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Rabbit as sustainable meat source: carcass traits and technological quality of meat and of mechanically deboned meat

Coelhos como fonte de carne sustentável: características de carcaça e qualidade tecnológica da carne e da carne mecanicamente separada

Conejos como fuente de carne sostenible: características del canal y calidad tecnológica de la carne y de la carne separada mecánicamente

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Abstract

This study aimed to characterize rabbit carcass traits, meat quality, and mechanically deboned meat (MDRM) from New Zealand × Botucatu crossbred rabbits to determine the potential use by the meat industry. Average yields of the carcass (52.46%) and retail hind leg (33.88%), foreleg (15.51%), loin (11.63%), and back (39.83%) cuts were assessed, with total meat-to-bone ratio of 1.65. The meat proximate composition and technological characteristics pH, water retention capacity, and total collagen were similar to meat of commonly market species. Rabbit meat color was light (L^* = 65.93) and with a low shade of red (C^* = 19.24 and h = 52.79 °) due to the low content of heme pigments (19.89 µg acid hematin/g). The obtained MDRM met the levels of protein and fat required by Brazilian legislation, but a high calcium content (1.45% dry basis). It can be concluded that rabbits represent a viable unconventional meat resource with high potential for use in processing. In addition to raw meat, MDRM can also be obtained to be used as a meat ingredient in industrial products.

Keywords: Cuniculture; Industrialization; Meat processing.

Resumo

Para determinar o seu potencial de uso pela indústria, esta pesquisa objetivou avaliar as características de carcaça e a qualidade da carne *in natura* e da carne mecanicamente separada (CMS) de coelhos da cruza Nova Zelândia × Botucatu. Foram avaliados os rendimentos médios de carcaça (52,46%) e dos cortes perna traseira (33,88%), perna dianteira (15,51%), lombo (13,63%) e dorso (39,83%), tendo uma razão carne/osso total de 1,65. A composição centesimal e as características tecnológicas pH, capacidade de retenção de água e colágeno total da carne foram similares às carnes das espécies comumente comercializadas. A carne de coelho possui uma cor clara (*L** = 65,93) e de vermelho pouco intenso (C* = 19.24 e h = 52.79°) devido ao baixo teor de pigmentos heme (19,89 µg hematina acida/g). A CMS obtida atendeu aos teores de proteína e gordura exigidos pela legislação brasileira, mas com o alto conteúdo de cálcio (1,45% base seca). Concluiu-se que os coelhos representam um recurso viável de carne não-convencional com alto potencial de uso no processamento. Além da carne, a CMS também pode ser obtida para ser usada como ingrediente em produtos cárneos industriais.

Palavras-chave: Cunicultura; Industrialização; Processamento.

Resumen

Con el fin de determinar su potencial de uso por parte de la industria, esta investigación tuvo como objetivo evaluar las características de la canal y la calidad de la carne fresca y la carne separada mecánicamente (CSM) de conejos del cruce de Nueva Zelanda × Botucatu. Se evaluaron cortes promedio de canal (52,46%) y pata trasera (33,88%), pata delantera (15,51%), lomo (13,63%) y espalda (39,83%), con una relación carne/hueso de 1,65. La composición próxima y las características tecnológicas del pH, la capacidad de retención de agua y el colágeno total de la carne fueron similares a la carne de las especies comúnmente vendidas. La carne de conejo es de color claro (*L** = 65,93) y rojo poco intenso (*C** = 19,24 y *h* = 52,79 °) debido al bajo contenido de pigmentos hemo (19,89 µg hematina ácido/g). El CSM obtenido cumplió con los niveles de proteína y grasa requeridos por la legislación brasileña, pero con un alto contenido de calcio (1,45% base seca). Se concluyó que los conejos representan un recurso viable de carne no convencional con alto potencial de uso en procesamiento. Además de la carne, también se puede obtener CSM para su uso como ingrediente en productos cárnicos industriales.

Palabras clave: Cría de conejos; Industrialización; Procesamiento de carne.

