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Rice bran as a substitute for soy protein and erythorbate in chicken nuggets

Farelo de arroz como substituto de proteína de soja e eritorbato em nuggets de frango

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Highlights:

Defatted rice bran is an interesting substitute of allergenic meat products additive.
The soy protein can be replaced by defatted rice bran in chicken nuggets.
Rice bran presents antioxidant activity comparable to sodium erythorbate.
Chicken nuggets added of defatted rice bran are sensory accepted.

Abstract

Rice bran is a byproduct with high biological value protein, fiber and phytic acid content. The nutritional and technological properties of rice bran have been highlighted and are attractive for food application. This research aimed at replacing soy protein (SP) and sodium erythorbate (SE) by defatted rice bran (DRB) in chicken nuggets. Three formulations were prepared: T1 with SP and SE; T2 with SP and without SE; and T3 with total SP and SE replacement by DRB. Lipid stability was evaluated by thiobarbituric acid reactive substances (TBARS) on storage days 0, 30, and 60 (-18 °C). Physico-chemical and microbiological parameters were also evaluated. Color, aroma, flavor, texture acceptance, and overall impression was evaluated using a 9-point hedonic scale for 60 days of storage. T3 presented lipid stability comparable to T1 in all intervals evaluated reinforcing the antioxidant potential of DRB. However, T2 showed the lowest lipid stability due to the absence of antioxidants, presenting rancid aroma and flavor not allowing for its sensorial evaluation. Physico-chemical and microbiological parameters were either not influenced or positively influenced by DRB addition. For all attributes, T3 and T1 presented similar acceptance sensory means, with > 72.4% acceptability index. DRB is a rice byproduct potentially suitable for its use by the meat industry.

Key words: Antioxidant. Byproduct. Lipid peroxidation. Meat product. Sensory acceptance. Thiobarbituric acid reactive substances.

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Resumo

O farelo de arroz é um subproduto que contém proteína de alto valor biológico, fibra e ácido fítico. As propriedades nutricionais e tecnológicas do farelo de arroz têm sido destacadas e se mostrado vantajosas para a aplicação em alimentos. O objetivo desta pesquisa foi substituir a proteína de soja (SP) e o eritorbato de sódio (SE) por farelo de arroz desengordurado (DRB) em *nuggets* de frango. Três formulações foram preparadas: T1 com SP e SE; T2 com SP e sem SE; e T3 com substituição total de SP e SE por DRB. A estabilidade lipídica foi avaliada por substâncias reativas ao ácido tiobarbitúrico aos 0, 30 e 60 dias de armazenamento (-18 °C). Os parâmetros físico-químicos e microbiológicos, e a aceitação também foram analisados. Na análise sensorial, os atributos de cor, aroma, sabor, textura e impressão global foram avaliados usando-se a escala hedônica de 9 pontos após 60 dias de armazenamento. O T3 apresentou estabilidade lipídica comparável ao T1 em todos os intervalos analisados reforçando o potencial antioxidante do DRB. Entretanto, T2 apresentou menor estabilidade lipídica devido à ausência de antioxidantes, apresentando aroma e sabor de ranço que não permitiram sua avaliação sensorial. Os parâmetros físico-químicos e microbiológicos não foram influenciados, ou foram positivamente influenciados pela adição de DRB. Para todos os atributos, T3 e T1 apresentaram médias sensoriais de aceitação semelhantes, com índice de aceitabilidade superior a 72,4%. O DRB é um subproduto do arroz com potencial para ser usado pela indústria da carne.

Palavras-chave: Antioxidante. Subproduto. Oxidação lipídica. Produto cárneo. Aceitação sensorial. Substâncias reativas ao ácido tiobarbitúrico.

Introduction

Rice bran is obtained during rice grain processing, representing approximately 10% of the total grain weight (Gul, Yousuf, Singh, Preeti, & Wani, 2015). It possesses excellent nutritional quality as it is originated from grain pericarp, with large protein, fiber, lipids, vitamins, and minerals contents (Pestana, Mendonça, & Zambiázi, 2008). It is an excellent source of phytochemicals and antioxidative compounds such as phytic acid (Canan et al., 2012), oryzanols (Akihisa et al., 2000), tocotrienols, tocopherols (Jariwalla, 2001), phytosterols, squalene, polycosanols, ferulic acid, and inositol (Chotimarkorn, Benjakul, & Silalai, 2008).

