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Baru almonds from different regions of the Brazilian Savanna: Implications on physical and nutritional characteristics

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ABSTRACT

While some reports show that physical characteristics of the baru fruits (*Dipteryx alata* Vog.) differ within and among the Brazilian Savanna regions, a study shows that there are differences in the nutritional composition of baru almonds from different trees from the same Savanna area. It is unknown, however, whether the Savanna's region influences the nutritional quality of this native almond. Thus, we evaluated the influence of East, Southeast and West regions of the Brazilian Savanna on physical characteristics, nutrient composition and protein quality of the baru almond. Chemical composition and amino acid profile were analyzed, and Amino Acid Score (AAS), Net Protein Ratio (NPR), and Protein Digestibility-Corrected Amino Acid Score (PDCAAS) were estimated. The physical characteristics significantly differed within but not among regions. The protein (309 g·kg^{-1}), lipid (412 g·kg^{-1}), fiber (121 g·kg^{-1}) and calcium (1297 mg·kg^{-1}) contents of baru almonds were high, with significant differences among regions for insoluble fiber content (94.3 - 128.3 g·kg^{-1}) and amino acid profile (AAS = 77% - 89%). The relative NPR (RNPR) values were similar among regions (mean value of RNPR = 71%), and the PDCAAS values ranged from 65% to 73%. The region of the Brazilian Savanna influences the fiber and amino acid profiles, but not the total content of nutrients, the protein quality and the physical characteristics of the native baru almonds. The baru almond is a potential food as source of complementary protein for healthy diets and as a nutritious raw material for various food systems.

Keywords: *Dipteryx alata* Vog.; Edible Seeds; Nuts; Savanna; Nutritive Value; Amino Acids

1. INTRODUCTION

Native plants from the Brazilian Savanna, the second largest biome in Brazil, have been studied because of their agricultural and technological potentials. These native species represent several dozen families that produce fruits of different sizes, attractive colours, and unique flavours, which can be consumed fresh or as ingredients in juices, liquors, ice creams, and jellies [1,2].

The baru tree (*Dipteryx alata* Vog.) is a native species of the Brazilian Savanna and belongs to the Fabaceae family. The tree reaches a height of up to 15 m, and its fruit is a light brown drupe that is 5 - 7 cm long and 3 - 5 cm wide. Each fruit contains a single light to dark brown almond, approximately 2 - 2.5 cm long and weighing approximately 1.5 g [3,4]. The baru almond is usually roasted for consumption by the Brazilian Savanna population and it is used in regional gastronomy. It has a pleasant taste that resembles the taste of peanuts but its taste and texture are softer [1]. The baru almond contains high amounts of lipid and protein, and is a good source of fiber, minerals, and unsaturated fatty acids, especially oleic acid, and this composition suggests its use in healthy diets [5].

Concerning the physical characteristics, Corrêa *et al.* [4] reported high physical diversity of fruits and almonds from trees from the same region, with slight differences among the regions of the Brazilian Savanna. The authors of this study conclude that the wide variability within regions could indicate a high potential for plant breeding [4]. Because of this great physical variability of the fruits and almonds from the same region, Fernandes *et al.* [6]

studied baru almonds from different trees from the same region of the Brazilian Savanna, and a significant variability was found in the nutritional quality among the baru almonds.

According to the protein quality, a previous study showed a marked deficiency in sulphur-containing amino acids in baru almonds from the East region of the Brazilian Savanna, in which the Amino Acid Score (AAS) was approximately 35% [7]. However, almonds from the different plants of the Southeast region of the Brazilian Savanna (Goiás State) presented only a slight deficiency in sulphur-containing amino acids (AAS = 90%) or lysine (AAS = 97%), depending on the plant that baru almond came from [6]. In another study, the baru almond from the West region of the Brazilian Savanna showed a relatively higher deficiency in lysine (AAS = 75%) [8].

Nevertheless, it is unknown if the differences in the nutritional quality of the baru almonds are attributed to intrinsic differences in the trees or differences among Savanna areas, since the previous studies investigating almonds from only one region of this biome. Therefore, this study tested the hypothesis in which the native region of the fruit influences the physical characteristics, nutrient composition, and protein quality of the baru almond. The protein quality was investigated on growing rats, as a model for evaluating the protein bioavailability for humans [9].