1. Introduction

Protein foodstuffs of animal origin are vital sources of macronutrients for basic metabolism, representing the major supply of protein with high biological value and balanced essential amino acids in human nutrition. The projected demand for protein is of particular concern because by 2050, the global population is likely to reach 10 billion and the food production/protein supply will need scaling up by almost 70% (FAO, 2018). Live animal tissues converted to meat obtained from conventional slaughter-species in traditional agricultural-livestock productive systems such as cattle, sheep, pigs, and poultry, are currently the major marketed sources of animal protein. However, protein originating from meats and their current production systems have been broadly questioned in terms of food security scenarios of global population growth, protein availability, production efficiency (g protein/time/area of used land) and sustainability (FAO, 2017). Besides sustainability issues, consumer health concerns will result in changes in consumption and, therefore, the types of foods demanded and their relative contributions to diets will also change.

Multidisciplinary efforts are underway by academia and industry to provide viable, innovative, and unconventional dietary protein alternatives with which to feed humans. Meats from less popular animal species, but sourced from more environmentally friendly and efficient production systems, such lagomorphs and rodents, have commercial market value and represent a valid opportunity to improve food security and sustainability, with high dietary/nutritional value for humans (Cullere & Dalle Zotte, 2018). Lagomorphs such as rabbits have many qualities that should theoretically render them as ideal meat producers. Rabbits are promising in terms of zoo-technical productive performance, due to a short life cycle, rapid growth rate, short gestation period, and notable performance responses including daily weight gain and feed conversion ratios (Nasr, Abd-Elhamid, & Hussein, 2017). Furthermore, rabbit meat is considered as a healthy food, because it is low-fat, balanced in terms of unsaturated fatty acids and cholesterol, source of highly available micronutrients, such as vitamins and minerals, rich in high-quality protein and the taste is appealing (Bosco, Castellini, & Bernardini, 2001; Dalle Zotte & Szendrő, 2011).

However, rabbit meat is not prevalent worldwide, even in countries where it is considered a traditional meat species such as China and Mediterranean Europe. Currently, the rabbit production industry is encumbered by structural difficulties. The costs of semi-automated rabbit meat processing are quite high and specific technological developments for processing are limited because the industry is relatively small. Most commercial rabbit meat is still sold as whole carcasses and little effort has been directed towards the research and development of rabbit meat products (Li et al., 2018; Petracci, Soglia, & Leroy, 2018). Although rabbit meat adapts well to the cuisine and tastes prevalent in Brazil, this branch of agribusiness is underutilized, leading to low meat production and consequently low consumption (Machado, 2012).

Thus, the scientific development of processing alternatives that would allow better carcass availability, added value, commercialized specific cuts, meat recovery and processing might contribute to upscaling the rabbit meat industry. For example, in the poultry industry slaughter and automated processing lines commercially separate legs, wings and breast, and debone and technologically process mechanically deboned meat (MDM) from the back thoracic cage and trimmings. Such processes might help to diversify rabbit meat and processed meat-products and optimize carcass yield and value. Therefore, this study aimed to assess the potential industrial uses of rabbit meat by evaluating its carcass yields and traits, including boning, and obtaining and characterizing mechanically deboned rabbit meat (MDRM).

2. Material and methods

2.1 Animals and carcass traits

The animals used in this study were reared and slaughtered in accordance with the ethical standards of the National Council for Animal Experimentation (CONCEA), Brazil, approved by the Federal Institute of Education, Science and Technology of Minas Gerais (IFMG), Bambuí Campus, Ethics Committee (License No: 011/2017).

Twenty white New Zealand × Botucatu crossbred rabbits of both sexes were reared in collective cages (0.60 × 0.60 m) containing two rabbits each from weaning to slaughter at the IFMG experimental farm. The rabbits were given a commercial pelleted diet (17.7% crude protein, 17.2% acid detergent fiber and digestible energy of 2450 kCal/kg of feed) and access to water *ad libitum*. The animals were slaughtered at the age of 84 days (live weight, 2.68 ± 0.22 kg) at the IFMG slaughterhouse, according to federal standards for humanitarian and sanitary slaughter. Carcasses were chilled at 4°C for 24 h before cutting.

