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ANIMAL PRODUCTION

Effect of oat bran fiber on physicochemical properties and acceptance of enriched rabbit meat burgers

Heloísa Lara Silva[1], Paula Gabriela da Silva Pires[2], André Luis Ferreira Lima[1], Aline Chiarelli Cristofolini[1], Diego Peres Netto[1], Marília Miotto[3], Lucélia Hauptli[1] and Priscila de Oliveira Moraes[1*]

[1]Departamento de Zootecnia e Desenvolvimento Rural, Universidade Federal de Santa Catarina, 88034-000, Florianópolis, Santa Catarina, Brazil. [2]Departamento de Zootecnia, Universidade Federal do Rio Grande do Sul, Porto Alegre, Rio Grande do Sul, Brazil. [3]Departamento de Ciência e Tecnologia de Alimentos, Universidade Federal de Santa Catarina, Florianópolis, Santa Catarina, Brazil. *Author for correspondence. E-mail: priscila.moraes@ufsc.br

ABSTRACT. Burger is a practical source of animal protein for consumers, sold both raw (ready-to-cook) and cooked (ready-to-eat), and can be an alternative to stimulate the consumption of rabbit meat, which is a source of healthy animal protein. This study evaluated the effects of different levels of oat bran addition on physicochemical properties and sensory acceptance of rabbit meat burgers. Burgers were formulated with 0, 5, 10, and 15% oat bran plus garlic and salt, then manually processed and analyzed for composition, technological parameters (pH, cooking loss, shrinkage percentage, water holding, texture, and color), and sensorial acceptance. The higher the levels of inclusion of oat bran, the lower the burger moisture ($p < 0.0001$). Burgers with 15% oat bran presented higher content of lipids and carbohydrates, thus higher caloric value ($p < 0.0001$). The loss of water during cooking was greater in the burger without the inclusion of oat bran ($p < 0.05$). No significant difference was found for color and aroma attributes. Overall acceptability was higher for burgers with 5% oat bran. Rabbit meat burgers containing oat bran may represent a viable alternative to improving their sensory and technological profiles and overall consumer acceptance.

Keywords: burger; fiber; low-fat meat product; rabbit meat; sensory analysis.

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Introduction

Meat products contain highly digestible proteins, and essential amino acids and are an excellent source of B vitamins and minerals, yet, for some consumers, its consumption is not consistent with a healthy lifestyle, as meat is also a source of animal fat, cholesterol, and synthetic additives that may be associated with degenerative diseases (Cofrades, Serrano, Ayo, Carballo, Jiménez-Colmenero, 2008; Hygreeva, Pandey, & Radhakrishna, 2014). Some meats, though, are considered healthier due to their composition in fat and protein content, which is the case of rabbit (*Oryctolagus cuniculus*) meat, which is considered lean because, in comparison to meat from other species, it has a low-fat content and lower levels of cholesterol (47 mg 100 g^{-1} for rabbit meat, while 55.3 mg 100 g^{-1} for poultry and 62.7 mg 100 g^{-1} for pork), it also contains lower levels of sodium and higher levels of essential amino acids such as lysine, threonine, valine, isoleucine, leucine, and phenylalanine (Dalle Zotte, & Szendro, 2011).

The food industry is increasing the availability of rabbit meat products and industrialized options that facilitate meal preparation, meeting the demands of modern consumers, once rabbit meat is mainly marketed as a whole carcass or in cuts, which require more time to prepare (Cavani & Petracci, 2004).

Dietary fibers are found in the cell wall of plants and are not digested by the human body; they have effects on satiety and energy intake, and are beneficial to health, reducing the risk of diabetes, high blood cholesterol, cardiovascular disease, and colon cancer (Gill, Rossi, Bajka, & Whelan, 2021). Fibers are also capable, depending on the water-holding capacity and viscosity, of preserving or, even, improving, food juiciness (Petersson, Eliasson, Tornberg, & Bergenståhl, 2013). Several studies have been carried out on the replacement of fat with dietary fiber to improve meat product properties and healthiness (Carvalho et al., 2019; Choe, Kim, Lee, Kim, & Kim, 2013; Kehlet, Pagter, Aaslyng, & Raben, 2017; Kim et al., 2018). The addition of oat bran or oat fiber to modify the fatty acid profile of comminuted meat products has been successfully demonstrated previously (Dawkins et al., 2001; Yilmaz & Dağlioğlu, 2003).

