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Full Length Research Paper

## Evaluation of the physicochemical properties of Northern Ghana *Sclerocarya birrea* seed oil and proximate analysis of the process waste

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Physicochemical properties and proximate composition of *Sclerocarya birrea* was studied by n-hexane extraction of its oil. The oil contents of raw and roasted kernel were determined to be 46.4 and 44.1% respectively, and their specific gravity to be 0.88 and 0.91 with acid values of 4.20 and 2.52, respectively. Saponification values were also calculated to be 12.48 and 11.36 in raw and roasted kernel respectively. Regarding the proximate compositions of the raw seed powder and its residue, moisture contents of 4.17 and 4.00%, respectively, were calculated. Respective fibre, fat, and carbohydrate contents were also determined. Of interest were the high lipid contents of 57.25 and 26.50%, respectively. This suggests that the oil from marula seeds can be extracted commercially. Also, the high protein content indicates that both the raw powder and its residue can contribute to the nutritional needs of the local population.

**Key words:** *Sclerocarya birrea*, physicochemical properties, proximate analysis, nutrient, oil.

### INTRODUCTION

The *Sclerocarya birrea* tree, known as marula tree, is indigenous to most parts of the Northern regions of Ghana and often referred to as the “tree of life” due to its ability to provide two fundamental human needs; that is, food and medicine. The marula tree is taxonomically derived from the Anacardiaceae plant family to which belong the mango, cashew and pistachio nut, and it is an indigenous, fruit-bearing tree of sub-Saharan Africa at low altitudes and can reach up to 20 m in height and

1.2 m in diameter (Russo et al., 2013).

The marula tree has gained attention in numerous chemical, biological and environmental investigations since 1906 and has been identified as one of five fruit tree species that should be integrated in the domestication process in African farming system (Russo et al., 2013), for its usage as source of food and medicine and its potential to increase income in rural communities. The barks, leaves and roots of *S. birrea*

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Figure 1. *Sclerocarya birrea* fruit.



Figure 2. Raw powdered seed kernel.

have been traditionally used to treat some human ailments such as dysentery, fevers, malaria, diarrhea, stomach problems, rheumatism, sore eyes, infertility, headaches, toothache and body pains. Extractions from parts of this plant have been reported to possess antioxidant, antibacterial, antifungal, astringent, anticonvulsant, antihyperglycaemic, anti-inflammatory and antiatherogenic properties (Russo et al., 2013). Several of these properties could be attributed to the high content of polyphenols and its antioxidant activity. Unsaturated lipids in foods generally results in deterioration in flavour, colour as well as lower nutritional value. The antioxidant properties of the extractions from marula tree can be used in a case like this to control oxidation of the unsaturated lipids in foods.

Marula oil has a clear, pale, yellowish-brown colour and a pleasant nutty aroma. The oil is classified as medium rich and is silky to the touch with an excellent slip factor making it ideal as massage oil. Like many other fixed oils (e.g. baobab seed oil; olive oil), marula oil is rich in monounsaturated fatty acids which makes the oil very stable (Hore, 2004; Mariod et al., 2004; Zimba et al., 2005; Kleiman et al., 2008). The oxidative stability of marula oil is much higher (induction period of 34.2 h) when compared to other fixed oils such as olive oil (4.6 h), sunflower oil (1.9 h), palmolein oil (8.5) and cottonseed oil (3.1 h) (Glew et al., 2004). Marula oil is

contains saturated fatty acids palmitic (9.0 - 12.0%) and stearic (5.0 - 8.0%) and unsaturated fatty, such as oleic acid (70.0 - 78.0%),  $\alpha$  linoleic (0.1 - 0.7%) and arachidonic acid (0.3 - 0.7%) (Glew et al., 2004). The oil is particularly rich in oleic acid and can be considered an excellent source of natural oleic acid. A study conducted by Ogbobe (1992) revealed that the oil was rich in stearic and palmitic acids (50.8 and 22.6%) respectively. Mariod et al. (2004) investigated the composition of selected Sudanese oils and found that the marula oil contains tocopherols, sterols, procyanidine and gallotannin in addition to saturated and unsaturated fatty acids. Marula oil is similar to olive oil in terms of the high content of oleic acid. Therefore it can be used as starting material for the production of pomade equivalents that can be used in the food and cosmetic industries (Zimba et al., 2005).

It is a worldwide trend to explore wild oil plants to augment the existing sources of oil. The evaluation of marula nut oil as a potential oil source had to be included (Gandure et al., 2013). The marula nut oil is used as a base oil for soap and as nose- drops for infants (Zimba et al., 2005). In some rural areas, it is also used to treat leather and preserve meat, due to its high moisturizing capacity (Mariod et al., 2004). Moreover, it was found that the seed kernel of marula had high nutritional value which could serve as supplement to diet when mixed with vegetable or meat (Shone, 1979). The utilization of marula fruits can help to improve the economic growth of individuals and people living around where it is grown for the oil is listed as a possible ingredient in cosmetic and personal care application (Hein et al., 2009).