2. MATERIALS AND METHODS

2.1. Fruit Collection, Almond Extraction, and Sample Preparation

Fruits of the baru tree were collected from three different regions of the Brazilian Savanna in the State of Goiás: East region (lat 15˚52'21" to 16˚00'09"S, long 48˚56'44" to 49˚04'25"W), Southeast region (lat 16˚42'41" to 16˚47'58"S, long 48˚10'21" to 48˚14'05"W), and West region (lat 16˚51'32" to 17˚01'22"S, long 50˚09'43" to 50˚32'14"W). The fruits collected were newly fallen or were on the ground in perfect morphological condition. After, the collected fruits were kept in cotton bags and stored for approximately 60 days at ambient temperature [4] to facilitate the release of the almond from the endocarp. The almonds were stored at −18˚C for around two months and roasted for the analysis. A schematic representation of fruit collection, almond extraction, and sample preparation is shown in **Figure 1**.

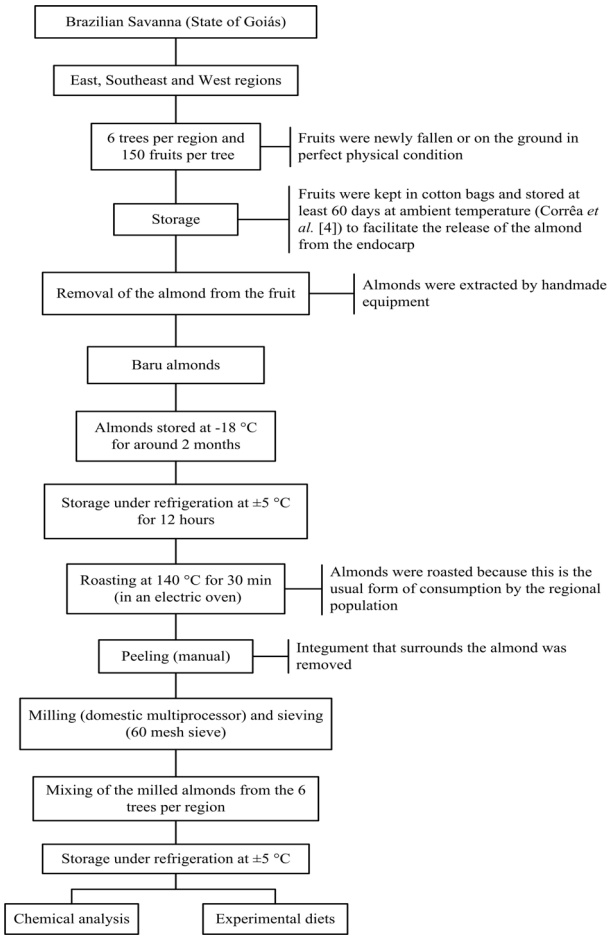

Figure 1. Schematic representation of baru fruit collection, almond extraction, and sample preparation.

2.2. Physical Characterization of the Fruits and Almonds

Physical analyses were performed after the storage of the fruits (**Figure 1**). Twenty fruits were randomly selected among 150 fruits collected from each of 6 trees per region. Baru fruits and almonds were weighed on an analytical balance, and length and width were measured using a metallic digital caliper. Fruit and almond lengths were measured as the distance from the insertion of the peduncle to the opposite side, and widths measurements were based on average lengths. Almonds with injuries or incomplete development were discarded.

The yield of almond mass in relation to fruit mass was also evaluated using the following formula: Yield (%) = [almond mass (g)/fruit mass (g)] × 100.

2.3. Chemical Characterization of Almonds

Proximate composition was performed by the following analyses: moisture [10]; nitrogen, determined by the micro-kjeldahl method [10], using a conversion factor of 6.25 [11]; total lipids, gravimetrically determined by extraction with chloroform and methanol [12]; ash, analysed by burning the sample in an oven at 550˚C [10]; and total dietary fiber (soluble and insoluble), determined using the enzymatic-gravimetric technique [13]. Carbohydrate content was estimated by difference, sub-

tracting 1000 values obtained for moisture, protein, lipids, ash, and dietary fiber. The energy value of the almond was estimated from the chemical composition data by using the Atwater conversion factors of 4 kcal for protein and carbohydrates and 9 kcal for lipids [14].

Calcium, iron, sodium, and zinc were characterized and quantified in triplicate. Samples (30 g) were incinerated and then dissolved with concentrated hydrochloric acid. Calcium, iron, and zinc analyses were performed by atomic absorption spectrophotometry (Analyst 200 spectrometer, Perkin-Elmer). Sodium content was analyzed using the same equipment but by the emission mode. Specific instrumental parameters (lamp, wavelength, lamp current, and slit width) were used for each mineral [10].

The analysis of amino acids was performed in duplicate. The samples were acid hydrolysed [15] or alkali hydrolysed (for tryptophan) [16]. After hydrolysis, the samples were placed in an automatic amino acid analyzer (Nicolas V., Protein Chemistry Centre of the University of São Paulo, Ribeirão Preto, Brazil). After elution in the column and reaction with ninhydrin, the amino acids were detected colorimetrically and quantified. The AAS was estimated by comparing the results of the amino acids' profile to the requirement pattern, according to the World Health Organization (WHO) [17], using the following formula: AAS = [(mg of amino acid in 1 g test protein/mg of the amino acid in requirement pattern) × 100].

