



Physicochemical characterization of by-products from beef cattle slaughter and economic feasibility of commercialization

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ABSTRACT. The aim was to evaluate the proximate food composition, cholesterol content, coloring and economic aspects of the main nutrients present in by-products from the slaughter of cattle. The samples were collected from 14 organs, with four repetitions each, of which we conducted the analyses of moisture, crude protein, mineral matter, cholesterol and fat content. The color was measured through the coordinates L*, a*, b*. The differences between the groups of red and white viscera were evaluated by contrasts analysis. Subsequently, the data were subjected to multivariate analysis of variance, which was complemented by the principal component technique. In the analysis of contrast between red and white viscera, the results showed that the components with the highest content of total fat does not necessarily have the highest content of cholesterol and vice-versa. For minerals, the red viscera presented higher content than white viscera and, in order to analyze the protein composition, there was less variability for red viscera in relation to white viscera. In the color analysis, the values for the color readings indicated uniformity between the external and internal readings, except for the tongue. On mean, the proximate composition values for the offals are similar to the values for beef, especially regarding the red viscera.

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Introduction

Brazil generates a large quantity of non-carcass products from the expressive slaughterings of cattle, which are carried out to meet the demands of the internal and external beef market. Lynch, Mullen, O'Neill, Drummond, and Álvarez (2018) estimates that in the next few years, there will be an increase in the production of meat products, accompanying the increased demand for animal protein. The frigorifics seek in the non-carcass components important products for the final value composition of the slaughter activity, commercializing these products for *in natura* consumption, or for the manufacture of processed products intended for human consumption or animal feed.

There is a wide variety of applications of meat by-products. The skin, for instance, can be used for leather, and recent innovative proposals include the use of meat by-products as a source of animal protein. Besides the most common use as food for humans and animals, the use of fat for cosmetic and chemical purposes promoted an improvement of technological or nutritional properties, besides the generation of bioactive peptides, antimicrobial agents and biodiesel production (Toldrá, Aristoy, Mora, & Reig, 2012).

The by-products of meat are highly nutritious, being an excellent source of protein, vitamins and minerals (Lynch et al., 2018). Alfaia et al. (2017), based on their studies on the nutritional characteristics, by recommending the consumption of animal meat in small quantities, as a part of a balanced diet.

A study made with goats and sheeps shows that the chemical composition of the by-products varies greatly between the viscera, but some have high nutritional value, comparable to that of meat cuts of carcasses of sheep, goats and cattle, such as protein, which is of high biological value, ranging from 17 to 20% in its raw form (Carmichael et al., 2012; Riley, Savell, Shelton, & Smith, 1989; Sharman et al., 2013).

In the recent years, these products have aroused the interest of researchers, who have emphasized that the non-components of the carcass are an important source of food for society (Silva Sobrinho, Gastaldi, Garcia, & Machado, 2003). The waste of these products generates loss of value for the entire production chain, because they are food or raw materials that are lost and could contribute to an improvement in the living standards of populations, especially those with low animal protein consumption.

Dias et al. (2008) and Brasil et al. (2014) reported that the use of edible viscera in the preparation of regional dishes can be a good and viable economic alternative, because it increases the profitability of production by the aggregated value. To complete, some authors mention the importance of studying the use of animal by-products as a way of reducing the cost of waste management (Toldrá & Reig, 2011), in addition to provide new ingredients and products, aiming to reduce the environmental impact of a growing production of meat (Henchion, McCarthy, & O'Callaghan, 2016).

The aim was to evaluate the approximated composition, cholesterol content, color and economic aspects of the main nutrients present in edible by-products from the slaughter of cattle.

Material and methods

The study was conducted on the premises of the Department of Food Science and Technology at the Universidade Federal de Santa Maria, Rio Grande do Sul, Brazil, between the months of July and November, in 2013.