However, the marula fruits found in the Northern regions of Ghana are not being utilized effectively and most of marula fruits are consumed by livestock and birds.

In the present study, the evaluation of selected physicochemical properties, proximate composition and nutritional value of marula seed oil was performed, which would help to identify its potential uses.

## MATERIALS AND METHODS

### Sample collection and preparation

Ripened fresh fruits (Figure 1) were collected from marula trees grown at "Bonia" village in the Upper East Region of Ghana and around the University for Development Studies, Navrongo Campus which were the study areas. Five trees were randomly selected and the fruits were collected from different branches of the trees. The juice, peels and the seeds were separated by squeezing ripened fruits. The seeds were air dried and the kernel was removed manually using sizable stone, pulverized to fine powder (Figure 2) using pestle and mortar. The powdered kernel was stored in a closed glass container to be used for various analyses. Liquid-liquid extraction method was used to establish actual oil yield levels of the selected wild fruit nuts. The



**Figure 3.** Raw sample of marula oil.



**Figure 4.** Roasted sample of marula oil.



**Figure 5.** Raw seed residue of *S. birrea* kernel.

process involved hard seed cracking of nuts to remove oil seeds, grinding, maceration, filtration and distillation.

#### Oil extraction

Marula fruit oil was extracted from the ground seed kernel using n-hexane in a mass to volume ratio of 1:3. The solvent for the

extraction was evaporated under the influence of direct sunlight after decantation leaving the extracted oil. Figures 3 and 4 show the sample oils obtained from the raw and the roasted kernel. The solid residue of the raw sample left after extraction (Figure 5) was used for proximate analysis and the roasted sample was discarded.

#### Physicochemical properties of the oil

The selected physicochemical properties, that is, specific gravity, pH, refractive index, acid value, peroxide value, saponification value and iodine value of the *S. birrea* seed oil were determined using the methods specified in the Official Methods of Analysis of Association of Official Analytic Chemistry (AOAC) International, 19th Edition. However, colour and odour of the oil were determined using visual observation and sense of smell.

#### Proximate analysis of *S. birrea* raw seed kernel (nuts)

The moisture, ash, fat, fibre, crude protein and carbohydrate contents of the raw seed kernel (cake) after the oil extraction were determined using the methods describe in Official Methods of Analysis of AOAC International, 19th Edition.

#### RESULTS AND DISCUSSION

The physicochemical properties of crude oil extracted from the raw and roasted seed of *S. birrea* were shown in Table 1.

The results indicate that the acid value of the raw sample of *S. birrea* seed oil (4.20) which is an index of free fatty acid content due to enzymatic activity in the samples was found to be higher than the minimum acceptable value of 4.0 for Sesame recommended by the Codex Alimentarius Commission for oil seeds (Abayeh et al., 1998) but low in the roasted sample of *S. birrea* seed oil. The saponification values of raw and roasted sample of *S. birrea* seed oil were found to be (12.48 and 11.36) mg KOH/g respectively, having lower saponification value than the range 188 to 199 mg KOH/g suitable for soap making. According to Ezeagu et al. (1998), a saponification value of 200 mg KOH/g indicates high proportion of fatty acids of low molecular weight. Saponification values of virgin marula oil outside the range mentioned does not have a potential for use in soap making industry. Peroxide value is an index of rancidity, thus the high peroxide value of oil indicates a poor resistance of the oil to peroxidation during storage. The peroxide values of both raw and roasted sample birrea seed oil are below the maximum acceptable value of 10 meq KOH/g set by the Codex Alimentarius Commission for groundnut seed oils (Abayeh et al., 1998). The quantity of crude oil in both raw and roasted sample of *S. birrea* seed oil (46.4 and 44.1%) respectively are comparable to the values reported in seeds of linseed 40%, cotton seed 24% and groundnut 46% (Abdullahi et al., 1991). This indicated that *S. birrea* seed oil is good source of oil. The oils were shown to



**Table 1.** Physicochemical properties of *Sclerocarya birrea* seed oil\*.

Parameter	Raw sample of <i>S. birrea</i> seed oil (Figure 3)	Roasted sample of <i>S. birrea</i> seed oil (Figure 4)
Colour	Light yellow	Brownish
Odour	Nutty aroma	Coconut oil flavor
Oil yield (%)	46.40 ± 0.07	44.10 ± 0.04
Specific gravity	0.88 ± 0.01	0.91 ± 0.01
Refractive index (20°)	1.37 ± 0.01	1.38 ± 0.02
Peroxide value (meq O <sub>2</sub> /kg)	1.30 ± 0.02	1.80 ± 0.03
Iodine value (g I <sub>2</sub> /100 g)	19.56 ± 0.02	23.88 ± 0.01
Acid value (mg KOH/g)	4.20 ± 0.01	2.52 ± 0.02
Free fatty acid	2.11 ± 0.01	1.27 ± 0.02
pH (at 35.2°C)	4.06 ± 0.01	4.47 ± 0.01
Saponification value (mg KOH/g)	12.48 ± 0.02	11.36 ± 0.01

\*The values are average of three replicates.