The carcasses were weight and the retail cuts of forelegs, hind legs, loins (*Longissimus thoracis et lumborum* muscle) and back (thoracic cage and flank) were obtained (Figure 1). The cuts were weighed, manually deboned, then the weight of the meat and the bones were recorded. The meat and bones from the back were identified according to the respective carcass, vacuum-packaged, stored at -20°C, and sent to the Laboratory of Meat Science and Technology (LabCarnes) at the Federal University of Lavras (UFLA) for further analysis and processing.

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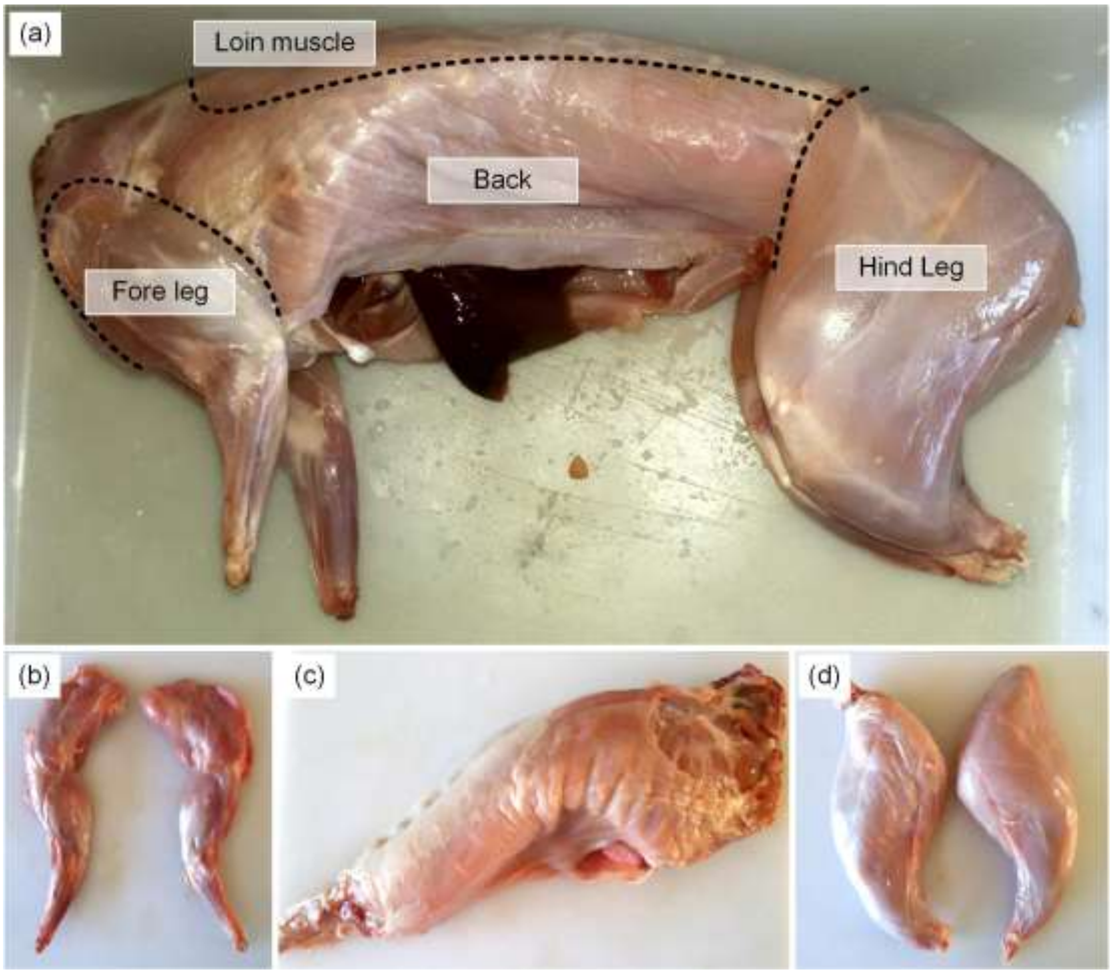
Figure 1. Photographs of the rabbit carcass (a) highlighted with the retail cuts used in the experiment: (b) forelegs; (c) back (thoracic cage and flank) with loin (*Longissimus thoracis et lumborum* muscle); and (d) hind legs.



