pilot tests were carried out in order to produce cookies with interesting nutritional properties and pleasant sensory aspects. Therefore, the original soy oil formulation was totally replaced by baru oil and PDBF partially replaced (30%) the wheat flour (WF) of the original formulation. The percentage of substitution by PDBF was defined after preliminary tastings. The following percentages of WF replacement by PDBF were initially used during the development of the cookies; 15%, 30% and 45%. After defining the best concentrations of ingredients, the formulation described in Table 1 was obtained.

2.5 Baru oil fatty acid profile

The fatty acid profile of baru oil was analyzed on a capillary gas chromatograph (Agilent, 6850 Series GC System, U.S.A.) after esterification, Hartman & Lago (1973). The methyl esters of fatty acids were separated according to the method of American Oil Chemists' Society (2009) using an Agilent DB-23 capillary column (50% cyanopropyl-methylpolysiloxane), with dimensions 60 m, Ø int: 0.25 mm, 0.25 μm film. The operating conditions of the chromatograph were as follows: column flow 1.00 mL / min; linear velocity 24 cm / sec; detector temperature 280 °C; injector temperature 250 °C; furnace temperature 110 °C; C-5 min 110-215 °C (5 °C / min), 215 °C-24 min. The carrier gas used was helium, and an aliquot of 1 μL of the samples was injected into the apparatus. Fatty acid determination was determined by comparing the peak retention times with the respective fatty acid standards.

2.6 Extract preparation

To obtain the extracts for cookies, 1.0 g of dry material was added to deionizated water, agitating in a vortex, applying ultrasound and centrifuging at 11 000rpm/15min at 4 ± 1 °C (5810-R, Germany) and the extract was filtered with filter paper (Whatmann nº3). Subsequently, 80% ethanol was added to the filtrate and agitated in a vortex, before applying ultrasound and centrifuging (sequence repeated twice) at 11 000 rpm/15 min at 4 ± 1°C (5810-R, Germany) and filtered with filter paper (Whatmann nº3). The extract was transferred to a volumetric flask and the contents adjusted with 80% ethanol to a volume of 20mL. Subsequently the extracts were packaged in amber bottles and kept at –80 °C until the time of determination of total phenolic compound concentrations.

2.7 Determination of total phenolic concentration

The Folin-Ciocalteu method was used to quantify the concentration of total phenolic compounds (FT) of the oat cookie and baru cookie extracts, according to the methodology described by Singleton & Rossi (1965). Initially a standard curve was elaborated

Table 1. Percentage compositions of ingredients in the baru cookie and oat cookie formulations.

Ingredients (%)	Baru cookie	Oat cookie
Oat	28.4	28.4
Brown sugar	18.1	18.1
Wheat flour (WF)	17.5	25.0
Partially deffated baru flour (PDBF)	**7.5**	--
Egg	14.0	14.0
Soy oil	--	**12.5**
Baru oil	**12.5**	--
Vanilla extract	1.3	1.3
Baking poder	0.7	0.7
Total yield (g)	100.0	100.0

using solutions with increasing concentrations (50-300 µg / mL) of gallic acid, subsequently, 100 µL of Folin-Ciocalteu reagent were added to 20 µL of each extract in a microplate. The mixture was allowed to react at room temperature (25 ± 1 °C) in the dark for 5 minutes. Sodium carbonate (Na_2CO_3; 80µL) was then added at 7.5%, before incubating for 30 minutes in a dark room and at room temperature (25 ± 1 °C). The absorbance was measured at 750 nm using a microplate reader (Microplate Spectrophotometer, Biotek, Winooski). Results are expressed as mg of gallic acid equivalents (EAG) per 100 grams of the dry sample.

2.8 Chemical composition

The PDBF, baru almond and baru cookie were analyzed to determine their nutritional compositions (macronutrients and minerals). Their moisture, protein and ash concentrations were determined using the methods described by the Association of Official Analytical Chemists (American Oil Chemists' Society, 2009). The protein content was determined by the micro-Kjeldahl method, multiplying the total nitrogen by a factor of 6.25. The dosage of the lipid content was performed using the Soxhlet method, employing ethyl ether. The carbohydrate content was calculated by the difference. The dietary fiber content was determined by the enzymatic-gravimetric method of Prosky et al. (1988). The whole metabolizable energy value was expressed in kilocalories (kcal), considering the Atwater conversion factors: (4 x g protein) + (4 x g carbohydrates (carbohydrates total – dietary fiber) + (9 x g lipids total). In addition, the mineral composition was determined by elemental Scanning Electron Microscopy (SEM) microanalysis (Hitachi brand, model TM 3000 – Tabletop Microscope) coupled with Dispersive Energy Spectroscopy (DES) (Hitachi brand, Swift model ED3000). The samples were sectioned into small pieces and placed on the equipment's platform. Minerals were analyzed with magnifications of 2500, 5000 and 8000 times (Goldestein & Newbury, 1992). All data were converted to dry base parameters.