2.4. Biological Assay and Food Intake Control

Three-week-old male Wistar rats (body weight, 42 to 58 g) purchased from Bioagri Laboratories Experimental Animal Center (Planaltina, Federal District, Brazil) were randomly divided into 6 groups (n = 6 each) and housed individually in cages under standardized environmental conditions (12-hour cycles of light and dark, temperature of 22˚C ± 2˚C and relative humidity of 60% ± 5%, with frequent exchanges of air). The entire assay was conducted in accordance with the guidelines for the care and use of laboratory animals [18], and the experimental protocol was approved by the Research Ethics Committee of the Federal University of Goiás-UFG (Protocol No. 153/2008).

Diets were formulated according to AIN-93G [19], modified to 10% protein, as follow: 2 casein diets (with 7% lipids [reference group, CAS_7] and with 14% lipids [control group, CAS_{14}]); three experimental diets ($BARU_E$ [East region], $BARU_S$ [Southeast region] and $BARU_W$ [West region], with approximately 14% lipids); and a protein-free diet (PF). The baru almond was not defatted to preserve its natural characteristics, and the diet CAS_{14} was used as an internal control of the experiment because it had equivalent lipid content to the baru almond diets. The ingredients and chemical composition of these diets are shown in **Table 1**.

The animals were fed their respective diets for 17 days (3 days of acclimatization and 14 days of experiment) (**Figure 2**). Body weight of the rats was measured three times per week.

The animal groups were fed according to the pair-feeding method [20], to ensure similar energy intakes. The amount of food consumed was monitored daily (food consumed = food offered − food wasted). The CAS_7 and CAS_{14} groups received amounts of diet corresponding to the average intake of the BARU groups, corrected by the energy conversion factor (ECF) for each diet (food offered = average intake of BARU groups × ECF). Potable water was provided *ad libitum*. At the end of the experiment, the animals were weighed and euthanized with ethyl ether in a closed container.

2.5. Protein Indexes

True protein digestibility was determined as recommended by the FAO for *in vivo* testing [21]. The rats' faeces were marked and collected during the second week of the experiment and ground for nitrogen analysis. Protein digestibility was estimated considering the amount of nitrogen consumed by the animals (I), the amount of nitrogen excreted in faeces by animals fed a protein diet (F), and the amount of metabolic faecal nitrogen (endogenous), which corresponds to nitrogen excreted in faeces by animals fed a protein-free diet (Fk). Thus, protein digestibility was calculated as follow: True protein digestibility (%) = [I – (F – Fk)/I] × 100.

The protein quality of roasted baru almonds was assessed by the Net Protein Ratio (NPR) and Protein Digestibility-Corrected Amino Acid Score (PDCAAS) indexes. The NPR and the Relative Net Protein Ratio

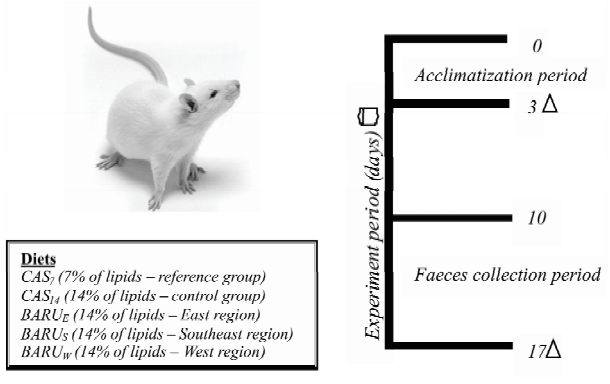

Figure 2. Biological assay design to evaluate protein quality of baru almond from different regions of the Brazilian Savanna. ⛁ Food intake control (pair-feeding method); △ Body weight measure on alternate days.

Table 1. Composition of experimental diets.