The main goal of this study was to evaluate the effects of different levels of oat bran addition on the physicochemical composition, and technological and sensorial characteristics of rabbit meat burgers.

Material and methods

Hamburger processing

To obtain the meat, twenty White New Zealand male rabbits were used, with a carcass yield of 1.357 ± 0.23 kg. The whole carcass without viscera, paws, and head was deboned and the meat was ground using a stainless-steel meat grinder (CAF22, CAF - Brazil). Four formulations with different levels (0% - control, 5, 10, or 15%) of oat bran addition plus 1.5% salt and 0.25% garlic were manufactured. The ingredients used were selected according to the Technical Regulation of Identity and Quality of Hamburger from the Brazilian Ministry of Agriculture, Livestock and Supply (Instrução Normativa nº 20, 2000). The whole experiment was prepared on separate days for each replicate from each batch of meat (Table 1).

Table 1. Formulations of burgers made with different levels of oat bran (Oat) and rabbit meat.

Level of oat bran	Rabbit meat (%)	Salt (%)	Garlic (%)
0%	98.25	1.5	0.25
5%	93.25	1.5	0.25
10%	88.25	1.5	0.25
15%	83.25	1.5	0.25

All ingredients were weighed according to each formulation and manually mixed to a homogeneous mass and modeled in a specific format for burgers with 80 g each, as stated by the Brazilian Legislation (*Resolução RDC nº 359*, 2003). Each burger was individually packed and frozen at −20°C for 5 days.

Proximate analysis

Burgers were thawed, homogenized, and dried in a forced-air oven at 55ºC for 72h, according to recommendations of the Association of Official Analytical Chemists (AOAC, 1998). Samples were analyzed for dry matter (DM - AOAC 934.01), mineral matter (MM - 942.05), and crude protein (CP - AOAC 954.01), and lipids were quantified by the Bligh and Dyer method (1959). Calories were calculated according to Equation (1):

Calories = (C * 4) + (P * 4) + (F * 9) (1)

In which:
C = Carbohydrate Content (g 100 $^{g-1}$)
P = Protein Content (g 100 $^{g-1}$)
F = Fat Content (g 100 $^{g-1}$)

Physical analysis

pH and cooking loss

A portable meat pH meter was used to measure pH (Hanna Instruments, USA) by inserting the probe directly into eight burgers per treatment.

Cooking loss was assessed by raising the internal temperature of burgers to 71°C using a grill. Cooking loss was calculated as shown in Equation (2), described by Wang, He, Gan, and Li (2018).

Cooking loss (%) = (Final weight − Initial weight)/(Initial weight * 100) (2)

Shrinkage percentage

The shrinkage percentage was calculated according to Berry as shown in Equation (3) (Berry, 1992).

$$Shrinkage(\%) = \frac{Diameter\ of\ the\ raw\ sample - Diameter\ of\ the\ cooked\ sample}{(Diameter\ of\ the\ raw\ sample * 100)} \quad (3)$$

Water holding capacity

The water holding capacity was determined according to Hamm (1986), for this 500 ± 20 mg burger was placed on a filter paper between two acrylic plates, and, on top of them, a weight of 10 kg was placed for five minutes. The resulting meat sample was weighed, and, by difference, the amount of water loss was calculated as in Equation (4).

Water loss = Weight of the raw sample – Weight of the pressed sample (4)

Texture analysis

Texture analysis was carried out as described by Carvalho et al. (2019), using a texture analyzer (TA.XT.plus, Stable Micro Systems, England) equipped with a 30 mm cylindrical probe (speed: 3 mm s^{-1}; distance: 30 mm; force: 5 g f^{-1}) on 10 samples of 20 mm x 20 mm per treatment.

Color measurement

Burger color was analyzed using a computer vision system, according to the methodology described by Girolami, Napolitano, Faraone, and Braghieri (2013). In a Styrofoam tray, one burger was placed at a time and inserted in a mini photographic studio measuring 60x60x60 cm, and photographed without flash using a Canon EOS Rebel T6 camera placed 30 cm vertically above the sample using EF-S18-55 mm lenses. Mean red (R), green (G), and blue (A) colors were measured using ImageJ 1.37 software (National Institutes of Health, Bethesda, MD, United States; http://rsb.info.nih.gov /ij/). Five photos of five burgers from each treatment were taken, five measures were taken for each photo in a circular area of 1.5 cm^2 at the center of each nucleus, and, then, each measurement was evaluated twice.