The collection of meat by-products of cattle occurred in a commercial frigorific, supervised by the Federal Inspection Service, located in the same municipality. The collection of products was performed after the standard procedure for boning and cleaning, which occur simultaneously, right after the evisceration of the slaughtered animals. After being cleaned and washed, these organs remained for 15 minutes in a cooled environment between -1 and +1°C, for outflow of the remaining cleaning water.

After this last procedure, the samples were vacuum-packed, refrigerated in thermal box and carried to the laboratory. To perform the analyses, fourteen non-carcass components items were used: heart, diaphragm, abomasum, lung, thymus, kidney, liver, tongue, rumen, reticulum, omasum, tendon, aorta and rectum. Each component was collected with four replications, totaling 56 samples.

For colorimetric analysis, the samples were removed from their original packaging and exposed to air for 30 minutes, and then, we performed six color readings at different locations in each sample, including the internal part, and excluding regions with accumulation of fat or presence of blood vessels, in order to achieve greater uniformity. Regarding the lungs, liver and thymus, the color measurement was performed only on the outside. This analysis was not done in the tendons, since they are too small for the correct use of the appliance. We used the system tri-stimulus of the Commission Internationale de L'Eclairage CIE with the coordinates L^* , a^* , b^* (CIELAB scale), where L^* represents lightness, a^* redness and b^* yellowness colour. The shafts of color (L^* , a^* , b^*) were determined by colorimetric spectrophotometer Minolta® CR-310 (Konica Minolta Sensing Americas Inc., Ramsey - New Jersey, USA), with illuminant D65 and scan angle of 10°.

Subsequently, the samples were fractionated into three equal parts: the first for cholesterol analysis, the second for fat analysis, and the third for the centesimal composition. First, the samples intended for the centesimal composition were lyophilized to obtain the pre-dried matter (PDM), and then milled in a mill (model 630/1, Marconi, Brazil) set at 20°C until the obtainment of homogeneous particle of reduced size. From the lyophilized samples, we conducted the analyses of moisture (967.03), crude protein (2001.11) and mineral matter (942.05), by the protocols of the Association Official Analytical Chemist (AOAC, 2005). The analysis of cholesterol was performed according to the technique described by Saldanha, Mazalli, and Bragagnolo (2004), and the quantification of fat was in accordance with the procedures suggested by Hara and Radin (1978).

The data were subjected to univariate analysis of variance (ANOVA) by the GLM procedure. The averages were adjusted by the method of least ordinaries squares as LSMEANS statement and compared by the Tukey test at 5% significance level. The difference between red and white viscera groups were evaluated from the orthogonal contrasts analysis.

Subsequently, the data were subjected to multivariate analysis of variance (MANOVA) complemented by the technique of principal components using the GLM procedure, PRINQUAL, PRINCOMP AND FACTOR. The graphics were developed according to Lipkovich and Smith (2002).

The statistical analyzes were performed in SAS®, Version 9.4 Statistical Analysis System (SAS Institute Inc., Cary, NC, USA), set at 5% level of significance.

Results and discussion

The by-products analyzed were classified into two groups: red viscera and white viscera (Table 1), following the classification of Mullen and Álvarez (2016). The red viscera comprise parts that are directly edible, and some are considered delicacies in certain parts of the world. The white viscera refer to parts that are edible, but require additional processing, such as the stomach and intestines (Mullen & Álvarez, 2016).

The centesimal composition (Table 1) showed that the rectum has the lowest moisture content, while the abomasum has greater value for this fraction among all the analyzed components. In the abomasum, a high correlation between protein and moisture was not observed, since, visually, this organ has less muscular appearance and higher moisture content when compared to rumen, reticulum and omasum. The absorption of a good part of the water of the feed bolus occurs in the omasum, however, in the abomasum there is the release of gastric juices that act effectively in the digestion of food, and for the transport of this fraction to the intestine, the rehydration of bolus occurs in this organ. This process explains the high humidity of its walls, without, however, high protein content. These data, which differ from the analysis of meat cuts, show the need of studying these foods in a differentiated way, since they present peculiar nutritional characteristics.