Content (g·kg^{-1} of diet)	Diet[a]					
	CAS_7	CAS_{14}	$BARU_E$	$BARU_S$	$BARU_W$	PF
Ingredient[b]						
Casein (83.5% protein)	119.8	119.8	-	-	-	-
$BARU_E$	-	-	317.2	-	-	-
$BARU_S$	-	-	-	331.8	-	-
$BARU_W$	-	-	-	-	322.6	-
L-cystine	2.0	2.0	-	-	-	-
Soybean oil	66.6	136.6	13.5	1.9	3.7	70.0
Cellulose[c]	50.0	50.0	7.5	5.5	6.8	50.0
Mineral mix	35.0	35.0	35.0	35.0	35.0	35.0
Vitamin mix	10.0	10.0	10.0	10.0	10.0	10.0
Choline bitartrate	2.5	2.5	2.5	2.5	2.5	2.5
Corn starch	714.1	644.1	614.3	613.3	619.4	832.5
Chemical composition						
Protein (g·kg^{-1})	104.6	104.8	94.5	97.8	96.4	6.0
Lipids (g·kg^{-1})	68.7	137.3	146.3	135.9	137.9	66.7
Energy value (kcal)	4143.5	4486.5	4531.5	4479.5	4489.5	4133.5

[a]According to the AIN-93G diet [19]. CAS_7: casein with 7% lipids (reference); CAS_{14}: casein with 14% lipids (control); BARU: diets with roasted baru almonds from the East region ($BARU_E$), the Southeast region ($BARU_S$), and the West region ($BARU_W$); PF: protein-free. [b]Casein, cellulose, mineral and vitamin mixes were supplied by Rhoster (São Paulo, Brazil). [c]For BARU diets, cellulose was added to complete the fiber content of the baru almond.

(RNPR) were calculated according to the following formulas [22]: NPR = [weight gain (test group) + weight loss (protein-free group)]/protein intake (test group); RNPR = [NPR (test group)/NPR (reference group)] × 100. The PDCAAS was determined as follows [21]: PDCAAS (%) = [(AAS of the test protein × true digestibility of the test protein)/100].

2.6. Statistical Analysis

The data are presented as mean ± standard deviations and coefficient of variation (physical characteristics). Analysis of variance and the Tukey mean comparison test were used to compare the physical characteristics, chemical composition and biological assay data. STATISTICA version 7.0 (StatSoft, Inc., Tulsa, OK, USA, 2004) was used for the statistical analyses. Differences were considered significant when $P < 0.05$.

3. RESULTS AND DISCUSSION

3.1. Physical Characteristics

Baru (fruits and almonds) from the same region of the Brazilian Savanna showed significant diversity in physical characteristics, whereas, there were no significant differences in the physical characteristics of baru fruits and almonds among regions (**Table 2**). Thus, the wide variability of physical characteristics of the baru within each region prevented possible differences among regions.

Corrêa *et al.* [4] studied the physical characteristics of fruits and baru almonds from three regions of the Brazilian Savanna (50 plants per region), and compared the characteristics of the fruits and almonds from plants from different regions and from the same region, as well as fruits from the same plant. According to these authors, the largest variation of physical characteristics occurs among plants of the same region, and this variability indicates high potential of improvement of the evaluated characteristics.

The analysis of the almond yield also showed no significant differences among regions (East: 4.39% [±0.64%]; Southeast: 5.28% [±1.22%]; West: 4.14% [±0.72%]), but variability in yield was found among trees in the same

Table 2. Physical characteristics of fruits and almonds of baru (*Dipteryx alata* Vog.) from three regions of the Brazilian Savanna (State of Goiás).