**Table 2.** Proximate composition of raw seed kernel of *Sclerocarya birrea* fruit (before and after oil extraction).

Parameter	<i>S. birrea</i> raw seed powder	<i>S. birrea</i> raw seed residue (After oil extract)
Moisture content (%)	4.17 ± 0.23	4.00 ± 0.47
Fibre content (%)	2.47 ± 0.02	6.77 ± 0.69
Ash content (%)	4.63 ± 0.08	7.31 ± 0.08
Lipid content (%)	57.25 ± 0.35	26.50 ± 0.24
Protein content (%)	28.36 ± 0.49	53.04 ± 0.38
Carbohydrate content (%)	7.29 ± 0.04	6.38 ± 1.09

have specific gravities of 0.884 (raw sample) and 0.914 (roasted sample) g/cm<sup>3</sup>, which is comparable to the values reported in seeds of *Balanite aegyptiaca* (0.895) and *Lophira lanceolata* (0.8867) (Eromosele and Pascal, 2003). Minzangi et al. (2011) summarized that seed oils containing specific gravity within the range of 0.880 to 0.9400 are more suitable for edible purposes whereas those with values 0.8114 to 1.0714 which include edibles have more potential for biofuels. The specific gravities 0.884 (raw sample) and 0.914 (roasted sample) g/cm<sup>3</sup> of these oils put it within the edible range. The iodine values of the crude oils were 19.56 and 23.88 gI<sub>2</sub>/100 g for raw and roasted samples respectively, which is high, indicating that it is non-dry oil and has an appreciable degree of unsaturation and hence could be liable to oxidative degradation (Dangarembizi et al., 2015). Thus, the oil will attract high interest in the paint and coatings industry (Abayeh et al., 1998). On the other hand, the values obtained are lower than 53.4 to 101.5 reported as iodine values for some selected vegetable oils such as cotton seed, melon seed and shea (Fernando and Akujobi, 1987) and other wild seed oil grown in Bauchi,

Nigeria (Abayeh et al., 1998), but lower than 178.8 reported in palm oil (Oshinowo, 1987). The results of proximate composition of both raw seed powder and raw seed residue are presented in Table 2.

The moisture content of both *S. birrea* raw seed powder and *S. birrea* raw seed residue are relatively low (4.17 and 4.00%) respectively. The value recorded was smaller than 7.50% w/w recorded in *Lophira lanceolata* seed kernel (Ighodalo and Catherine, 1991). Similarly, the moisture content in the raw seed powder and raw seed residue of *S. birrea* was smaller as compared to 5.5% w/w in the seed kernel of *Zizyphus sonorensis* (Marcelino et al., 2005). Higher moisture content is associated with a rise in microbial activities during storage (Hassan and Umar, 2004). Therefore seed kernel with high amount of moisture content should be properly dried before storing. The ash content of both *S. birrea* raw seed powder and *S. birrea* raw seed residue was recorded to be 4.63 and 6.77%, respectively, which is an indication that, the seed contains nutritionally important mineral elements. These ash content values of both raw seed powder and raw seed residue (4.63 and

6.77%) respectively were higher than 2.0% dry weight (DW) in the seed kernel of *Zizyphus sonorensis* (Marcelino et al., 2005) and also the *S. birrea* raw seed residue is a little bit higher than 6.5% dry weight (DW) in the kernel of baobab seed reported by Chadare et al. (2009). Both the raw seed powder and raw seed residue have a crude protein content of 28.36 and 53.04%, respectively. These values of crude protein content were higher than 27.0% dry weight (DW) observed in the kernel of *L. lanceolata* seed (Ighodalo and Catherine, 1991), the value of *S. birrea* raw seed powder was relatively lower than 32.7% dry weight (DW) recorded in the kernel of baobab seed, but higher in the *S. birrea* raw seed residue (Chadare et al., 2009). When compared with 19 g set as recommended daily intakes for children 4 to 8 years (Chadare et al., 2009), the kernel can supply a significant proportion of the daily protein requirements. The crude lipid content of both *S. birrea* raw seed powder and *S. birrea* raw seed residue was 57.25 and 26.50% respectively. The value observed in the raw seed powder is within the range of 53.50 to 60% DW in the raw seed powder of *S. birrea* but higher than 40.0% dry weight (DW) recorded in the raw seed powder of *L. lanceolata* seed (Ighodalo and Catherine, 1991). The value recorded in the raw seed powder was higher than 27.80% dry weight (DW) recorded in the raw seed powder of baobab seed reported by (Chadare et al., 2009), also higher than 44.0% dry weight (DW) observed in the seed of sugar apple (*Annona squamosa*) reported by Hassan et al. (2008). Lipids are the principal sources of energy but should not exceed the daily recommended dose of not more than 30 calories so as to avoid obesity (Hassan et al., 2008).