Source: The authors.

2.2 Rabbit meat characterization

To investigate the technological potential of rabbit meat in industrial processing, the raw frozen meats were thawed (4° C/24 h), grounded (Beccaro Ltda, Rio Claro, SP, Brazil) twice, and homogenized before sampling to be analyzed for pH, instrumental color, proximate composition, water holding capacity (WHC), total heme pigments, and collagen contents.

2.3 Mechanically deboning and characterization

To assess maximal carcass utilization, mechanically deboned rabbit meat (MDRM) was obtained from frozen bones of the back-retail cut (Figure 2) using a mechanical deboning machine (PV Máquinas; Chapecó, SC, Brazil). Foreleg and hind leg bones were not used due to the limitations of the mechanical deboning equipment. The frozen bones were grouped in three batches (replicates), cut into smaller pieces with a cleaver and then processed. As a reference, mechanically deboned poultry meat (MDPM) was also prepared from poultry backs and necks, with skins, obtained (triplicate) in local trade.

Figure 2. Photographs of the rabbit raw material (bones of the manually deboned thoracic cage and flank) used to produce the mechanically deboned rabbit meat (MDRM).

Source: The authors.

The mechanically deboned meats (MDM) obtained were homogenized and a portion was removed for pH and instrumental color analyses before being packed in polyethylene bags (~ 400 g samples; pack thickness, 15 mm) and immediately frozen at -18°C. Proximate composition, calcium content and total heme pigments were also analyzed in MDM samples.

2.4 Meat and MDRM analysis

The total moisture (AOAC 950.46B), fat (AOAC 960.39), protein (AOAC 981.10, using 6.25 as conversion factor) and ash (AOAC 950.46) contents of rabbit raw meat and MDM were analyzed according to the Association of Official Analytical Chemists (AOAC, 2012). Calcium content (%dry matter; AOAC 975.03) was also analyzed in MDM.

The raw meat and MDM samples were homogenized (Turratec TE102; Tecnal Equip. Científicos, Piracicaba, SP, Brasil) in distilled water (1:10 w/v) for about 30 s, and the pH was measured, in triplicate, using a combined glass electrode coupled to a digital DM20 pH meter (Digimed Analítica Ltda., São Paulo, SP, Brazil). The total content of heme pigment (µg hematin/g) in raw meat and MDM were determined as described by Hornsey (1956). The total collagen content (mg/g) was determined only in rabbit raw meat using the AOAC 960.39 method (AOAC, 2012) and 7.25 as a factor for converting hydroxyproline to collagen (Ramos & Gomide, 2017). Water holding capacity (WHC) in rabbit raw meat was assessed using the filter paper press method (FPPM) as described by Aroeira et al. (2020).

The instrumental color was measured using a Minolta CM-700d colorimeter (Konica Minolta Sensing Inc, Osaka, Japan) with an aperture of 8 mm, an observer angle of 10° and the specular component excluded (SCE) mode. Ground raw meat and MDM samples were placed in Petri dishes, exposed to atmospheric air for 30 min for blooming, and the CIE color obtained in the surface using illuminant A. The CIE lightness (*L**), redness (*a**), yellowness (*b**), chroma (*C**) and hue angle (*h*, degrees) were recorded from the averages of five surface readings.

All data obtained were analyzed using descriptive statistics.

3. Results and discussion

3.1. Carcasses traits

Table 1 shows the data obtained for rabbit carcass traits, dressing out ratios (%) and commercial cut yields.