Region	mass (g)	CV (%)	length (mm)	CV (%)	width (mm)	CV (%)
			Fruit			
East	37.56 ± 6.09^{a}	16	61.19 ± 3.83^{a}	6	40.62 ± 2.95^{b}	7
	35.90 ± 11.53^{a}	32	55.78 ± 7.32^{b}	13	$42.89 \pm 6.69^{a,b}$	16
	33.79 ± 4.98^{a}	15	$54.90 \pm 3.34^{b,c}$	6	40.64 ± 2.43^{b}	6
	33.27 ± 5.80^{a}	17	63.19 ± 3.70^{a}	6	44.21 ± 2.38^{a}	5
	24.11 ± 2.76^{b}	11	$51.87 \pm 3.02^{b,c}$	6	36.37 ± 2.51^{c}	7
	20.53 ± 3.00^{b}	15	51.44 ± 2.35^{c}	4	36.85 ± 2.84^{c}	8
Mean	30.86 ± 6.88^{A}	22	56.38 ± 4.81^{A}	8	40.26 ± 3.15^{A}	8
Southeast	31.05 ± 3.86^{a}	12	55.73 ± 2.46^{a}	4	41.91 ± 1.46^{a}	3
	$27.77 \pm 6.15^{a,b}$	22	$50.89 \pm 4.10^{b,c}$	8	42.41 ± 3.48^{a}	8
	$26.87 \pm 2.93^{a,b}$	11	48.10 ± 2.90^{c}	6	39.19 ± 1.35^{b}	3
	26.43 ± 5.00^{b}	19	52.53 ± 3.93^{b}	7	38.61 ± 3.64^{b}	9
	21.71 ± 4.67^{c}	22	$50.55 \pm 2.72^{b,c}$	5	41.50 ± 2.23^{a}	5
	21.07 ± 4.90^{c}	23	51.07 ± 2.66^{b}	5	34.52 ± 1.85^{c}	5
Mean	25.82 ± 3.80^{A}	15	51.48 ± 2.53^{A}	5	39.69 ± 2.96^{A}	7
West	50.87 ± 12.45^{a}	24	71.35 ± 2.89^{a}	4	53.67 ± 1.76^{a}	3
	36.62 ± 4.02^{b}	11	53.51 ± 2.59^{c}	5	46.75 ± 3.44^{b}	7
	33.64 ± 7.47^{b}	22	57.11 ± 3.72^{b}	6	42.55 ± 3.18^{b}	7
	$30.72 \pm 5.41^{b,c}$	18	52.48 ± 2.83^{c}	5	39.56 ± 1.65^{d}	4
	26.62 ± 3.27^{c}	12	49.28 ± 2.72^{d}	6	37.57 ± 1.67^{d}	4
	24.83 ± 3.86^{c}	16	48.48 ± 2.65^{d}	5	38.01 ± 2.15^{d}	6
Mean	33.88 ± 9.39^{A}	28	55.37 ± 8.42^{A}	15	43.03 ± 6.22^{A}	14
			Almond			
East	1.45 ± 0.19^{b}	13	28.93 ± 1.65^{a}	6	10.56 ± 0.49^{b}	5
	1.73 ± 0.27^{a}	16	26.46 ± 1.66^{b}	6	12.00 ± 0.73^{a}	6
	1.43 ± 0.10^{b}	7	26.83 ± 0.91^{b}	3	11.37 ± 0.24^{a}	2
	1.39 ± 0.15^{b}	11	29.27 ± 1.27^{a}	4	11.86 ± 0.67^{a}	6
	1.03 ± 0.11^{c}	11	24.34 ± 0.82^{c}	3	10.44 ± 0.47^{b}	4
	1.16 ± 0.12^{c}	10	25.07 ± 1.19^{c}	5	10.34 ± 0.50^{b}	5
Mean	1.37 ± 0.24^{A}	18	26.82 ± 1.99^{A}	7	11.10 ± 0.74^{A}	7
Southeast	1.46 ± 0.11^{a}	8	28.10 ± 1.19^{a}	4	12.07 ± 0.90^{a}	7
	1.29 ± 0.22^{b}	17	$24.13 \pm 1.55^{c,d}$	6	10.81 ± 0.66^{b}	6
	1.12 ± 0.10^{c}	9	23.77 ± 1.19^{d}	5	10.91 ± 0.39^{b}	4
	1.31 ± 0.15^{b}	11	26.45 ± 1.27^{b}	5	10.63 ± 0.81^{b}	8
	1.62 ± 0.17^{a}	10	$25.41 \pm 0.80^{b,c}$	3	11.98 ± 0.76^{a}	6
	1.12 ± 0.17^{c}	15	24.95 ± 1.27^{c}	5	9.76 ± 0.60^{c}	6
Mean	1.32 ± 0.20^{A}	15	25.47 ± 1.60^{A}	6	11.03 ± 0.87^{A}	8
West	1.67 ± 0.27^{a}	16	28.36 ± 1.23^{a}	4	12.19 ± 1.15^{b}	9
	1.58 ± 0.14^{a}	9	$26.23 \pm 1.24^{b,c}$	5	13.23 ± 0.82^{a}	6
	1.54 ± 0.21^{a}	14	26.34 ± 1.41^{b}	5	13.28 ± 1.07^{a}	8
	1.13 ± 0.17^{b}	15	24.98 ± 1.41^{d}	6	10.42 ± 0.77^{c}	7
	1.09 ± 0.12^{b}	11	$25.13 \pm 1.21^{c,d}$	5	10.41 ± 0.51^{c}	5
	1.23 ± 0.14^{b}	11	24.90 ± 0.97^{d}	4	10.81 ± 0.79^{c}	7
Mean	1.37 ± 0.25^{A}	18	25.99 ± 1.32^{A}	5	11.72 ± 1.35^{A}	12

Data are mean ± standard deviations of 20 replicates from each tree (6 trees per region). CV: coefficient of variation. Means with the same letter ($^{a-d}$) in the same column are not significantly different in the same region. Means with the same letter (^{A}) in the same column are not significantly different among regions (Tukey test, $P < 0.05$).

region. The highest almond yield was 7.62% (±1.26%), for the Southeast region, and the lowest almond yield was 3.04% (±0.50%), for the West region.