The crude fibre content of both *S. birrea* kernel and *Sclerocarya birrea* kernel residue were 2.47% and 6.77% respectively. The value were low compared to 21.20% dry weight (DW) in the kernel of baobab seed (Chadare et al., 2009) also lower than 36.33% dry weight (DW) in the seed of sugar apple (*Annona squamosa*) reported by (Hassan et al., 2008). Hassan and Umar (2004) reported that consumption of vegetable fiber can reduce serum cholesterol level; risk of coronary heart disease, hypertension, and it enhances glucose tolerance and increase insulin sensitivity.

Thus, the fruit could be a good source of dietary fiber and could have potential of providing some human body requirements. The available carbohydrate content of both *S. birrea* raw seed powder and *S. birrea* raw seed residue was (7.29% and 6.28%) respectively. The values observed in both raw seed powder and raw seed residue was lower than 17.32% dry weight (DW) and 24.05% dry weight (DW) of *L. lanceolata* respectively (Ighodalo and Catherine, 1991), but high compared to 34.52% dry weight (DW) in baobab seed (Chadare et al., 2009).

The main function of carbohydrate is for energy supply, therefore; the raw seeds could be used to supplement

carbohydrate especially to rural populace.

## Conclusion

The results of the oil content, iodine value, specific gravity determinations and other physicochemical analysis of the oil extracted from the *S. birrea* seed compared favourably with those reported by other researchers. The high percentage oil content of the seeds makes them viable for commercial extraction. The oil was also found to be suitable for human consumption. The results obtained in the study show that *S. birrea* raw seed powder and raw seed residue has a great potential as source of important nutrition. It was found to be rich in fat, protein and carbohydrate which are important in human diet. This is an indication that the fruit can contribute to nutritional needs of the communities where it grows and also as raw materials to support local fruit processing industries.

## Conflict of Interests

The authors have not declared any conflict of interests.

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*Full Length Research Paper*

## Quality indicators of ground beef purchased by bidding in a Brazilian university restaurant

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The objective of the present study was to evaluate the physicochemical characteristics (moisture, lipids, proteins, collagen, collagen-related protein, fixed mineral residue, pH, water activity and color) of bovine ground meat used in a Brazilian university restaurant for over 60 days to ensure the quality of the products purchased. Some of the results were not in line with legislation and literature, suggesting the supplier was probably delivering ground beef composed of different meat cuts. The results returned to the desired values when the supplier was warned about the problem, which reinforces the need of constant supervision from the food service to ensure the reception of high quality raw material.

**Key words:** Ground beef, bidding process, physicochemical quality, community restaurants.

### INTRODUCTION

The Brazilian population has undergone major social transformation in the recent decades, resulting in changes regarding physical spaces for sharing meals and daily practices of food preparation (Brasil, 2008b). Among some facilities where meals are consumed outside home, university restaurants of the Federal Institutions for Higher Education (IFES) have the responsibility of ensuring the right for adequate and safe food for its students and staff (Brasil, 2008a).

Meats stand out among the foods used in the human diet, often representing the main part of most meals (Teichmann, 2000). They are considered one of the foods most valued by consumers for having exceptional

organoleptic characteristics and high nutritional value. Due to its high protein content, the meat has singular importance in the development of the organism and may also serve as an energy source (Sauvant et al., 2004).

The chemical composition of beef differs as result of factors such as species, age, breed and sex of cattle, type of cattle feed and cuts or muscles analyzed. Beef is mostly composed of water (73.1%), proteins (23.2%) and fats (2.8%) and may contain 11-29% of polyunsaturated fatty acids (PUFA). In addition, it is rich in iron and zinc, providing over two thirds and one quarter of the daily requirement, respectively. It is an excellent source of high biological value proteins, vitamin B12, niacin, vitamin B6,

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phosphorus, endogenous antioxidants and other bioactive substances including taurine, carnitine, carnosine, ubiquinone, glutathione and creatine (Williams, 2007).

In food services, the receipt of raw material is important to guarantee the safety of the final product (Silva and Cardoso, 2011; Associação Brasileira de Normas Técnicas, 2008). Therefore, it is imperative to adopt it in order to comply with the good manufacturing practices, particularly concerning the reception area, process control, supplier evaluation and transport system. This goes beyond technical visits and observation of the adequacy of the transportation system used (Associação Brasileira de Normas Técnicas, 2008; Agência Nacional de Vigilância Sanitária, 2004). The procedures still do not include laboratory tests to establish whether the products are suitable for use, which would ensure that only products that are in good nutritional and safety conditions are used in the preparation of foods (Food and Drug Administration– FDA, 2009). The final quality of the beef is the result of what happened to the animal during the entire production chain, reason why appropriate transportation, storage, handling, display and preparation of meat must be ensured (Marin, 2014).

The ground beef is used in various menus for the production of a wide variety of culinary preparations. Due to the good acceptance of these preparations, observed in the practice of community restaurants, coupled with the reasonable cost, ground beef is an ingredient routinely acquired and constantly present on the menu of these establishments. However, the use of ground meat has inconvenience which is the lack of standardization as a consequence of the composition and characteristics of the various sections of animals that originate from it.