The proteins found in rice bran (about 15%) have been studied by a number of researchers, due to their suitable nutritional quality and high biological value, adequate amino acid composition to human metabolism (Han, Chee, & Cho, 2015), and digestibility higher than 90% (Zhang, Zhang, Wang, & Guo, 2012; Han et al., 2015). Studies have reported their hypoallergenic characteristics (Wang, Hettiarachchy, Qi, Burks, & Siebenmogen, 1999), hypocholesterolemic (Chrastil, 1992), anticancer (Shoji et al., 2001) and antioxidant activity (Chanput, Theerakulkait, & Nakai, 2009; Thanonkaewa, Wongyai, Mcclements, & Decker, 2012; Goufo & Trindade, 2014).

Rice bran dietary fiber content reaches nearly 27% and it has been correlated with positive effects, such as laxative and cholesterol-lowering abilities. Rice bran contains many biological active polysaccharides with excellent physiological properties that could improve health and prevent diseases - working as an anti-tumor and immune function (Takeshita et al., 1992; Tzianabos, 2000). The effects of soluble and insoluble rice bran fiber in the fasting and postprandial reduced glucose levels were confirmed by C. R. Silva, Oliveira, Souza and Silva (2005). Rice bran when applied to food products improves texture, gelation, emulsification, and stabilization of foods (Zheng, Nisi, Wu, & Yin, 2019). The increased demand for rice bran oil as a functional food ingredient has led to an increase of defatted rice bran supply obtained after oil extraction. It is considered a rice processing secondary byproduct and often discarded or used as animal feed (Chan, Khong, Iqbal, & Ismail, 2013).

On the other hand, oxidation and auto-oxidation of lipids are one of the major causes of quality deterioration and reduced meat products' shelf life. The oxidative process could alter meat quality parameters such as color, flavor, aroma, texture and even its nutritional value (Basanta et al., 2018; Estévez, & Lorenzo 2019). Mincing, cooking, like other meat processing methods disrupt muscle cell membranes. This process allows for the interaction of unsaturated lipids with pro-oxidant such as non-heme iron, accelerating lipid oxidation and leading to rapid quality deterioration and development of rancidity, especially prior to refrigerated storage (Shimokomaki, 2006). The use of antioxidants could prevent undesirable oxidative effects preserving meat and meat products' quality and stability during their shelf life (Olivo, 2006).

The addition of soy proteins, currently classified as food allergen (Ebisawa, Ito, & Fujisawa, 2017), into meat products is carried out due to its functional properties and low cost (Piccolo et al., 2016). Its addition to meat products could lead to health problems in individuals allergic to these proteins. Thus, alternative ingredients ought to be studied, especially rice bran, which besides its low cost it possess a high antioxidant potential (Zheng et al., 2019). Taking into account the various health benefits associated with rice bran consumption and its antioxidant potential, it could be used as raw material for the development of food products improved quality (Gul et al., 2015; Nandi & Ghosh, 2015). Additionally, rice bran possesses distinctive functional properties that could improve meat products quality. Thus, this study aimed at evaluating the replacement of soy protein by defatted rice bran in chicken nuggets. The antioxidant potential of rice bran in chicken nuggets was compared to sodium erythorbate, and physico-chemical and microbiological quality, and sensory acceptance were determined.

Material and Methods

Chicken nuggets preparation

The pellet-form defatted rice bran (DRB) was provided by Riograndense de Óleos Vegetais Company (Irgovel, Pelotas-RS, Brazil), and previously ground in a Wiley mill (Solab, SL 31, Piracicaba-SP, Brazil) with a 70 mesh mean particle size, packed in plastic bags and frozen at -20 °C. Thigh and boneless drumstick, mechanically separated meat and abdominal chicken fat used as raw materials were provided by the Industrial Poultry Unit in Western Paraná. They arrived frozen and were kept under freezing (-20 ± 1 °C) until the nuggets preparation.