3.2. Nutrient Composition

We observed high protein (309 g·kg^{-1}) and lipid (412 g·kg^{-1}) contents in baru almonds, with no significant differences among regions (**Table 3**). These high amounts of protein and lipid of the baru almond are supported by the literature [6,8,23]. Protein contents of baru almonds were slightly higher than those of traditional nuts studied by Venkatachalam and Sathe [24], and the lipid contents (**Table 3**) were lower than those of the brazil nut, hazelnut, macadamia nut, pecan, pine nut, and walnut, which contain approximately 600 g·kg^{-1} [24]. Besides these nutritional advantages, it should be added that the baru almond has a healthy fatty acid profile [5,25].

The dietary fiber content of the baru almonds from the three regions was high (**Table 3**), since 20 g of baru almond provides approximately 10% of the Dietary Reference Intake (DRI) for dietary fiber [26]. The fiber amount of baru almond is comparable to those of the nuts and edible seeds (80 - 130 g·kg^{-1}) [5,8]. Analysis of the fiber fractions showed that the concentration of insoluble fiber was much higher than the concentration of soluble fiber; similar to the results of other studies [6, 8,25]. Regarding the influence of the Savanna's region, we found that there were significant differences in the insoluble fiber contents of the baru almonds among the three regions, and the almonds from the East region showed the highest amounts of insoluble fiber-approximately 130 g·kg^{-1} (**Table 3**). Insoluble fibers produce some physiological effects, such as increasing faecal volume and reducing transit time in the large intestine. Overall, dietary fibers regulate bowel movements, thus they are relevant to the prevention and treatment of various diseases [27].

Baru almonds showed considerable ash (**Table 3**) and calcium contents, and they are rich in iron and zinc (**Table 4**). A portion (20 g) of baru almonds provides 2.6% of the DRI for calcium, 8.0% of the DRI for iron, and 6.3% of the DRI for zinc [28]. In addition, the baru almond has very low sodium content, other nutritional advantage which would justify its consumption. In general, sodium contents are much lower in nuts and edible seeds than in animal and processed foods [29]. Mineral analysis of baru almonds showed no statistical differences among the three regions (**Table 4**).

The AAS values of baru almond protein were different among the three regions, and the almonds of West region presented the highest value (**Table 5**). Therefore, we found that the amino acid profile of baru almond can be influenced by the native region of the fruits. The mean of AAS values found in the present study was 83% and the AAS values of the baru almond protein reported in the literature range from 35% [23] to 92% [6]. In addition, valine was found to be the first limiting amino acid in baru almond protein (**Table 5**).

The valine limitation does not compromise the protein quality of the diet, because valine is not typically a limiting amino acid in protein foods [9,11,21]. In previous studies, the first limiting amino acids were lysine and

Table 3. Proximate composition and energy value of roasted baru (*Dipteryx alata* Vog.) almonds from three regions of the Brazilian Savanna (State of Goiás).

Proximate composition (g·kg^{-1})	Region			Mean
	East	Southeast	West	
Moisture	33.2 ± 0.6^{b}	35.8 ± 1.1^{a,b}	38.2 ± 1.5^{a}	35.8 ± 2.4
Proteins (N × 6.25)	316.2 ± 13.7^{a}	301.4 ± 6.3^{a}	310.0 ± 9.6^{a}	309.2 ± 11.0
Lipids	398.8 ± 7.9^{a}	416.2 ± 17.7^{a}	422.6 ± 18.8^{a}	412.5 ± 17.2
Ashes	30.7 ± 0.1^{a}	30.0 ± 0.2^{a}	28.7 ± 0.1^{b}	29.8 ± 0.9
Dietary fibers	140.0 ± 0.0^{a}	111.0 ± 1.7^{b}	111.3 ± 0.6^{b}	120.8 ± 14.4
soluble fiber	11.7 ± 1.5^{b}	16.7 ± 1.5^{a}	11.0 ± 0.0^{b}	13.1 ± 2.9
insoluble fiber	128.3 ± 1.5^{a}	94.3 ± 2.1^{c}	100.3 ± 0.6^{b}	107.7 ± 15.8
Carbohydrates	81.0	105.6	89.2	92.0 ± 16.1
Energy value (kcal)	5178.0 ± 41.3^{b}	5373.4± 85.2^{a,b}	5399.7 ± 97.3^{a}	5317.0 ± 125.0

Data are mean ± standard deviations of three replicates from each region, except carbohydrates (estimated by difference), and of nine replicates for mean of the three regions. Means with the same letter ($^{a-c}$) in the same row are not significantly different (Tukey test, $P < 0.05$).

Table 4. Mineral composition of roasted baru (*Dipteryx alata* Vog.) almonds from three regions of the Brazilian Savanna (State of Goiás).