Supplier selection and acquisition of food ingredients have low levels of compliance with the current Brazilian legislation (Medeiros et al., 2012). Obtaining raw material from unreliable sources is a risk factor that contributes to outbreaks of foodborne illnesses (Food and Drug Administration, 2009). A special focus should be placed on raw foods of animal origin, which are considered particularly dangerous (Ebene et al., 2011). Fresh beef, when handled under inadequate sanitary conditions, can be a primary source of infection (Almeida et al., 2010). Thus, the quality of meat depends on the adoption of control measures and monitoring of the pre-slaughter period up to the meat consumption. All parties involved in the supply of meat should ensure the quality of the products (Conceição and Gonçalves, 2009).

Public institutions such as hospitals, barracks, prisons, university restaurants, kindergartens and schools often use bidding for acquiring food genres. In this type of purchase, prices should be compatible with the current market and the maximum cost per period should be considered as defined in specific regulation in order to comply with the management of financial resources (Brasil, 1993). A strategic purchase should therefore combine an effective pricing comparison with the

assessment of consistent quality indices according to the standards designated by the establishment (Brasil, 1993). The sanitary quality of products offered by food services is an important issue for the individual and population health because many food poisoning outbreaks occur when food is prepared for large groups (Codex Alimentarius Commission, 1993). In Brazil, restaurants rank second in number of reported foodborne diseases. An epidemiological analysis of 8451 cases of foodborne illnesses reported by the Ministry of Health between 2000 and 2011 revealed that foods of animal origin were the most commonly involved foods (Brasil, 2011).

In addition, the evaluation of quality parameters by the receiver is an indispensable factor in combating fraud, since a product other than stated in the contract can be delivered, which is not always possible to detect sensorially without the aid of appropriate physico-chemical analysis. In the study of Combris et al. (2009) with pears, it was found that flavor can beat food security, that is why the acceptance of a meal prepared with that raw material by the consumer does not indicate by itself integrity. It is necessary to evaluate certain physical and chemical aspects that are indicators of the quality of the raw material, as established by the Normative Instruction no. 83, from 21/11/03, of the Brazilian Ministry of Agriculture, Livestock and Supply (Brasil, 2003). This normative stipulates minimal quality characteristics for meats, a maximum fat percentage of 15% and a maximum addition of 3% water, the only additive permitted.

Therefore, the aim of this study was to evaluate the physical and chemical characteristics of ground beef purchased through bidding by a community restaurant (CR) for students from a federal public university in the city of Curitiba, in Brazil.

## MATERIALS AND METHODS

The ground beef was received fresh and vacuum packed, in temperatures ranging from 0 to 7°C. The samples were separated and packed in disposable plastic bags and stored between 0 and 2°C until the analyses. Only the samples collected for evaluation of collagen and collagen-related protein were kept frozen (approximately -15°C) until the day of analysis. All other assessments were conducted on the reception day. These analyzes were conducted in triplicate right after receipt of the ground beef by the community restaurant, making a total of 24 samples (8 weeks × 3 batches a week) of 1 kg. All the assessments were carried out between August and October of 2010 in the Departments of Chemical Engineering and Nutrition of the Federal University of Paraná, Curitiba, Brazil.

### Proximate analysis

Moisture, crude protein (micro-Kjeldahl), crude fat (Soxhlet), pH, collagen and collagen-related protein (spectrophotometric hydroxyproline), and ash content as well as water activity ( $A_w$ ) (Hygrometer Aqualab, model AT-2, Decagon Devices Inc., USA)

**Table 1.** Physicochemical characteristics of the ground beef received weekly in the community restaurant.

Week	Characteristic (wet basis)					
	Moisture* (%)	Ash* (%)	Fat* (%)	Protein** (%)	pH**	Aw
1	76.38±1.24 <sup>a</sup>	0.47±0.02 <sup>c</sup>	3.10±0.30 <sup>cd</sup>	19.85±1.05 <sup>a</sup>	5.73±0.01 <sup>ab</sup>	0.996±0.001 <sup>b</sup>
2	70.84±0.28 <sup>d</sup>	0.93±0.04 <sup>ab</sup>	8.55±0.77 <sup>a</sup>	20.41±0.44 <sup>a</sup>	6.02±0.01 <sup>a</sup>	0.998±0.002 <sup>ab</sup>
3	72.93±0.37 <sup>c</sup>	0.97±0.03 <sup>ab</sup>	6.28±0.23 <sup>ab</sup>	20.17±0.13 <sup>a</sup>	5.95±0.01 <sup>ab</sup>	0.999±0.001 <sup>a</sup>
4	73.11±0.27 <sup>bc</sup>	0.86±0.08 <sup>b</sup>	5.67±0.29 <sup>abc</sup>	19.63±0.85 <sup>a</sup>	5.95±0.05 <sup>ab</sup>	0.999±0.001 <sup>a</sup>
5	75.47±0.12 <sup>a</sup>	1.05±0.02 <sup>a</sup>	2.72±0.78 <sup>d</sup>	20.39±0.28 <sup>a</sup>	5.79±0.02 <sup>ab</sup>	0.997±0.001 <sup>b</sup>
6	74.98±0.58 <sup>ab</sup>	1.02±0.01 <sup>a</sup>	3.88±0.25 <sup>bcd</sup>	20.30±0.16 <sup>a</sup>	5.62±0.02 <sup>b</sup>	0.998±0.001 <sup>ab</sup>
7	75.15±0.45 <sup>a</sup>	1.01±0.04 <sup>a</sup>	4.01±1.95 <sup>bcd</sup>	19.83±2.69 <sup>a</sup>	5.93±0.18 <sup>ab</sup>	0.999±0.001 <sup>a</sup>
8	75.39±0.61 <sup>a</sup>	1.03±0.04 <sup>a</sup>	2.75±0.60 <sup>d</sup>	20.42±1.17 <sup>a</sup>	5.71±0.01 <sup>b</sup>	0.998±0.001 <sup>ab</sup>
Average	74.28±1.71	0.92±0.18	4.62±1.92	20.13±0.29	5.84±0.13	0.998±0.001