Carcass yield CY (% dressing out), that is the correlation between chilled rabbit carcass weight (CCW) and live weight at slaughter (LW), represents a major profit and economic parameter in carcass traits evaluation. Our findings showed that this parameter ranged from 49.59% to 54.91% (mean 52.46%), being inside the range in current literature for rabbit carcasses (rabbit body dressing out of leather/skin, head, tail, foot, and entrails). Despite similar results, several factors significantly affect carcass yield, including genetic, nutritional and production systems (Dalle Zotte & Szendrő, 2011; Loponte et al., 2018; Metzger et al., 2011). The proportions of middle and hind joints (expressed as % CCW) were higher in carcasses; thus, a high proportion of hind parts might result in more profitable carcass utilization, considering commercial cuts. Nevertheless, an increased mass of rabbit middle parts mainly comprising the thoracic cage and flanks with lower added value (39.83% of carcass), might impact this economic evaluation.

Table 1. Descriptive statistic for dressing and carcass traits of the rabbits (n = 20) at the end of the trial (84 d of age).

Characteristics	Mean	Std.Dev.	CV (%)	SEM	Minimum	Maximum
Chilled carcass (CC), %LW	52.46	1.70	3.24	0.38	49.59	54.91
Retail cuts, %CC						
Hind leg (HL)	33.88	0.98	2.89	0.22	32.65	36.53
HL meat	25.28	1.60	6.33	0.36	23.11	30.40
HL bone	8.59	1.61	18.68	0.36	2.43	10.07
Foreleg (FL)	15.51	1.23	7.92	0.27	13.45	18.38
FL meat	12.05	1.10	9.16	0.25	10.08	14.17
FL bone	3.46	0.32	9.39	0.07	2.96	4.22
Loin muscle	11.63	0.96	7.05	0.21	11.96	15.57
Back	39.83	5.10	12.80	1.14	31.01	45.05
Back meat	12.95	1.61	12.46	0.36	9.92	15.84
Back bone	26.88	4.13	15.36	0.92	19.40	31.74
Total meat, %CC	61.92	3.39	5.31	0.76	58.58	70.82
Total bone, %CC	38.93	4.20	10.78	0.94	30.55	45.27

Std.Dev. = standard deviation; CV = coefficient of variation; SEM = standard error of mean; and LW = live weight. Source: The authors.

The total meat-to-bone ratio in the experimental group was lower (1.65) than that reported (5-6) by Cullere and Dalle Zotte (2018), but this relationships is related by these authors to the specific carcass parts such as hind legs and forelegs and not the entire carcass. As expected, the meat-to-bone ratios of the retail cuts were lower for the back (0.48) than hind legs (2.94) and forelegs (3.48), demonstrates the difficulty in obtaining and using the meat from that cut. Overall, as stated by North, Nkhabutlane, and Hoffman (2017), variables including age at slaughter and different crossbreeds significantly affect carcass traits, commercial meat portion yields, and proximate composition.

3.2 Rabbit meat characteristics

Table 2 shows the proximate composition and technological characteristics of color, heme-pigments, WHC and pH in rabbit meat.

Table 2. Proximate composition and technological characteristics of the rabbit ground meats.

Characteristics	**Mean ± standard deviation**
Proximate composition	
Moisture (%)	72.01±1.38
Protein (%)	22.20±0.74
Fat, ether extract (%)	5.16±0.49
Ash (%)	1.40±0.15
pH value	5.56±0.09
Water holding capacity	0.28±0.07
Total collagen contente (mg/g)	6.47±2.55
Heme pigment content (µg acid hematin/g)	19.89±2.08
CIE Color	
Lightness (*L**)	65.93±2.76
Redness (*a**)	11.59±0.59
Yelloness (*b**)	15.22±1.46
Chroma (*C**)	19.24±0.93
Hue angle (*h*, degrees)	52.79±3.68

Source: The authors.