Mineral ($mg \cdot kg^{-1}$)	Region			Mean
	East	Southeast	West	
Calcium	1325.2 ± 24.1[a]	1377.5 ± 52.8[a]	1188.1 ± 58.1[b]	1297.0 ± 94.2
Iron	33.1 ± 2.0[a]	31.4 ± 1.1[a]	31.0 ± 3.3[a]	31.8 ± 1.5
Sodium	109.2 ± 29.6[a]	115.0 ± 8.3[a]	70.9 ± 18.0[a]	98.3 ± 27.4
Zinc	39.5 ± 2.6[a]	31.9 ± 3.5[a]	32.5 ± 4.2[a]	34.6 ± 4.8

Data are mean ± standard deviations of three replicates from each region, and of nine replicates for mean of the three regions. Means with the same letter ([a,b]) in the same row are not significantly different (Tukey test, $P < 0.05$).

Table 5. Amino acid composition of roasted baru (*Dipteryx alata* Vog.) almonds from three regions of the Brazilian Savanna (State of Goiás) and Amino Acid Score (AAS) according to the WHO/FAO/UNU requirement pattern.

Amino acid ($mg \cdot g \cdot protein^{-1}$)	Region			WHO/FAO/UNU[a]
	East	Southeast	West	
		Indispensable (Essential)		
His	26.42 ± 0.26[a]	21.86 ± 0.01[c]	24.23 ± 0.12[b]	16.0
Ile	25.61 ± 0.25[b]	24.59 ± 0.26[b]	28.17 ± 0.22[a]	31.0
Leu	79.22 ± 0.47[a]	78.79 ± 0.14[a]	78.24 ± 0.41[a]	61.0
Lys	54.42 ± 0.32[a]	52.54 ± 0.33[b]	50.64 ± 0.24[c]	48.0
Met + Cys	27.00 ± 0.11[a]	21.21 ± 0.15[b]	26.80 ± 0.19[a]	24.0
Phe + Tyr	76.09 ± 0.12[c]	76.78 ± 0.09[b]	79.92 ± 0.08[a]	41.0
Thr	44.47 ± 0.11[a]	40.96 ± 0.10[b]	44.82 ± 0.03[a]	25.0
Trp	18.10 ± 0.41[b]	20.13 ± 0.53[a]	15.62 ± 0.46[c]	6.6
Val	32.99 ± 0.03[b]	30.90 ± 0.12[c]	35.69 ± 0.13[a]	40.0
TOTAL	384.32	367.76	384.12	292.6
AAS (%)	82.5[b] (Val)	77.2[c] (Val)	89.2[a] (Val)	100
		Dispensable (Non-Essential)		
Asp	103.68 ± 0.92[b]	107.53 ± 0.57[a]	102.49 ± 0.60[b]	-
Glu	214.26 ± 0.16[c]	223.51 ± 0.18[a]	219.86 ± 1.12[b]	-
Ala	46.81 ± 0.21[b]	50.19 ± 0.06[a]	45.18 ± 0.13[c]	-
Arg	95.82 ± 0.21[a]	91.80 ± 0.03[b]	91.68 ± 0.42[b]	-
Gly	49.11 ± 0.41[b]	52.19 ± 0.12[a]	48.50 ± 0.06[b]	-
Pro	57.03 ± 0.19[c]	57.83 ± 0.02[b]	58.91 ± 0.26[a]	-
Ser	48.99 ± 0.22[a]	49.20 ± 0.21[a]	49.25 ± 0.01[a]	-

Data are mean ± standard deviations of two replicates. Means with the same letter ([a-c]) in the same row are not significantly different (Tukey test, $P < 0.05$). [a]Requirement pattern of essential amino acids [17].

sulphur-containing amino acids, for baru almonds from the Southeast region [6], lysine for almonds from the West region [8], and sulphur-containing amino acids for almonds from the East region [23] of the Brazilian Savanna. These data justify the study of almonds from different regions of the Brazilian Savanna and they reinforce

Table 6. Body weight gain, food and protein intakes, Net Protein Ratio (NPR), true protein digestibility, and Protein Digestibility-Corrected Amino Acid Score (PDCAAS) of Wistar rats during 14 days of experiment.