\*Means followed by the same letter in a column are not significantly different according to the Tukey test ( $p < 0.05$ ). \*\*Means followed by the same letter in a column are not significantly different according to the Kruskal-Wallis test ( $p < 0.02$ ). Observation: The only chemical composition specifications for ground beef as stipulated by the Brazilian food legislation (Normative Instruction n. 83, 2003, from the Brazilian Ministry of Agriculture, Livestock and Supply) are the maximum fat percentage (15%) and maximum addition of water (3%).

were determined using the methods of AOAC (1995), as described by Brasil (1999) and IAL (2005).

#### Color parameters

The color of the tested meat samples was measured using a spectrophotometer Hunter Lab Scan XE Plus Mini (Reston, VA, USA) equipped with illuminant D65/10° and suitable for analysis of meat (Hunter lab, 2008), using the CIELAB system ( $L^*$ ,  $a^*$  and  $b^*$ ) (Hunter lab, 2008). The readings were taken within 10 min after exposure to oxygen. All determinations were done in triplicate.

#### Statistical analysis

All measurements were replicated three times. Analysis of variance (ANOVA) was carried out and the average values were compared with the Tukey test, or the Kruskal-Wallis test followed by nonparametric multiple comparisons (Hollander and Wolfe, 1999). Differences were considered statistically significant at  $p < 0.05$ .

## RESULTS AND DISCUSSION

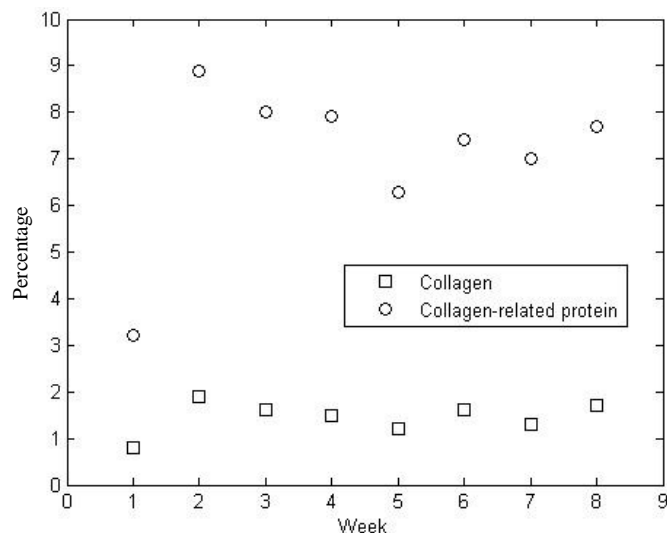
Proximate compositions of the grounded beef samples are presented in Table 1. As indicated, meats showed relatively homogeneous results in all assessments, with the exception of the second week, for which the values of moisture and lipids showed significant differences, as well as the fixed mineral residue for the first week. The moisture content of the samples ranged from 70.84 to 76.38%. The fixed mineral residue content varied significantly in the first and fourth weeks, from 0.47 to 0.86%, respectively. In the other weeks there were no significant variations regarding this analysis, yielding results between 0.93 and 1.05%.

The lipid content, for instance, ranged from 2.72 to 8.55% during the 8 weeks of study. In the 2<sup>nd</sup> and 3<sup>rd</sup> weeks, the contents were 8.55 and 6.28%, respectively,

and in the following weeks there was a clear reduction of these rates, which ranged between 2.72 and 5.67%. The protein content was very homogeneous during all the period of assessment, showing values between 19.63 and 20.42%, with no significant variation.

The pH of the samples varied between 5.62 and 6.02 during the two months of study, showing the higher rate in the second week. The higher percentage of lipids (8.55%) and lower content of moisture (70.84%) that occurred in the same week indicate a probable link between lipids and moisture content. The  $a_w$ , in its turn, only changed significantly in the first week of evaluation, showing a result of 0.996 versus 0.999 for the other weeks.