In general, the average values of moisture, fat and ash obtained for rabbit meat were similar to those reported in the literature (Cullere & Dalle Zotte, 2018; Hernández, Pla, & Blasco, 1998; Loponte et al., 2018). In general, it reinforces the high protein content (22.2%) of this meat like other commercial meats with similar fat content such as beef sirloin (24.0% protein and 6.0% fat), pork loin (24.0% protein and 6.0% fat) and poultry (20.6% protein and 4.6% fat) described in the Brazilian Food Composition Table (TACO, 2011). According to Bueno (2018), this relatively high-fat content observed for the rabbit meat is mainly due to the back meat (9.0%), with the hind leg (3.66%) and loin (2.75%) meats showing much less fat.

The average pH value is within the observed range (5.47 to 5.69) for rabbit meat (Bueno, 2018; Cruz et al., 2020), being slightly below that observed in other species (5.6 to 5.8) such as poultry, pork and beef, when not resulting from any meat anomaly (Ramos & Gomide, 2017). The pH value is directly associated with other quality characteristics, such as color, water holding capacity (WHC) and meat texture (Hughes, Oiseth, Purslow, & Warner, 2014), which are also important for meat processing. Despite the small differences in the pH values, the rabbit meat WHC was within the range (0.25 to 0.30) observed for sirloin beefs (Aroeira et al., 2020) evaluated by the same technique (filter paper press method). The WHC is an important process quality parameter, as it can result in technological and economic losses. Meats with a high WHC indicate intact and more soluble proteins, which means greater technological functionality such as protein binding and fat emulsifying capacities (Ramos & Gomide, 2017).

The total collagen and heme pigment contents are also very important for meat processing. A good selection of meat raw material is essential to produce uniform products and is indispensable for efficient meat processing. Thus, in addition to the total protein content, one must know the constituent protein fractions, due to their role in the protein gel matrix formation, responsible for the texture, and color of meat products (Ramos, Ramos, Bressan, & Fontes, 2014). The rabbit meat total collagen content was close to that observed by Bueno (2018) for pork shank (8.07 mg/g). Collagen is the main protein in the connective tissue, having low binding and emulsifying capacity (Ramos & Gomide, 2017). In the restructured and emulsified products processing, there is evidence that low amounts of collagen in the meat batter favors the stabilization of fat globules, the ability to retain water, and the texture of the meat products (Ramos et al., 2014). Finally, the color formation capacity is attributed to the content of sarcoplasmic proteins, notably to the content of heme pigments myoglobin, and hemoglobin (Ramos & Gomide, 2017). The heme pigment content found for rabbit meat was lower than that reported for pork shank (97.36 µg acid hematin/g) by Bueno (2018). However, Lombardi-Boccia, Martinez-Dominguez, and Aguzzi (2002) reported that the heme-iron content in rabbit meat (0.25 mg/100g) was similar to pork and chicken, being about 85% less than the values observed in beef and lamb meats. Both collagen and pigment contents may vary in meat according to several factors, from species, physical activity, age, diet, muscle location, among others (Ramos & Gomide, 2017).

The low content of heme pigments found for rabbit meat is consistent with the observed CIE color parameters. Rabbit meat has a light color (high L^* values) and a low shade of red (high h value), more similar to that observed for poultry (L^* ~ 62.1 and h ~ 74.4°) meat than for pork lean (L^* ~ 42.7 and h ~ 24.3°) meat used in the elaboration process of meat products (Dufossé, Fernández-López, Galaup, & Pérez-Álvarez, 2015). In addition, regarding visual perception, Cavani, Petracci, Trocino, and Xiccato (2009) analyzed the main strengths and weaknesses of the productive chains of poultry and rabbits, and concluded that there was greater variability in the appearance and in technological and sensorial characteristics in poultry than in rabbit meat.

3.3 MDRM characteristics

To optimize the yield and value of carcass utilization, the less noble parts (namely the thoracic cage and flanks) can be used for the deboning and the technological processing of mechanically deboned rabbit meat (MDRM), which would allow the diversification of rabbit meats and processed meat products. Table 3 shows the MDRM characterization together with data obtained from mechanically deboned poultry meat (MDPM) for further comparisons.