The low moisture seen in the rectum (Table 1) is probably related to the high lipid content of this component, which was only lower than the lipid content of tongue and comparable to the fat of the kidneys. Thus, we can infer that some viscera reach the consumers with lower moisture content, which may be a result of its chemical structure or even the outcome of the industrial processing, which includes complimentary washing, cutting and storage.

The mean level of moisture found for red viscera was approximately 75%, of its weight in water (ranging from 65 to 80%). It is important to emphasize the low content of lipids in the heart composition (Table 1). If the restricted consumption of non-carcass components is related to the concern about their lipid content, as occurs with the heart of broilers and birds in general, the consumption of heart as a lean product can be recommended.

Nonetheless, regarding the nutritional recommendations, it is observed that within the white viscera, with the exception of reticulum and rectum, the fat is not a representative factor. This may explain the preference of eastern countries by the consumption of these organs. It is worth mentioning that the countries with hot climate in Africa are also buyers of white viscera, especially those with lower commercial value.

Table 1 shows that the organs with the highest percentage of total fat does not necessarily have the highest content of cholesterol and vice-versa; This fact was already expected, since these two items are not correlated, thus highlighting the need for further research to perform the lipid classification of the fat from these organs.

Table 1. Composition of the by-products from cattle slaughtering, expressed on an as-received basis

Viscera	Moisture, %	Minerals, %	Protein, %	Lipids, %	Cholesterol, mg/100 g
Red					
Lung	79.8 ^{ab1}	1.05 ^{bcde}	17.3 ^{ed}	1.82 ^e	603.9 ^{bc}
Heart	76.3 ^{ab}	1.56 ^{abcd}	19.9 ^{ed}	2.18 ^{de}	170.1 ^e
Kidneys	74.4 ^b	1.81 ^{ab}	17.7 ^{ed}	6.09 ^{bc}	502.3 ^{bcd}
Liver	74.7 ^b	1.71 ^{abc}	19.5 ^{ed}	4.05 ^{cd}	335.7 ^{cde}
Tongue	71.5 ^b	0.92 ^{de}	17.3 ^{ed}	10.30 ^a	728.6 ^{ab}
Diaphragm	74.6 ^b	1.00 ^{cde}	19.0 ^{ed}	5.39 ^e	101.6 ^e
Mean	75.21	1.34	18.45	4.97	407.03
White					
Timo	77.6 ^{ab}	2.07 ^a	17.8 ^{ed}	2.58 ^{de}	-
Aorta	62.0 ^c	0.90 ^{de}	36.5 ^b	0.57 ^e	186.8 ^e
Rumen	75.8 ^{ab}	0.48 ^e	22.0 ^{cd}	1.74 ^e	824.0 ^a
Reticulum	74.6 ^b	0.46 ^e	20.8 ^{cd}	4.02 ^{cd}	244.6 ^{de}
Omasum	74.1 ^b	0.42 ^e	24.6 ^{cd}	0.84 ^e	267.7 ^{de}
Abomasum	84.5 ^a	0.90 ^{de}	11.9 ^e	2.61 ^{de}	301.6 ^{de}
Rectum	45.4 ^d	1.26 ^{bcd}	45.3 ^a	8.00 ^b	224.2 ^{de}
Tendons	70.8 ^{bc}	0.45 ^e	28.8 ^{bc}	-	-
Mean	70.60	0.86	25.96	2.54	341.48
Overall mean	72.59	1.07	22.75	3.86	389.1
Red vs. White ²	0.0001	0.0001	0.0001	0.0001	0.0001
CV ³ , %	5.13	28.57	14.90	21.74	30.90
SEM ⁴	1.28	0.07	1.20	0.40	40.80

¹Means followed by different letters in the same column differ by Tukey test ($p < 0.05$). ²Contrast of white viscera versus red. ³Coefficient of variation. ⁴Standard error of the mean.