Diet	Body weight gain (g)	Intake (g)		NPR	True protein digestibility (%)	PDCAAS (%)
		food	protein			
CAS_7	59.87 ± 10.7[a]	172.83 ± 21.61[a]	18.08 ± 2.26[a]	3.78 ± 0.19[a]	94.69 ± 0.66[a]	-
CAS_{14}	60.85 ± 9.3[a]	167.20 ± 14.42[a,b]	17.72 ± 1.51[a]	3.95 ± 0.21[a]	95.73 ± 0.22[a]	-
$BARU_E$	31.10 ± 5.1[b]	146.98 ± 10.81[b,c]	13.89 ± 1.02[b]	2.85 ± 0.19[b]	84.91 ± 1.75[b]	69.60 ± 1.44[a]
$BARU_S$	30.82 ± 4.1[b]	146.14 ± 3.84[b,c]	14.29 ± 0.38[b]	2.76 ± 0.25[b]	83.82 ± 2.01[b]	64.50 ± 1.55[b]
$BARU_W$	24.38 ± 5.9[b]	137.93 ± 9.55[c]	13.30 ± 0.92[b]	2.47 ± 0.32[b]	81.93 ± 4.46[b]	72.90 ± 3.97[a]
PF	-8.62 ± 1.4[c]	-	-	-	-	-

Data are mean ± standard deviations of six animals, except for true digestibility and PDCAAS (four animals). CAS_7: casein with 7% lipids (reference); CAS_{14}: casein with 14% lipids (control); BARU: diets with roasted baru almonds from the East region ($BARU_E$), the Southeast region ($BARU_S$), and the West region ($BARU_W$); PF: protein-free. Means with the same letter ([a-c]) in the same column are not significantly different (Tukey test, $P < 0.05$).

the unique diversity of this biome. In addition, these data suggest that the protein profile of the baru almonds changes according to the native region of the fruits. A study with seeds of baru from only one Savanna area showed that its protein fractions are mainly globulins (around 60%) and albumins (approximately 15%) [30]. Considering the great variability in the amino acid profile of the baru protein, as observed in this study (**Table 5**) and reported in the literature [6,8,23], further studies are necessary to characterize this protein more completely, including samples of baru from different regions of the Brazilian Savanna. These data are important to select seeds with more nutritious and technological potential for application on various food systems.

3.3. Protein Quality

The animal groups fed diets containing baru almonds from the different regions ($BARU_E$, $BARU_S$, and $BARU_W$) had similar body weight gains and protein intakes, which were lower than those of casein groups (**Table 6**). The experimental groups of animals had similar food intakes, and the $BARU_E$ and $BARU_S$ groups also showed similar food intakes to that of the CAS_{14} group. The groups fed casein diets (CAS_7 and CAS_{14}) had similar weight gains, confirming the importance of the pair feeding method to control the energy intakes of the animals (**Table 6**).

The true protein digestibility of the baru almonds was relatively high, ranged from 82% to 85%, comparable to those of the nut proteins (85% - 89%) [8,11], and higher than those reported in the literature for baru almonds (66% - 79%) [6,8,23]. There were no differences in the protein digestibility of the almonds from the three regions (**Table 6**).

The protein quality of the baru almond was evaluated by NPR and PDCAAS methods (**Table 6**). The NPR method is used traditionally [9,22] and the PDCAAS is recommended by the WHO [17] and the IOM [26] as the most suitable method for evaluating the protein quality of vegetable foods. There were no differences in protein quality of the baru almonds from the three regions, according to the NPR index (**Table 6**). The RNPR values also were not different among the regions: 75.5% (±4.9%), for the East region; 72.9% (±6.7%), for the Southeast region; and 65.3% (±8.4%), for the West region. The RNPR values of $BARU_E$ and $BARU_S$ were similar to that reported for almonds from the Southeast region of the Brazilian Savanna (74%) [6].

The PDCAAS value of the almonds from the West region (73%) was similar to that of the almonds from the East region (70%), and higher than that of the almonds from the Southeast region (65%). These slightly differences among the PDCAAS values can be attributed to the different AAS values of almond samples from each region (**Table 5**), since the protein digestibility of almonds were similar among regions (**Table 6**). In a previous study, PDCAAS values of the baru almond protein ranged from 66% to 82% and marked differences in the amino acid profile were found in almonds from different plants from the same area of the Brazilian Savanna [6]. These data suggest that the variability in the protein quality of the baru almond is greater among plants from the same region than from different regions, as was observed for physical characteristics of the baru in the present study and in a previous study [4]. In spite of this variability, the baru almond has a high content of intermediate to good quality protein, based on PDCAAS and RNPR indexes, and according to Friedman's classification [9]. Therefore, it can be included in the diet and in various food systems as a complementary source of protein.

4. CONCLUSION

The region of the Brazilian Savanna influences the fi-

ber and amino acid profiles, but not the total content of nutrients, the protein quality and the physical characteristics of native baru almonds. Apart from the native region, the nutritional value of the baru almond is relevant to human health, and its consumption and use in processed foods should be encouraged as a protein food for healthy diets.

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