Three chicken nuggets formulations (2 kg each) were prepared (Table 1) as described below:

Treatment 1 (T1): added with soy protein and sodium erythorbate as an antioxidant, considered the standard one;

Treatment 2 (T2): added with soy protein, without sodium erythorbate;

Treatment 3 (T3) added with DRB and without both soy protein and sodium erythorbate.

The frozen chicken was minced and meat emulsions were prepared using a cutter (MTK 661 model, Mado, Germany). The emulsions were comprised of abdominal fat, mechanically separated chicken meat, ice and soy protein or rice bran. The minced meat in conjunction with salt, and sodium tripolyphosphate were blended for one minutein cutter. The condiments were slowly added during a further two and a half minutes of blending. The final temperature was between 10 and 12 °C. Subsequently, the resulting mass was placed on polyethylene recipients and covered with a polyethylene film and stored for 24 h in a freezer (-20 ± 2 °C). The frozen mass was cut into pieces (2.25 cm long and 2 cm wide), breaded and frozen (-20 ± 2 °C). The frozen nuggets were kept at 4 ± 2 °C for 3 h before pre-frying in soybean oil for one min at 180 ± 1 °C. The chicken nuggets were stored in polyethylene wrappers at -20 ± 2 °C for 60 days.

Table 1
Chicken nuggets formulations

	Raw material and ingredientes	T1 (%)	T2 (%)	T3 (%)
Mass	Minced thigh and drumstick boneless	50.00	50.25	50.25
	Salt (Moc)	1.60	1.60	1.60
	Sodium erythorbate (Ibrac)	0.25	-	-
	Sodium tripolyphosphate (Ibrac)	0.25	0.25	0.25
	Monosodium glutamate (Ajinomoto)	0.05	0.05	0.05
	Dehydrated garlic (Geriba)	0.15	0.15	0.15
	Green seasoning (Geriba)	0.10	0.10	0.10
	White pepper (Geriba)	0.05	0.05	0.05
	Dehydrated onion (Geriba)	0.05	0.05	0.05
Emulsion	Abdominal fat of chicken	4.75	4.75	4.75
	Mechanically separated meat	23.75	23.75	23.75
	Crushed ice	14.25	14.25	14.25
	Concentrated soy protein (Ibrac)	4.75	4.75	-
	Defatted rice bran (Irgovel)	-	-	4.75

T1: chicken nuggets added of soy protein and sodium erythorbate; T2: chicken nuggets added of soy protein without sodium erythorbate; T3: chicken nuggets added of defatted rice bran without soy protein and sodium erythorbate.

Physico-chemical parameters

Moisture, ash, lipids, and crude protein were determined according to the Association of Official Analytical Chemists [AOAC] (2005). Carbohydrate values were calculated by difference: 100 - (% moisture + % ash + % protein + % lipids). Physico-chemical analyses were performed in duplicate. Water activity (a_w) was determined in triplicate at 25 ºC using a Decagon water activity meter (DCG-40530 model, WA, USA). The nuggets samples pH was measured in triplicate using a pH-meter (pH 21, Hanna®, Romania) using 10 g of sample homogenized with 50 mL distilled water (International Standards Organization [ISO], 1999).

Color measurements were performed inside the nuggets at three different points using a Konica Minolta colorimeter (CR400 model, NJ, USA) with an integrating sphere and 45° viewing angle (d/45 lighting and D illuminating) (Seganfredo, Rodrigues, Kalschne, Sarmento, & Canan, 2016). Lightness (L*), green-red chromaticity (a*) and blue-yellow chromaticity (b*) were measured according to CIELAB system.

For shear force evaluation, the nuggets were cut into 1.5 x 1.0 x 2 cm (height x width x length) pieces. Analyses were performed using a texture analyzer (TA.HD plus, Stable Micro Systems, UK) fitted with a Warner Bratzler probe and 5 g charge cell at a 5.0 mm s^{-1} speed and a 20 mm distance with a 0.001 mm resolution. The results of the minimum force required for cutting were given in Newton (N) and determined by five repetitions.