Table 3. Characteristics (mean ± standard deviation) of mechanically deboned meats from rabbit (MDRM) and poultry (MDPM) and requirements under Brazilian law[1].

Characteristics	MDRM	MDPM	Limits[1]
Moisture (%)	69.37 ± 0.50	63.37±0.07	-
Protein (%)	19.08 ± 0.50	12.66±0.19	12 (Min.)
Fat, ether extract (%)	9.44 ± 0.33	17.97±0.10	30 (Max.)
Ash (%)	2.10± 0.33	6.88±0.18	-
Calcium (% dry matter basis)	1.47±0.39	0.81±0.41	1.5 (Max.)
pH	6.56 ± 0.02	7.01±0.07	-
Heme pigment (µg acid hematin/g)	35.36 ± 3.84	147.90±15.86	-
CIE Color			
Lightness (*L**)	56.78 ± 1.10	56.64±0.07	-
Redness (*a**)	14.73 ± 0.12	22.03±0.65	-
Yelloness (*b**)	18.84 ± 0.57	20.74±0.25	-
Chroma (*C**)	23.91 ± 0.53	30.26±0.65	-
Hue angle (*h*, degrees)	51.98 ± 0.63	43.27±0.50	-

[1]According to Brazilian legislation (Brasil, 2000) for mechanically deboned meats from beef, pork, or poultry. Min. = minimum; and Max. = maximum. Source: The authors.

The MDRM fit the Brazilian regulation requirements for protein, fat and calcium contents (Brasil, 2000). Due to the mechanical deboning of poultry backs and necks, MDRM comprised more protein and calcium, and less fat than MDPM. The MDM composition extensively varies according to factors such as the equipment setup and target processing yield, anatomical body parts and raw material (back, front, neck) used during mechanical extraction, raw material pre-processing as dripping-carcasses and neck skin abstraction (Froning, 1981). The pH of MDM was higher than that of raw meat due to the incorporation of marrow and calcium phosphate from bones during mechanical deboning (Pereira et al., 2011). This process also incorporates unsaturated fat and hemoglobin from the spinal cord, which explains the higher content of fat and heme pigments in MDRM than in rabbit raw meats manually deboned (Table 2).

With respect to the technological processing utilization potential of MDRM, some issues need to be highlighted. The calcium content was 1.45% (dry basis). Meat contains very little calcium, but it is incorporated into MDM due to grinding bones during extraction (Pereira et al., 2011). Thus, the calcium content is an important parameter that should be legislated to determine the maximum amount of MDM that can be added to a prepared meat product. In addition, a limited calcium content in MDM allows control of the yield obtained by mechanical separation processes, since more pressure created by deboning implies not only higher yield, but also a higher content of bone particulates and calcium (Froning, Cunningham, Suderman, & Sackett, 1981; McNitt, Negatu, & McMillin, 2003). Technological issues should also be highlighted. Poor color characterization (darker and less red than rabbit raw meat; Table 2) was described for MDRM that had a lower heme-pigment content accompanied by reduced color intensity (higher C^* values) and a decreased red tone (higher h values) than MDPM. Overall, MDM are vulnerable to oxidation and spoilage, and its addition to meat products might negatively affect the sensory properties mainly of color, flavor, and texture (Pereira et al., 2011). Therefore, besides the great potential for use as meat ingredient, these issues must be assessed before MDRM could be used in rabbit meat products.

4. Conclusions

The nutritional and quality characteristics of rabbit meat are similar to that of other animal species commonly traded, which qualifies this meat as an unconventional, but viable and sustainable alternative, able to be explored in Brazilian marketing. In addition, its technological characteristics are highly suitable for processing, allowing them to obtain industrialized products with greater added value.

It was also found that mechanically deboned rabbit meat (MDRM) is a viable and profitable alternative for greater use of the carcass, allowing the diversification of products made from rabbit meat and, or, use as an ingredient in conventional meat products. This would allow not only to meet the demands of current consumers for healthier and more conventional products but also to strengthen and develop the rabbit production chain.

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