It is noteworthy that the values of lipids and cholesterol of the tendons were not reported because the analytical methodology used in this study was inappropriate to evaluate this particular item, due to the difficulty to solubilize/digest tendons. Other techniques, used for meat and its derivatives, have been applied; however, the results are also unsatisfactory. Thus, there is a need to develop a specific protocol for this type of substrate. On the other hand, perhaps the inconsistency in the analytical results obtained is associated with the absence or scarcity of lipids and cholesterol in the tendons, since this viscera is basically composed of fibrous proteins.

In relation to the minerals, the red viscera showed a higher content when compared to the white viscera (Table 1), possibly due to the higher content of heme proteins, whose heme group gives the red color to the organs.

There is less variability in the protein composition of red viscera in relation to the white. Florek, Litwińczuk, Skąłeczki, Kędzierska-Matysek, and Grodzicki (2012), in their study on the chemical composition and inherent properties of offal from calves, verified that the animal by-products are abundant sources of proteins, comparable to proteins of muscle tissue. The same authors concluded that the chemical composition, mineral concentration, percentage of fatty acids and inherent properties of viscera of calves are significantly affected by the type of organ.

Table 2. Means values of color from the coordinates L*, a*, b* for products of cattle slaughtering

Viscera	Inner Portion			External portion		
	L*	a*	b*	L*	a*	b*
Red						
Lung	--	--	--	55.24	26.59	11.58
Heart	39.47	16.95	8.35	40.14	16.58	7.98
Kidneys	41.74	15.46	9.76	31.44	17.65	8.80
Liver	--	--	--	32.77	9.13	8.25
Tongue	53.09	16.00	11.63	62.10	6.07	9.87
Diaphragm ¹	36.76	16.44	5.82	37.23	13.65	5.12
Mean	28.51	10.80	5.92	43.15	14.95	8.60
White						
Timo	--	--	--	57.52	20.84	12.46
Aorta	76.57	1.60	23.74	76.55	1.69	22.08
Rumen	63.16	8.14	16.44	64.77	6.85	16.25
Reticulum	64.01	3.42	21.25	63.86	3.46	20.68
Omasum	65.03	3.82	20.50	66.11	3.59	19.60
Abomasum	56.92	14.94	10.46	58.19	14.19	10.74
Rectum	79.38	-1.11	21.29	79.11	-0.92	21.30
Mean	50.63	3.85	14.21	58.26	6.21	15.38

¹The inner and outer portions correspond to left and right, respectively.

The first impression of a consumer in relation to a raw material or food product is determined visually, and among the properties observed are the characteristics of color, shape and surface (Nollet & Toldra, 2011). According to Nollet and Toldrá (2011), the appearance of colors, contrast and differences between the animal edible by-products and muscle-based foods may have a profound effect on consumer's mood and feelings, directly affecting their consumption preferences.

According to Pérez-Alvarez et al. (2000), the color is one of the main aspects that define the quality of the food, and the product can be rejected by the simple fact of its color, even when other aspects such as aroma, softness and palatability are evaluated.

Table 2 shows the values for the color readings of the studied organs, which were classified between red and white viscera, in accordance with the portion. These readings, which can be internal or external, indicated that the samples presented certain uniformity of values between the external and internal readings, with exception of tongue, which presented a variation of approximately 9 points for brightness, 10 points for paleness and 2 points for redness. This factor is probably associated with the high content of fat in the internal region of the tongue, where there is a higher incidence of fat molecules, differently from the external or glandular region. Toldrá, Mora, and Reig (2016) comment that some of the by-products are composed of lean tissue and fat; thus, the majority of the considerations related to the color of the muscle can be applied to the tissues of the animal by-products.