Lipid stability

The chicken nuggets were thawed (4 ± 1 ºC for 3 h) before the lipid oxidation analysis performed at days 0 (24 h after preparation), 30, and 60 by thiobarbituric acid reactive substances (TBARS). The samples were analyzed in duplicate using Tarladgis, Pearson and Dugan method (1964), modified by Crackel, Gray, Booren and Buclely (1988).

Microbiological parameters

The nuggets were evaluated in terms of *Salmonella* ssp., coagulase-positive *Staphylococcus* and coliforms at 45 ºC for 24 h in duplicate (Silva et al., 2010).

Sensory analysis

Sensory analysis was carried out for treatments T1 and T3 after 60 days of storage (-20 ± 1 ºC). Sample T2 (without antioxidant) was unsuitable for sensory analysis due to its high TBARS value and altered smell (rancid taste and aroma) after cooking. Notably, cooked meats are known to develop a fast and intense flavor deterioration after cold storage, usually described as warmed-over-flavor (WOF) (Carvalho, Shimokomaki, & Este 2017). An experimental randomized block design considering the samples and the panelists as a source of variation was used. Sensory analysis was performed according to ethical guidelines (CAAE 733.002/2014), under artificial white light using individual booths. A 50-person panel (consumers) randomly selected consisting of academics, teachers and university employees, aged from 19 to 50 years old, male and female, evaluated the samples.

The 9-point hedonic scale (9 = like extremely; 5 = not like/not dislike; 1 = dislike extremely) was employed to evaluate color, aroma, flavor, texture, and overall impression. The nuggets were thawed and baked until reaching 80 ± 1 °C minimum internal temperature (10537-13368 model Hot Grill, Fisher, Brazil), cooled to approximately 45 °C and served. The samples were coded with random three-digit numbers presented monadically and randomly balanced order.

The acceptability index (AI) was calculated according to the equation (Teixeira, Meinert, & Barbetta, 1987): AI = average grade/highest score*100.

Statistical analysis

Physico-chemical data were evaluated by a one-way ANOVA and the acceptance data evaluated by the main effects ANOVA and Tukey test (at a 5% significance level) using the STATISTICA version 8.0 software (Statsoft Inc., Tulsa, OK, USA).

Results and Discussion

Physico-chemical parameters

All chicken nuggets formulations followed the total carbohydrates content (maximum 30 g 100 g^{-1}) and protein (minimum 10 g 100 g^{-1}) (Instrução Normativa n. 6, 2001). Sample T3 (with rice bran) presented moisture, protein, lipids, and carbohydrate content ($p > 0.05$) similar to T1 (with soy protein and sodium erythorbate). The ash content was higher for T3, probably due to the high ash content form the DRB used (11.31 g 100 g^{-1}) (Table 2). According to Lacerda et al. (2010), rice bran could be considered a mineral source with contents between 7.76 and 7.63 g 100 g^{-1}. The main rice bran minerals are P, K and Mg and, to a lesser extent, Ca, Mn, Fe and Zn. For T2, a higher moisture value (5 g 100 g^{-1}) and lower lipid content (8 g 100 g^{-1}) than that for T1 was observed. This has probably occurred due to raw material composition, as previously reported by Seganfredo et al. (2016). However, this variation, although statistically significant ($p < 0.05$), was lower than the tolerated one (20 g 100 g^{-1}) (Resolução RDC n. 360, 2003).

The pH values were similar for all chicken nuggets samples ($p > 0.05$), varying between 6.55 and 6.67 (Table 2). Water activity for T3 was higher than that to T1 and T2 ($p < 0.05$), varying from 0.93 to 0.97. The highest water activity of T3 was probably due to soy protein absence, of which carbohydrates could bind water (Reid & Fennema, 2010).