The percentages of collagen content and collagen-related protein, as shown in Figure 1, showed significant variations between the first week and the others, not only as demonstrated by the graph, but also visually, since the ground beef received in the first week looked exempted of connective or fatty tissues. The collagen content and collagen-related protein in the first week were 0.66 and 3.33%, varying between 1.29 and 1.79, and 6.36 to 8.82%, respectively, during the following periods. These results are evidence that the supplier delivered a better quality product in the first week of the bidding process. Not only the composition of meats is influenced by a number of factors such as age, gender, place of origin and feeding of the animals, but also the collagen content depends on the cleaning phase, when the connective tissue is removed from the meat cuts, which in the case of this study is supposed to be from knuckle (*Quadriceps femoris*). Considering that the meat is already ground when received by the community restaurant, there is no way to ensure the intrinsic characteristics of the meat or the cut used. These values were lower than that recommended in literature in all weeks of testing: 2% of collagen and 15-18% of collagen-related protein



**Figure 1.** Contents of collagen and collagen-related protein.

(Shimokomaki et al., 2006). On the other hand, the excess collagen renders the product less digestible, harder and with reduced nutritional value due to amino acid imbalance and low content of essential amino acids (Ordóñez et al., 2005). In this context, some techniques such as hitting, grinding, chopping, soaking, application of hydrostatic pressure and use of enzymes/softeners are procedures commonly used to tenderize meats (Sun and Holley, 2010; Sullivan and Calkins, 2010; Ha et al., 2012; Lonergan et al., 2010). In addition, the evaluation of collagen-related protein is important for the preparation of meat emulsions from ground beef, inasmuch as this value should not exceed the range of 15 to 18% in order not to harm the mass stability when it comes to systems with high fat content (Shimokomaki et al., 2006).

Variations in the results between different weeks of analysis, as mentioned above, are attributed to the characteristics of the meat delivered by the supplier each week, taking into account that there are many factors that influence the chemical composition and pH of meat products: age, sex, origin and animal feed, cut type, processing (e.g., removal of connective tissues), among others.

Forasmuch as the lipid content of the meat was higher than 5% in the second, third and fourth weeks, the supplier was warned about the fact and informed that should the product should meet the standards of the bidding process (Brasil, 1993) and the technical specification from the nutrition service of the CR. In the following weeks, the value was indeed adjusted to less than 5%, indicating commitment from the butchery in delivering a quality product, most likely due to the warning applied by the CR.

It is worth noting that none of the samples showed lipid content higher than 15%, set as the maximum permitted by the Brazilian law, according to the Technical

Regulation of Identity and Quality of ground beef (Brasil, 2003). Although, lipids have the positive feature of providing juiciness, flavor and aroma for meats, they are easily oxidized and can lead to the formation of toxic and undesirable products (Shimokomaki et al., 2006), therefore should not be present in excess. Flemming et al. (2003) evaluated the fat ground beef sold at a supermarket chain of Curitiba, Brazil, finding a content of 3.43%, that is, less than the average result from the present study, which was 4.62%.

During the 60 days of analysis, the protein levels remained constant, however the fat percentage increased as moisture content decreased. Meats, like most foods, have a pattern of compensation between levels of moisture, lipids and proteins (Shimokomaki et al., 2006). Within the same class of meat products, the protein content is almost constant, whereas for certain fat levels, a reduction of moisture is verified (Shimokomaki et al., 2006). The inverse relationship between moisture, lipids and proteins was also evidenced by Pedrão et al. (2009) when comparing the chemical composition of hump steak (*Rhomboides m.*) and loin (*Longissimus dorsi m.*) of Nellore (*Bos indicus*): 36.70 and 73.34% of moisture, 48.82 and 3.39% of lipids and 12.6 and 21.8% of protein, respectively.

All samples showed pH below 6.1, indicating the absence of early decomposition and meeting the standards of the National Laboratory of Animal Reference (LANARA), which profess meat as proper for consumption when pH ranges from 5.8 to 6.2 (Brasil, 1999). However, there were significant differences between weeks, inasmuch as the pH assumed rates of 5.62 and 5.71 on the sixth and eighth weeks, respectively. Conceição and Gonçalves (2009) found pH values of 6.5 and 7 to ground beef collected in Rio de Janeiro and Niterói, Brazil, which indicate the beginning of bacterial decomposition. The range of  $A_w$  expected for fresh meat is greater than 0.985, which complies with the meat received in the CR, which ranged between 0.996 and 0.999.

The mean values (Table 1) obtained for the chemical composition and pH of bovine ground meat received at the CR can be compared with those found for knuckle beef cut by Della Torre and Beraquet (2005): 74.5, 1.1, 2.8, 21.1, 1.0, 5 and 5.56 for moisture, ash, lipids, proteins, collagen, collagen-related protein and pH value, respectively. The ground meat tested in the current study showed a much higher lipid content, indicating that there may be the possibility that the supplier used another cut of beef, different from knuckle, to obtain the product, such as those with larger content of fats, that is, topside, outside flat and chuck. Table 2 presents the results of color attributes of the ground beef samples during the eight weeks. Significant ( $p < 0.05$ ) differences were observed among meat samples during 8 weeks in lightness ( $L^*$ ) and yellowness ( $b^*$ ). The analysis of variance using ANOVA was performed for all physical

**Table 2.** Color coordinates  $L^*$ ,  $a^*$  and  $b^*$  of the ground beef received weekly in the community restaurant.