Table 3 shows the economic analysis of the products under study, drawing a comparison among the value and performance of a carcass, and two cuts sold in larger quantity in the state of Rio Grande do Sul, in order

to reach a better interpretation of the real difference in values between the kilo of crude protein and fat in by-products, and in the beef.

Table 3. Yield and price formation per kilo of protein and fat of the non-carcass components, with the comparative values of carcass and commercial cuts.

Byproduct	% ^{1*}	kg ²	US\$ kg ⁻¹ PB ³	US\$ kg ⁻¹ G ⁴
Heart	0.61	1.38	0.87	41.48
Diaphragm	0.56	1.26	2.49	46.26
Abomasum	0.40	0.90	0.43	16.44
Lung	0.45	1.00	0.43	23.58
Timo	0.03	0.06	2.12	82.34
Kidneys	0.31	0.71	0.77	12.69
Liver	1.44	3.25	1.52	37.52
Tongue	0.52	1.18	2.63	25.54
Rumen	1.63	3.67	2.28	130.97
Reticulum	0.14	0.32	2.81	69.93
Omasum	0.43	0.96	2.52	300.43
Tendons	0.26	0.59	2.42	-
Aorta	0.06	0.14	2.69	471.35
Rectum	0.03	0.06	2.20	27.52
Total	6.87	15.48	26.19	1,286.07
Carcass**	100	206	14.22	13.77
Rump tail**	0.90	2.07	27.47	91.56
Topside**	6.550	14.76	22.53	150.21

¹Percentage in relation to the cold carcass, ²Cutting weight in relation to a carcass of 225.4 kg, ³Revenue obtained per kilogram of crude protein in natural matter, ⁴Revenue obtained per kilogram of fat in natural matter.

In the Table 3, we can observe the numbers calculated for the obtainment of unique values for each kilogram of protein and fat in the analyzed components. It is noted that the prices charged per kg of fat are much higher than those paid for protein. Adding this to the higher percentage of protein in the cuts, it can be concluded that the amount paid by the consumer is more expensive, if based on the fat value of the cut. In relation to the protein, which is the main nutritional component of these by-products, the values are relatively low, ranging around 56% of the amount paid in fat in the tongue, and 33% in the kidneys and aorta, which contains 36.5% protein and only 1.62% of the value paid by fat.

In a simple analysis, looking at the aorta, you get \$ 471.35 per kilogram of fat versus just \$ 2.69 per kilogram of protein. This may be an important factor, and if disclosed by companies, it could be a way to encourage the consumption of such by-products.

In a world in which the benefits and risks of fat consumption is discussed, these analyses may serve for the consumers to note that when you purchase a product that has a protein value equal to or greater than meat, and lower percentage of fat, they are acquiring a product of excellent quality at a more accessible value than the meat.

In accordance with Toldrá et al. (2012), the use and the value of meat by-products dependss entirely on the culture and on the country, in which these cuts may be considered delicacies of high value or waste to be thrown out. However, because of their low or neutral market value, many edible by-products are redirected for purposes other than human consumption (Ockerman & Basu, 2014).

The principal components analysis (PCA) was performed to reduce the dimensionality of the sample and to understand the relationship between the studied variables (Figure 1). The evaluated components were grouped into four major groups, according to the quadrant to which they are (Figure 1). Rumen, omasum and aorta in the first (Group 1), abomasum, lung and reticulum in the second (Group 2), heart, stomach, liver, kidneys, thymus and tongue in the third (Group 3), and the rectum in the fourth quadrant (Group 4). The variables that explain the variability in the x-axis (principal component 1) were moisture, proteins, L, a, b and reais per kilogram of fat, whereas the variables that explain the variability in the y-axis (principal component 2) were ashes and lipids. Therefore, it is observed that the by-products of the Group 1 (rumen, omasum and aorta) showed higher values of luminosity (L*), pallor (b*) and US\$ kg⁻¹ of fat, and had lower levels of lipids and ash. The by-products of Group 2 (abomasum, lung and reticulum) showed higher values of moisture and redness (a*), and lower values of protein. Heart, stomach, liver, kidneys, thymus and tongue in the third (Group 3), showed higher values of ash and lipids, and smaller values of luminosity (L*), pallor (b*) and US\$ kg⁻¹ of fat. The rectum (group 4) showed higher content of protein, lower moisture and redness