Table 2
Results of physico-chemical parameters of chicken nuggets

Sample	Moisture (%)	Protein (%)	Ash (%)	Lipid (%)	Carbohydrate (%)	Water activity	pH
T1	54.56±0.48^{b}	11.03±0.14^{a}	2.58±0.24^{b}	18.17±0.04^{a}	13.66±0.63	0.93±0.01^{b}	6.62±0.12^{a}
T2	57.28±0.51^{a}	10.00±1.23^{a}	2.76±0.18^{b}	16.77±0.04^{b}	13.18±1.32	0.96±0.02^{ab}	6.67±0.07^{a}
T3	54.03±0.07^{b}	10.67±1.09^{a}	3.32±0.10^{a}	18.28±0.11^{a}	14.52±0.83	0.97±0.01^{a}	6.55±0.05^{a}
DRB	11.09±0.12	14.89 ± 0.29	11.31±0.64	1.67±0.04	61.03±0.53	-	-

T1: chicken nuggets added of soy protein and sodium erythorbate; T2: chicken nuggets added of soy protein without sodium erythorbate; T3: chicken nuggets added of defatted rice bran without soy protein and sodium erythorbate; DRB: defatted rice bran. Means ± standard deviation (n = 2 for all, except water activity and pH n = 3); different superscript letters on the same row have significant difference by Tukey test ($p < 0.05$).

DRB addition improved the darkness of T3 (L* = 59.32) ($p < 0.05$) compared to T1 and T2. The a* value (green-red component) was lower for T1 and statistically different from T2 and T3 ($p < 0.05$). The b* value (yellow-blue component) and shear force were similar among all samples ($p > 0.05$) (Table 3).

Table 3
Results of color parameters and texture of chicken nuggets

Sample	L*	a*	b*	Shear force (N)
T1	63.36±1.28^{a}	-1.5±0.48^{b}	16.05±0.57^{a}	9.32±0.46^{a}
T2	62.47±0.25^{a}	-0.25±0.29^{a}	15.84±0.80^{a}	8.64±0.44^{ab}
T3	59.32±2.28^{b}	0.22±0.23^{a}	15.51±0.74^{a}	8.12±0.29^{b}

T1: chicken nuggets added of soy protein and sodium erythorbate; T2: chicken nuggets added of soy protein without sodium erythorbate; T3: chicken nuggets added of defatted rice bran without soy protein and sodium erythorbate.
Means ± standard deviation (n = 3); different superscript letters on the same row have significant difference by Tukey test ($p < 0.05$).

Lipid stability

At day 0, no difference was observed among the chicken nuggets samples in terms of TBARS (Table 4). However, after 30 and 60 storage days, the lipid stability for T1 and T3 samples was greater than that for the T2 one ($p < 0.05$), due to the absence of antioxidants in T2. Moreover, T3 (with DRB as an antioxidant) and T1 samples exhibited a similar value for TBARS ($p < 0.05$) on all evaluated storage days, and a lower value compared to T2 at 30 and 60 storage days ($p < 0.05$). The malonaldehyde (MDA) results can be correlated with sensory characteristics of rancidity flavor and aroma; this can be observed in sample T2, which had a MDA content above the threshold (0.50 mg MDA kg^{-1}) and negative sensory characteristics (Andrade, Ribeiro-Santos, Guerra, & Sanches-Silva, 2019). Thus, the DRB showed suitability for lipid stability improvement, comparable to sodium erythorbate. Moreover, T3 presented greater lipid stability along the 60 days evaluated, taking into account that no difference on MDA content was observed.

Almeida, Villanueva, Gonçalves and Contreras-Castillo (2015) reported a greater value for TBARS, ranging from 0.20 and 0.34 mg MDA kg^{-1} 48 h after chicken nuggets elaboration. The

MDA content control - the major lipid oxidation byproduct- is of utmost importance in foods since it causes unpleasant flavors, discoloration, cytotoxic, carcinogenic and mutagenic effects, cholesterol oxidation and nutritional value loss due to vitamins and essential fatty acids destruction (Estévez & Lorenzo 2019).

The interest in natural food additives by consumers has reinforced the need for effective natural antioxidants development as an alternative to prevent meat products from deteriorating during processing and storage. Rice bran is a rich source of antioxidants (Canan et al., 2012) and it efficiently prevents lipid oxidation in meat products, as described in the present manuscript.