3 Results

3.1 Oil extraction yield and baru oil fatty acid profile

After cold oil extraction using a press type expeller, we obtained an oil yield of 20.43%, resulting in 79.47% PDBF. Thus, each 1000g baru almond yielded approximately 204.30g of oil. The analysis of the fatty acid profile of the baru oil, as well percentages in relation the recommendation for a daily diet can be observed in Table 2. The consumption of a serving size of the baru cookie (30 g) provides, on average, 4.00% of the daily recommendation of unsaturated fatty acids.

3.2 Total phenolic composition of cookies

Total phenolic (TP) concentrations were 13.6 mg GAE/100g for the oat cookie and 25 mg GAE/100 g for the baru cookie. The amount of TP found in the Baru cookie was almost 2 times greater than that of the oat cookies.

3.3 Centesimal composition and phenolic compound concentration of cookies

Before preparing the cookies, the antinutritional factors of the PDBF were inactivated by autoclaving, as recommended by Siqueira et al. (2015). Autoclaving is a thermal process that controls temperature and ambient pressure, in addition to applying moist heat, in a completely closed system to provide reproducible conditions that can improve the digestibility of food protein (Siqueira et al., 2015). In a previous study by our research group, we found similar levels of trypsin inhibitor in whole baru (12.84 ± 0.10 UTI / mg) and PDBF (12.67 ± 0.15 UTI / mg). After autoclaving the PDBF, the value of this antinutrient is reduced to 0.46 ± 0.44 UTI / mg without damaging its nutritional characteristics.

The results of the centesimal composition of baru almond and PDBF are described in Table 3. The concentrations of baru cookie nutrients are described in Chart 1, as are the results of

Table 2. Fatty acid composition of baru almond oil, expressed as percentages (mean ± SD) of the daily recommended value (DV) for the main fatty acids and percentage adequacy of the main fatty acids in a serving size of cookie (30 g).

Fatty acids	Baru almond oil (%)	Daily recommended value (Kcal)	Percentage serving size in relation to the recommended daily value (%DV)
C16:0 (palmitic)	6.38 ± 0.09	-	-
C18:0 (stearic)	6.66 ± 0.01	-	-
C20:0 (arachidonic)	1.72 ± 0.01	-	-
C22:0 (behenic)	3.57 ± 0.04	-	-
C24:0 (lignoceric)	5.03 ± 0.08	-	-
C18:1 (oleic) - ω9	48.26 ± 0.04	-	-
C20:1(elaidic/gadoleic)	2.11 ± 0.02	-	-
C18:2 (linoleic) – ω6	25.59 ± 0.03	100-200[a]	5.12
C18:3 (linolenic) – ω3	0.15 ± 0.01	12-24[b]	0.25
Total SFA	23.36	< 200[c]	3.5
Total UFA	76.11	520-600[a]	4.07
Total MUFA	50.37	400[a]	3.78
Total PUFA	25.74	120-200[a]	4.83

[a] Guidelines for the consumption of fats and cardiovascular health (Santos et al., 2013); [b] Institute of Medicine (2011); [c] Guia alimentar para a população brasileira (Brasil, 2008).

Table 3. Centesimal composition of baru almond and partially defatted baru flour (PDBF) (mean ± SD).

Analysis	Baru almond ($g.100g^{-1}$)[a]	PDBF ($g.100g^{-1}$)[a]
Moisture	4.10 ± 0.06	6.53 ± 0.02
Ash	2.65 ± 0.01	3.04 ± 0.04
Proteins	10.87 ± 0.50	12.67 ± 0.20
Lipids	61.03 ± 0.03	56.12 ± 0.06
Total dietary fiber	8.80 ± 0.90	10.05 ± 0.75
Carbohydrates[b]	12.55	11.59
Total energy value (kcal)	607.75	561.92

[a] Values expressed on a dry basis; [b] Obtained by difference.

Chart 1. Centesimal composition and mineral composition of baru cookies (mean ± SD), nutritional value of the serving size (30g) and adequacy percentage of the serving size, in relation to the daily value.