Microbiological and sensory analysis

The following microorganisms were investigated: coliforms at 35°C, coliforms at 45°C, coagulase-positive *Staphylococcus* sp., *Clostridium sp.,* and *Salmonella* sp. Microbiological analysis was performed according to American Public Health Association (APHA, 2001). Microbiological results were compared to the RDC 12 by the National Health Surveillance Agency (Resolução RDC nº 12, 2001).

Sensory acceptance was analyzed following the methodology described by Meilgaard, Civille, and Carr (2007). The study was approved by the Human Research Ethics Committee, with the following registration number: HREC: 19870519.6.0000.0121. The acceptance test was carried out using a group of non-trained panelists (n = 50), and a nine-point structured hedonic scale (1-dislike extremely; 9-like extremely), for the attributes color, aroma, texture, flavor, and overall acceptance. Burgers were kept on a grill (PR-220 G STYLE, Progás, Brazil) at 180°C until they reached an internal and central temperature of 75°C. About 20 g of each sample was monadically presented to regular consumers of hamburger and rabbit meat, of both sexes, non-smokers, and between 18-50 years old. Samples were coded with random three-digit numbers.

Statistical analysis and experimental design

The experimental design was completely randomized. Statistical procedures were performed using SAS statistical software (Statistical Analysis System, version 9.4). Data was tested by analysis of variance using PROC GLM. Differences ($p < 0.05$) were assessed by Tukey's multiple comparisons test.

Results and discussion

Proximate analysis

Moisture percentage decreased ($p < 0.05$) from 69.16 to 60.26% as oat bran was added to the burgers, probably due to the low moisture content of oat bran compared to raw rabbit meat (Table 2). This is in line with Pinho, Afonso, Carioca, Costa, and Ramos (2011), who included cashew apple residue as a source of fiber in burgers. Dawkins et al. (2001) also observed a reduction in moisture content with increasing addition of oat gum to rabbit burgers.

Protein content was not altered ($p > 0.05$). Lipid values had an increase ($p < 0.05$) from 4.33% in the control to 4.95% in the burger with the addition of 15% oat bran, which can be explained by the higher lipid content in oats (7.47%) compared to the rabbit meat. Cofrades et al. (2008) found an increase in lipid content in the preparation of meat batters caused by the addition of defatted walnut flour and concluded the increase is due to the higher fat content in the walnut flour. In the present study, no extra fat source was added to the formulations. However, other studies reporting a decrease in lipid content, with the addition of different fiber sources, have added an extra source of lipids (Carvalho et al., 2019; Sánchez-Zapata et al., 2010). Despite the elevation in lipid content due to the inclusion of oat bran, the lipid values found in the burgers of this study are lower than the low-fat formulations tested in the other aforementioned studies.

Table 2. Proximate composition of raw burgers made with different oat bran (Oat) levels and rabbit meat.

Oat (%)	Moisture (%)	Protein (%)	Lipid (%)	Calories (kcal 100 g^{-1})	Carbohydrate (%)
0%	69.16 ± 0.21^a	18.42 ± 0.10^a	4.33 ± 0.06^b	136.08 ± 0.80^d	5.86 ± 0.13^d
5%	65.76± 0.02^b	18.63 ± 0.33^a	4.37 ± 0.14^b	146.77± 0.86^c	8.24 ± 0.27^c
10%	63.10 ± 0.10^c	18.17 ± 0.28^a	4.27 ± 0.11^b	154.27± 0.68^b	10.79 ± 0.43^b
15%	60.26 ± 0.43^d	18.04 ± 0.18^a	4.95 ± 0.02^a	166.16± 1.74^a	12.36 ± 0.33^a
P-value	0.0000	0.383	0.004	0.000	0.0000
Oat	7.53	17.21	7.47	337,67	50.40

Values refer to the mean ± standard error. a-d Different letters in the same column indicate significant differences ($p < 0.05$)