Table 4
Results of lipid oxidation (TBARS, mg malonaldehyde kg^{-1}) on chicken nuggets

Sample	Day 0	Day 30	Day 60
T1	0.28 ± 0.01^{aA}	0.16 ± 0.03^{bB}	0.17 ± 0.01^{bB}
T2	0.22 ± 0.03^{aB}	0.36 ± 0.06^{aAB}	0.51 ± 0.02^{aA}
T3	0.28 ± 0.08^{aA}	0.13 ± 0.04^{bA}	0.23 ± 0.03^{bA}

T1: chicken nuggets added of soy protein and sodium erythorbate; T2: chicken nuggets added of soy protein without sodium erythorbate; T3: chicken nuggets added of defatted rice bran without soy protein and sodium erythorbate.
Means ± standard deviation (n = 2); different superscript lowercase letters on the same row or different superscript uppercase in the same line have significant difference by Tukey test ($p < 0.05$).

Microbiological parameters

The microbiological parameters results are seen in Table 5. *Salmonella* spp. was not detected on the samples, while the coagulase-positive *Staphylococcus* count was < 10^2 CFU g^{-1}, and the Coliforms at 45 ºC were < 3 MPN $g^{-1.}$ Similarly, Almeida et al. (2015) reported an expected microbiological quality for chicken nuggets (Resolução RDC n. 12, 2001).

Table 5
Results of microbiological parameters of chicken nuggets

Sample	*Salmonella* spp. (in 25 g)	Coagulase-positive *Staphylococcus* (CFU g^{-1})	Coliform at 45 ºC (MPN g^{-1})
T1	Absence	< 10^2	< 3
T2	Absence	< 10^2	< 3
T3	Absence	< 10^2	< 3
Limit*	Absence	5 x 10^2	10^2

T1: chicken nuggets added of soy protein and sodium erythorbate; T2: chicken nuggets added of soy protein without sodium erythorbate; T3: chicken nuggets added of defatted rice bran without soy protein and sodium erythorbate; CFU g^{-1}: colony-forming unit per gram of sample; MNP g^{-1}: most probable number per gram of sample.
* Resolução RDC n. 12, 2001.

Sensory acceptance

The sensory acceptance values for T1 and T3 samples are presented in Table 6. No differences were observed between samples for all attributes ($p > 0.05$). The acceptability index varied between 72.4 and 82.0% for attributes evaluated, and were higher than 70% - suggested as the minimum for a product to be sensorially accepted (Teixeira et al., 1987). Thus, the replacement of soy protein and sodium erythorbate by DRB can be performed in chicken nuggets, reinforcing the sensory acceptance of product after 60 days of storage. In the same context, Huang, Shiau, Liu, Chu and Hwang (2005) investigated the rice bran addition in Kung-wan (an emulsified pork meatball). The sensory acceptance of scores of flavor, texture, and overall impression of meatballs with up to 10% rice bran showed no difference from control meatballs (without rice bran).

Table 6
Results of sensory acceptance of chicken nuggets

Sample	Color	Aroma	Flavor	Texture	Overall impression
			Sensory mean		
T1	6.68±1.28[a]	7.38±1.37[a]	7.02±1.35[a]	7.04±1.55[a]	7.12±1.24[a]
T3	6.52±1.72[a]	7.10±1.63[a]	6.62±1.72[a]	6.96±1.73[a]	6.98±1.36[a]
			Acceptability index (%)		
T1	74.2	82.0	78.0	78.2	79.1
T3	72.4	78.9	73.6	77.3	77.6

T1: chicken nuggets added of soy protein and sodium erythorbate; T3: chicken nuggets added of defatted rice bran without soy protein and sodium erythorbate. Hedonic scale: 9 = extremely like; 5 = not like/not dislike; 1 = extremely dislike.
Means ± standard deviation (n = 50); different superscript letters on the same row have significant difference by Tukey test ($p < 0.05$).

Conclusions

The replacement of soy protein by DRB showed no influence on chicken nuggets texture, evaluated by instrumental and sensory analysis. Additionally, the DRB presented a suitable antioxidant potential, comparable to sodium erythorbate. The centesimal composition and microbiological parameters were either not influenced, or positively influenced by DRB addition. The total replacement of soy protein and sodium erythorbate by DRB ensured the sensory acceptance in terms of color, aroma, flavor, texture, and overall impression, with acceptability index greater than 72.4%. Thus, DRB is a natural ingredient that meets consumers demand for healthy meat products. Moreover, DRB addition to meat products increases the value for a secondary byproduct from rice-processing plants.

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