Nutrients	Nutritional value of baru cookie (100g)[a]	Nutritional value of baru cookie ($g.30g^{-1}$)	Adequacy percentage (% DV)[b]	Nutritional value of oat cookie ($g.30g^{-1}$)[a]	Adequacy percentage (% DV)[b]
Moisture (g)	7.80 ± 0.18	2.34	-	3.5	-
Ash(g)	3.30 ± 0.01	-	-	-	-
Proteins (g)	11.76 ± 0.02	3.53	5.65	3.43	5.48
Lipids (g)	20.18 ± 0.02	6.05	12.1	5.35	10.7
Total dietary fiber (g)	3.78 ± 0.11	1.13	4.52	1.05	4.20
Carbohydrates (g)[c]	60.98	18.29	5.63	25.10	7.72
Total energy value (kcal)	457.46	137.24	6.86	158.11	7.90
Minerals					
Calcium (mg)	234.10 ± 10.13	70.23	7.02	57.86	5.79
Magnesium (mg)	21.41 ± 5.24	6.42	1.61	4.07	1.02
Manganese (mg)	13.32 ± 2.41	3.4	147.82	6.49	282.26
Phosphorus (mg)	187.90 ± 6.74	59.37	8.48	44.52	6.36
Iron (mg)	21.56 ± 3.35	6.47	80.87	3.15	39.41
Sodium (mg)	55.80 ± 3.65	13.74	0.92	32.27	2.15
Potassium (mg)	272.70 ± 9.72	81.81	1.74	79.05	1.68
Cuprum (mg)	192.32 ± 7.43	57.70	6.41	64.01	7.11
Zinc (mg)	10.85 ± 9.94	3.26	29.64	8.58	78.00

[a]Values expressed on a dry basis; [b]Calculated according to the Guia alimentar para a população brasileira (Brasil, 2008) for macronutrients and Institute of Medicine (Institute of Medicine, 2011) for minerals; [c]Obtained by difference.

the mineral analyses (Chart 1). The minerals chosen for analysis were those with higher nutritional relevance and described in the Nutritional Food Composition Table (Núcleo de Estudos e Pesquisas em Alimentação, 2011); calcium, magnesium, manganese, phosphorus, iron, sodium, potassium, cuprum and zinc.

The concentration of manganese in a portion of baru cookie (147.82% RDA) was found to be above the recommendations recommended by IOM (2.05 mg/day) (2011). Baru cookies had higher concentrations of protein, dietary fiber and iron in a serving size, when compared to the oat cookies. The amount of protein found in the baru cookies was 1.03 times greater than that of the oat cookie and 1.7 times greater than other products of the same kind that are available on the market. Table 4 compares the serving size of the cookie developed in this study with the same quantity of similar cookies available on the market and marketed as healthy products and/or of functional appeal.

4 Discussion

The PDBF, obtained after cold oil extraction of the baru almond, was found to present a significant lipid concentration (56.12% ± 0.06). Siqueira et al. (2015), using a hydraulic press without heating and pressure control for baru oil extraction, obtained 12.97% lipids in the flour. This difference in extraction yield may be attributed to the conditions used, such as pressure and the time the almonds were in the press, as well as the initial quantity of nutrients in different cultivars. It would be of interest to combine solvent extraction and heating for the PDBF lipid content (up to 5%) (Moretto & Fett, 1986). However, the mechanical pressing extraction technique, commonly used for food and beverages, employs cold pressing and avoids the use of solvents and heating, thus generating a product with more preserved natural properties and being widely used for extracting oils with high contents of unsaturated fatty acids (Brennan et al., 1990). The flour obtained under the experimental conditions

Table 4. Comparison of nutritional information of a serving size of baru cookie (30g) with cookies sold on the national market (30g).

Nutritional value (Serving size = 30g)	Oat cookie containing oil and baru flour	Oat cookie (brand A)	Whole oat cookie (brand B)	Whole oat and raisin cookie (brand C)
Total energy value (kcal)	137.24	118.00	119.00	129.00
Carbohydrates (g)	18.29	18.00	18.99	18.75
Proteins (g)	3.53	2.10	2.30	2.47
Total fat (g), of which:	6.05	4.30	4.20	4.80
Saturated fat (g)	1.41	1.10	0.70	0.90
Trans fats (g)	-	0.00	0.00	0.00
Monounsaturated fats (g)	3.05	2.25	1.20	4.00
Polyunsaturated fats (g)	1.56	0.70	2.30	0.60
Cholesterol (g)	0.00	0.00	0.00	0.00
Fiber (g)	1.13	2.55	2.50	3.75
Sodium (mg)	16.74	29.20	52.00	88.50
Iron (mg)	6.47	NI	1.10	NI

used in this study presented a high content of unsaturated fatty acids, especially of monounsaturated fatty acids (MUFA), proteins, iron and dietary fiber.

The oil extracted from the baru almond had a high concentration of unsaturated fatty acids (76.11%), with 50.37% MUFA, of which 48.26% ± 0.04 was oleic acid (C18:1). On the other hand, the baru oil had a low concentration of saturated fatty acids (SFA) (23.36%). These results are consistent with previous studies relating concentrations of 41.40% (Freitas & Naves, 2010), 50.40% (Takemoto et al., 2001) and 48.40% (Fernandes, 2011) oleic acid in baru oil and low SFA in the baru almond (Freitas & Naves, 2010; Bento et al., 2014.). As regards its fatty acid profile, the baru almond stands out as the almond with the highest concentration of MUFA consumed in Brazil (Freitas & Naves, 2010) and may represent an approach for reducing the fractions of lipoproteins that augment serum cholesterol (LDL and VLDL).