In addition, there was a progressive increase in the carbohydrate, from 5.86% in the control to 12.36% in the 15% oat treatment, and caloric content, from 136.08 kcal 100 g^{-1} to 166.16 kcal 100 g^{-1}, ($p < 0.05$) of the burgers. The high content of lipids in oat bran is responsible for the increase in calories in these burgers. Dietary fibers, such as oat bran, are carbohydrates and this explains the increased carbohydrate content. The reduction in moisture in meatballs by replacing fat with oat bran was also shown by Yilmaz and Daglioglu (2003), and due to increasing addition of oat bran, there was a decrease in the fat content and a rise in protein and ash content of the meatballs.

Physical analysis

There was no difference in pH values for any of the treatments ($p > 0.05$). The loss of water during cooking was greater ($p < 0.05$) in the burger without the inclusion of oat bran, 23.37%. The reduction in the total diameter of the control treatment (0%) was 4.26%, only different ($p < 0.05$) compared to the 3.78% reduction of the burgers with the addition of 15% of oat bran (Table 3).

Water holding was higher for all samples ($p < 0.05$) containing oat bran compared to the retention of 45.42% of the control (0%). The higher water loss from the control (0%) burger in comparison to the formulas containing oat bran can be explained by the dietary fiber water-holding capacity (Petersson et al., 2013). Dietary fibers are represented by soluble and insoluble polysaccharides, which have free hydroxyl groups that can retain water by forming hydrogen bonds (Spiller, 2001). Sánchez-Zapata et al. (2010) observed that the presence of tiger nut fiber in pork burgers also improved the technological aspects of the product, such as less water loss, high moisture retention, and less diameter reduction. Besbes, Attia, Deroanne, Makni, and Blecker (2008) used pea fiber and wheat fiber concentrates as dietary fiber sources in beef burger formulations; the water-holding capacity of these beef burgers was significantly higher with the addition of fiber. The authors concluded that the use of dietary fiber in beef burger formulation improved cooking properties, as it increased cooking yield and decreased shrinkage, minimizing production cost without degradation of sensory properties.

Table 3. Results of physicochemical analysis of cooked burgers made with different oat bran (Oat) levels and rabbit meat.

Parameter	Oat 0%	Oat 5%	Oat 10 %	Oat 15 %	P-value
pH	5.72 ± 0.01	5.75 ± 0.02	5.78 ± 0.04	5.68 ± 0.02	0.183
Cooking loss (%)	23.37 ± 0.38^a	15.30 ± 0.82^b	9.56 ± 0.53^c	8.98 ± 0.65 ^{c}	0.000
Diameter shrinkage (%)	6.80 ± 0.69^a	4.26 ± 0.71^{ab}	4.74 ± 0.45^{ab}	3.78 ± 0.54^b	0.027
Moisture retention (%)	45.42 ± 3.57	64.69 ± 1.32^a	71.14 ± 1.28^a	70.99 ± 1.95^a	0.000
Hardness (g)	16.28 ± 2.12^d	22.58 ± 2.50^c	85.0 ± 3.9^b	126.3 ± 6.0^a	0.003
Cohesivity	0.53 ± 0.01^a	0.34 ± 0.03^b	0.37 ± 0.04^{bc}	0.24 ± 0.01^c	0.000
Chewiness (g.mm)	7.11 ± 0.87^b	9.37 ± 1.13^b	15.23 ± 6.89^a	20.6 ± 12.8^a	0.000
Elasticity	83.64 ± 1.37	83.24 ± 0.79	84.60 ± 0.42	82.74 ± 1.79	0.741
Lightness (L*)	76.12 ± 0.46^b	78.36 ± 0.01^{ab}	78.9 ± 1.04^{ab}	79.69 ± 0.50^a	0.019
Redness (a*)	8.19 ± 0.60^a	4.12 ± 0.95^b	4.89 ± 0.45^{ab}	3.59 ± 0.83^b	0.009
Yellowness (b*)	12.6 ± 0.51	9 ± 1.20	11.24 ± 0.63	8.68 ± 1.42	0.075

Values refer to the mean ± standard error of the results. a-d Different letters in the same row indicate significant differences ($p < 0.05$)

Hardness proportionally increased due to the addition of oat bran ($p < 0.05$), with the highest value, 126.3 g, for the 15% oat burger. Cohesiveness decreased and chewability increased from the 10% oat inclusion formula. Fernández-Ginés, Fernández-López, Sayas-Barberá, Sendra, Pérez-Álvarez, (2004) and Petersson et al. (2013) reported that the inclusion of fibers in meat products increased hardness, probably because of the high content of lignin and cellulose. Sánchez-Zapata et al. (2010) found an increase in elasticity and no difference in hardness with the inclusion of tiger nut fiber in pork burgers.