Week	$L^*$	$a^*$	$b^*$
1	39.5± 0.42 <sup>ab</sup>	21.11± 2.31 <sup>a</sup>	17.32± 0.94 <sup>ab</sup>
2	40.89± 1.93 <sup>ab</sup>	17.95± 1.68 <sup>a</sup>	15.99± 1.21 <sup>ab</sup>
3	40.58± 0.90 <sup>ab</sup>	17.14± 0.60 <sup>a</sup>	15.58± 0.40 <sup>ab</sup>
4	42.23± 0.69 <sup>a</sup>	18.98± 1.19 <sup>a</sup>	17.47± 0.64 <sup>ab</sup>
5	40.37± 1.62 <sup>ab</sup>	17.26± 0.45 <sup>a</sup>	15.70± 0.66 <sup>ab</sup>
6	41.37± 1.32 <sup>ab</sup>	18.30± 0.20 <sup>a</sup>	15.93± 0.66 <sup>ab</sup>
7	37.91± 1.25 <sup>b</sup>	17.84± 1.16 <sup>a</sup>	15.31± 0.76 <sup>b</sup>
8	42.19± 0.16 <sup>a</sup>	19.49± 0.46 <sup>a</sup>	18.12± 0.26 <sup>a</sup>

Means followed by the same letter in a column are not significantly different according to the Tukey test ( $p < 0.05$ ).

and chemical parameters, however when the assumptions for this analysis were not satisfied, a corresponding non-parametric analysis, the Kruskal-Wallis test, was used and followed by non-parametric multiple comparisons. When the hypothesis  $H_0$  was rejected by the Kruskal-Wallis test, the presence of significant difference was indicated (Hollander and Wolfe, 1999).

The color analysis showed average values of  $L^*$  (lightness) and  $b^*$  (yellow) of 40.63 and 16.43, respectively. Cañeque et al. (2003) suggested that increased brightness may be ascribed to intramuscular fat content. According to Marin (2014), color intensity depends on the quantity of hemoglobin and fat and differs depending on pH and cutting and also on age, sex and activity of the animal. Brightness, in specific, depends on pH and it influences the conformation of proteins within the muscle. Zhang et al. (2005) reported that meat with high pH showed lower values of  $L^*$ ,  $a^*$  and  $b^*$  than meat with normal pH. The mean value obtained for the parameter  $a^*$  (red) was 11.1 to 23.6 according to a survey of Muchenje et al. (2009).

In summary, the beef received by the CR showed color, pH and water activity mostly within the standards established in the literature for ground knuckle, but the levels of collagen and collagen-related protein were smaller than that desired and the lipid content was greater than that prescribed by the bidding process (up to 5%), although always lower than the maximum permitted by the Brazilian legislation (15%) (Normative Instruction n. 83, 2003, from the Brazilian Ministry of Agriculture, Livestock and Supply). Thus, there is the possibility that the supplier is delivering a cut different from knuckle, such as topside, hard cushion and chuck, which have lower cost and higher fat content. However, when warned of lipid content greater than 5% (as specified in the bidding process) in the second, third and fourth weeks of analysis, the supplier adapted the product to the specifications of the CR. Hence, the continuous assessment of the physicochemical parameters of food products obtained by bid enhances the quality of the

products purchased. Such control renders it possible to maintain quality standards of raw materials used in community restaurants.

## Conclusions

The current study evaluated the physicochemical characteristics of bovine ground meat comparing them with legislation and literature in order to facilitate the identification of standards that can be used by public institutions that purchase meat by bidding process. The Brazilian legislation presents the technical regulation of identity and quality of ground beef in its Normative Instruction n. 83, from 2003. Such normative does not stipulate physical and chemical specifications for categories of ground beef, it rather only establishes maximum levels for fat (15%) and addition of water (3%), and prohibits additives other than water. This way, commercial establishments are free to market products with different quality standards, naming them accordingly as special, first and second quality cuts, however these quality standards are not regulated by the Brazilian food legislation regarding the fat and collagen content.

The ground beef received by the community restaurant (CR) was in general adequate in relation to color attributes, moisture content,  $A_w$  and pH, according to the values mentioned in previous studies and the maximum fat content (15%) established by the Brazilian food legislation. Nevertheless, the contents of collagen and collagen-related protein were found to be lower than the ideal. In addition, after the first week of analysis, the lipid content of the product received increased continuously and out of the range prescribed in the bidding contract, which was corrected by the supplier after receiving a warning from the CR, revealed the importance of evaluating the quality parameters continuously and not only in the first weeks of reception of the raw material. The standards set in this study may be used for other institutional food services to ensure the receipt of high



quality meat, consequently raising awareness among local butcheries.

## Conflict of Interests

The authors have not declared any conflict of interests.

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