Moreover, the fatty acid profile of the baru almond for ω-6:ω-3 was 20.48:1, while Freitas & Naves (2010) observed a profile of 13.6:1 (ω-6:ω-3), therefore fulfilling the recommendations of the Institute of Medicine (Institute of Medicine, 2005), which recommends a fatty acid proportion of 5 to 10:1 (ω-6:ω-3) in a healthy diet. This above-the-recommended proportion of ω-6:ω-3 in the baru almond, in association with its bioactive compounds and high content of MUFA, may provide health benefits such as a reduction in hypercholesterolemia (Bento et al., 2014) and reduced lipid oxidation (Siqueira et al., 2012). Recently, Bento et al. (2014) observed that the consumption of 20g baru almond reduced the serum concentrations of triglycerides, LDL-c and non-HDL-c in hypercholesterolemic individuals. The authors suggested that this positive effect may be attributed to the synergy between the fatty acid composition, fiber and bioactive compounds in the baru almond (Bento et al., 2014), such as phenolic acids.

The TP content of the baru cookie was 1.84 times higher than that of conventional cookies made with oats. Lemos et al. (2012) evaluated the TP content of roasted and unpeeled baru almonds and raw peeled baru almonds, reporting values of 111.3mg GAE/100g and 568.9 mg GAE/100g, respectively. The heating of almonds in any processing step affects the distribution of the TP between oil and TPDB, constituting the main cause of TP loss (Pineli et al., 2015a).

By comparing the centesimal composition of the original formulation developed with those of oat and WF, and without the addition of products derived from baru, there was an increase of 2.88% in protein concentration and 105.23% in iron. The increased nutritional quality of baru cookies may be due to the relevant nutritional quality of the residue generated by the baru oil almond extraction process (PDBF) and its high concentrations of antioxidants (Pineli et al., 2015a).

PDBF also contributed to the increase in dietary fiber concentration in the baru cookie and may consequently help reduce the consumer's glycemic index (GI). The baru cookie can be classified as a source of dietary fibers, because it contains approximately 3.78g of dietary fiber per 100g of product (Brasil, 2012). Previous studies have found similar results, where the addition of 8% PDBF (Soares et al., 2007), or the replacement of WF by 25% baru pulp in cookies (Alves et al., 2010), significantly increased the concentration of fibers in the products and presented a good sensory acceptance. Recently, Pineli et al. (2015b) developed a cake, replacing 100% of WF by PDBF, and obtained a product rich in fiber and with a high concentration of phenolic compounds, flavonoids and proteins.

The increased concentration of dietary fiber imparted by baru flour addition may be attributed to the baru almond shell present in this by-product (Pineli et al., 2015a). The presence of beta-glucans, resulting from the use of oats in cookies, is a relevant aspect of the product, as the consumption of these soluble fibers promotes health benefits, such as improved insulin resistance, dyslipidemia, hypertension and obesity (Khoury et al., 2012).

As observed in previous studies (Soares et al., 2007; Alves et al., 2010; Pineli et al., 2015a), cookies developed in this study also showed a high concentration of protein (11.76%) and minerals, especially iron. Compared to leading market brands, baru cookies presented a 1.70-fold greater protein content. According to Freitas & Naves (2010), the baru almond has an amino acid profile that fulfills the requirements of the majority of children's and adults' needs, and its use may also contribute to the recovery in health of individuals with nutritional complications, such as

malnutrition or catabolic nutritional status, for example (Freitas & Naves, 2010).

As such, the high protein content of the cookies developed in this study implies their potential for use as a food in school meals, with the aim of contributing to the essential amino acid supply at school. The significant iron content of the baru cookies (80.87% RDA) also deserves mention as these could reduce iron deficiency, the leading cause of most cases of anemia that can affect pre-school aged children. However, more studies need to be conducted to analyze the bioavailability of iron in these cookies and their benefits for the health of people who have a deficiency of this mineral. In addition, future studies should be carried out to analyze the content of other chemical compounds, such as phytosterols, selenium and tocopherols, which have antioxidant activities and may reduce the oxidative stress present in patients with obesity and dyslipidemia, for example.

5 Conclusion

The addition of baru oil and PDBF to bakery products, such as cookies, produces interesting foods from a nutritional point of view, as these cookies have high contents of MUFA, especially oleic fatty acid, dietary fiber, protein and iron. Thus, the use of baru flour in foods can contribute to the diversification of products with functional appeal as well as to the exploration of regional products, in order to promote the sustainable development of native areas. In contrast, the use of PDBF would reduce waste parts that are normally regarded as non-consumables, minimizing costs and waste generated to the environment.

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