Values of Luminosity (L*) increased ($p < 0.05$) with oat bran addition, from 76.12 to 79.69. The trend for decreasing hamburger luminosity with fiber inclusion has already been demonstrated in studies on the inclusion of wheat fiber (Carvalho et al., 2019), and tiger nut fiber (Sánchez-Zapata et al., 2010). Redness (a*) values decreased ($p < 0.05$) from 8.19 to 3.59 with the inclusion of oat bran. Kim et al. (2018) also observed a reduction in the value of (a*) in burgers included with wheat sprout fiber, which may be related to the decrease of meat on the formula. Yellowness (b*) showed no significant difference ($p > 0.05$).

Sensory evaluation

Clostridium perfringens, Staphylococcus sp.*, and Salmonella* sp. were not detected in any sample (Control 0, 5, 10, and 15% oat bran inclusion). Furthermore, the level of coliforms was less than 3 MPN g^{-1}, in all treatments. Microbiological analysis was performed according to APHA (2001). Therefore, they were considered suitable for human consumption, in accordance with the RDC 12 by the National Health Surveillance Agency (Resolução RDC nº 12, 2001).

According to the sensory evaluation panel, color and aroma were not different between treatments ($p > 0.05$). Flavor showed the lowest value, 5.88, ($p < 0.05$) in burgers with 15% oat bran. Texture also scored the lowest value ($p < 0.05$), 6.37, in the 15% inclusion treatment (Table 4). A tendency towards greater overall acceptance for burgers with 5% oat bran inclusion was observed, with a score of 7.82. The results found here for texture analysis and overall acceptance agree with Carvalho et al. (2019), who also reported the formula with higher wheat fiber inclusion decreased the overall acceptance of beef burgers.

Table 4. Sensory evaluation of acceptance of burgers made with different oat bran (Oat) levels and rabbit meat.

Parameter	Oat 0%	Oat 5%	Oat 10 %	Oat 15 %	P-value
Color	5.78 ± 0.38	6.00 ± 0.35	5.98 ± 0.37	5.76 ± 0.36	0.937
Aroma	7.06 ± 0.30	7.16 ± 0.30	7.20 ± 0.34	6.57 ± 0.36	0.497
Flavor	7.10 ± 0.29^{a}	8.02 ± 0.21^{a}	7.20 ± 0.24^{a}	5.88 ± 0.33^{b}	0.000
Texture	7.27 ± 0.32^{ab}	8.06 ± 0.20^{a}	7.22 ± 0.27^{ab}	6.37 ± 0.36^{b}	0.001
Overall Quality	7.08 ± 0.31^{ab}	7.82 ± 0.20^{a}	7.27 ± 0.25^{ab}	6.43 ± 0.31^{b}	0.004

Values refer to the mean ± standard error of the results. a-d Different letters in the same row indicate significant differences ($p < 0.05$)

Acceptance of a burger containing a fiber source may vary according to the type of fiber and level of inclusion. Carvalho et al. (2019) found the burger flavor only differed with a 6.25% inclusion of wheat fiber, and formulations with fiber inclusion up to 4.68% showed no significant difference from the control (no fibers added). On the other hand, studies have shown the tiger nut fiber inclusion did not change burger flavor at any concentration (Sánchez-Zapata et al., 2010), while the addition of *Himanthalia elongata* seaweed fiber even improved burger flavor (Cox & Abu-Ghannam, 2013).

Conclusion

The production of burgers with partial replacement of rabbit meat with oat bran improved the product's moisture retention without compromising the sensory properties up to 10% oat bran inclusion, and overall acceptance was higher for burgers with 5% oat bran. The research and development of rabbit-based meat products is a way of keeping rabbit meat relevant and appealing to consumers.

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