(a*), especially among the white viscera studied. Information regarding the composition and marketing values are of extreme importance for the frigorific industry in general, regardless if they trade or not the by-products from cattle slaughtering. In addition, the best use of these by-products allows the meat industry to be more sustainable (Lynch et al., 2018).

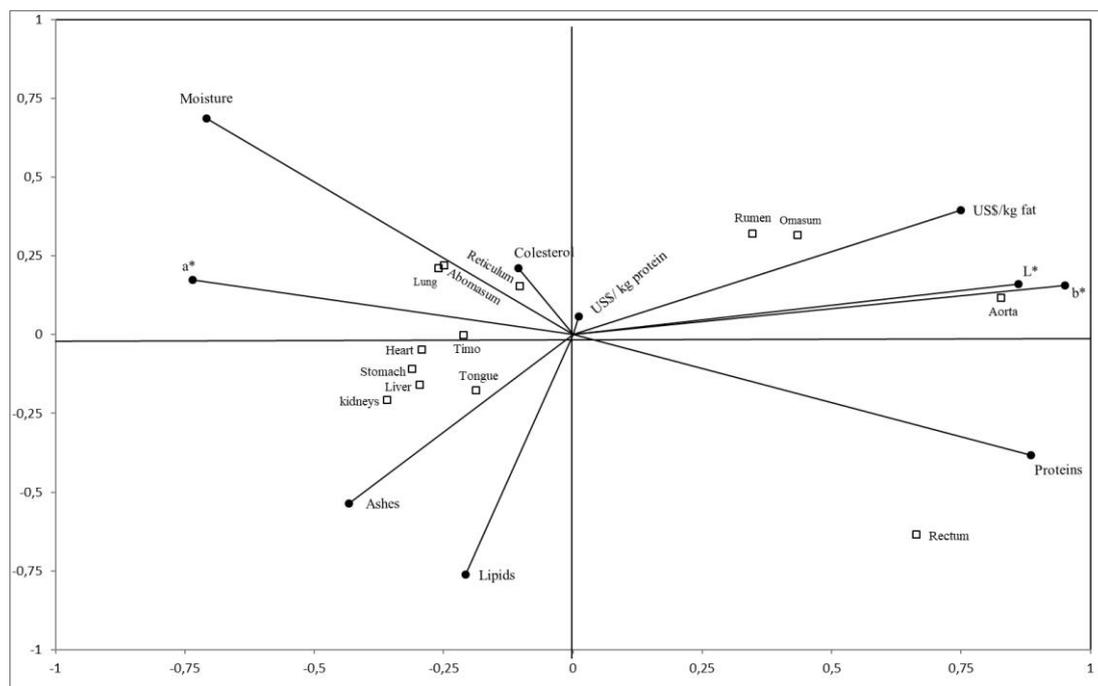


Figure 1. Biplot of by-products of the cattle slaughtering by principal component analysis from their physicochemical and economic characteristics.

Research efforts are going ahead to improve existing processes, as well as to produce new substances with new applications. The innovation is continuously directed to add value and find new applications for the by-products of meat (Toldrá, Mora & Reig, 2016). The efficient use of the animal by-products and low value cuts is important for the sustainability of the meat industry as a whole (Lynch et al., 2018).

Conclusion

On mean, the values of proximate composition for the offals are similar to the values of the proximate composition for beef, especially regarding the red ones. Many types of offal can be recommended for consumption as lean products, due to the low lipid content. However, some presented high cholesterol levels, which suggests that more research should be undertaken on the nutritional quality of these products.

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