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Physicochemical characteristics of pork meatballs mixed with *Amaranthus caudatus*

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Abstract The main objective was to compare the physicochemical characteristics of meatballs produced from pork meat and wheat flour mixed with *Amaranthus caudatus*. Meatballs were produced with two different formulations: meatballs without *Amaranthus caudatus* and meatballs having *Amaranthus caudatus*. The different parameters, such as temperature, P^{H}, fat content, weight loss, and titratable acidity, were compared from one formulation to another. The results showed that the p^{H} value and fat content of those having *A. caudatus*, were lower than those found in meatballs without *A.caudatus*, but the temperature, weight loss, and titratable acidity were more than those found in meatballs without *A.caudatus*. By this, the P^{H} value for the initial time was 6.1 compared to 6.3, the meatball fat content without *A. caudatus* of about 3.7% than the meatball fat content with *A. caudatus* of about 2.9%, and the different weight loss between those two meatballs was 19.47% (59g), and finally, the titratable acidity was 1.8% in meatballs with *A. caudatus* than 0.26% in those without *A. caudatus*. The meatballs with *A.caudatus* had a greater acidity and lower lipids than the meatballs without *A.caudatus*. Also, the acid concentration of both meatballs has significant for consumers and the loss of weight means that the lowering of water content is an indication of a good storage process.

Keywords: pork, fat content, acidity, pH value

1. Introduction

Pork as meat from the domestic pig is eaten in many countries, accounting for about 38% of meat production worldwide and about 21% of total dressed meat in Rwanda, compared to 46% from cattle, and its myoglobin content is lower than beef but much higher than chicken (Angier 2009). In developing countries, the total demand for animal products is expected to be doubled in 2030; thereby, pigs are expected to show domination in the meat supply (Shyaka et al 2022). However, pig meat production is expected to increase to meet the growing Rwandan population's nutritional requirements and increase household incomes in rural areas (MINAGRI 2020).

In Rwanda, although the production of livestock products has increased, demand still outstrips supply, primarily due to the rapidly expanding population and the high price of meat (MINAGRI 2008). Livestock food products are a source of essential amino acids, minerals, and vitamins; their fat content is also a source of calories. Meat processing is needed by adding non-meat ingredients to produce nutritional, safe, and shelf-stable products at an affordable price (www.fao.org).

Rwanda's pig population is currently accounting for 1.7 million head, according to statistics from the Ministry of Agriculture and Animal Resources (MINAGRI). The growth has been driven by the growing appetite for pork, disease control in pigs, availability of animal feeds, and high returns that farmers get from pig farming (MINAGRI 2020). Similarly, pig production in Rwanda is increasing rapidly to meet rising demand in urban and rural areas and for export to neighboring countries. Most restaurants in Rwanda serve the pork with banana roasts and fried potatoes (Shyaka et al 2022).

Processed meat products contain relatively high amounts of saturated fats and sodium, and the production of healthier foods requires reducing these two elements (García-García 2008). Fat is important to the palatability of the products such as sausage (Gollehon et al 2001). Consequently, when fat is reduced in meat products, they tend to become tough, dry, and rubbery and do not effectively bind water (Pearson and Gillet 1999). Meatball is a product made of ground meat and mixed with spices, and the meats are the main ingredients (Ulu 2004; Gujral et al 2002). Amaranth may be a promising source of protein, and its protein does not contain gluten (Gallagher and Gormley 2011). The non-meat ingredients can be additive to meat processing for health benefits. Thus, amaranth leaves have been added to improve their nutritional value and to replace

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some quantity of pork meat. The aim was to produce and compare improved quality meatballs made of pork meat and wheat flour mixed with *Amaranthus caudatus* and to assess the physicochemical characteristics of produced meatballs.

2. Materials and Methods

2.1. Meatball processing

Pork meat purchased in Musanze market, Northern Province of Rwanda, wheat flour and olive oil from Supermarket, *Amaranthus caudatus* leaves, and red onion harvested from the house-ground farm.

All ingredients were combined and minced in a machine, except olive oil, spices, and wheat flour, in a bowl and mixed with hands. The minced mixtures were mixed with wheat flour and spices using hands. Using hands, 36 small balls (15+ 21 balls without and with *A.caudatus,* respectively) were rolled (Figure 1). The balls were fried in butter in a frying pan (medium hot) for about 5 minutes and then turned around to get them fried on all sides. Meatballs were taken for consumption.

Figure 1 A: Mixture with *A. caudatus* B: Rolled balls without *A. caudatus* and C: Rolled balls with *A. caudatus.*

2.2. Temperature determination

Using a thermocouple, the internal temperature of the meatballs was measured. The temperature was taken at all steps, from meat reception to serving the last meal. The time of each preparation step was also registered. To evaluate the storage conditions of meat, thermometers for maximum and minimum temperatures were used.

2.3. P^H Determination

The P^H was measured using an electronic P^H meter; before each measurement P^H meter must be calibrated with a standard buffer solution and put in the solution composed of a mixture of sample and distilled water, noted the P^H value through the P^H meter for each sample.

2.4. Titratable acidity

The titratable acidity is expressed as a percentage of lactic acid and was determined by titration of a known amount of reconstituted meatball with 0.1 N NaOH using phenolphthalein as an indicator (www.gea.com).

The method used was as follows:

To prepare the NaOH solution was used a NaOH pellet and distilled water. Fill the burette with NaOH. Measure 10g of dry meat, Drop 5 drops of phenolphthalein with the help of a dropper into Erlenmeyer and mix. Open the cock on the burette and start dropping the NaOH solution into Erlenmeyer until a constant light pink color appears. Shake after each drop; when we get a light color, we stop the NaOH dropping and read how much NaOH is used on the buret's marking.

Titratable acidity results:

Percentage titratable acidity = $\frac{ml.N.90.100}{V.1000}$ (www.gea.com)

Where ml: ml 0.1 NaOH used, N: Normality of 0.1N NaOH, V: solution used in ml, MW of lactic acid: 90.

2.5. Fat Determination

Using Simplified Gravimetric after the chloroform-methanol extraction method (Katherine et al 1997); Samples of 1-5 g were massed into a polypropylene centrifuge bottle. Sodium acetate was added so that the total volume of the solution was

32 ml. Aliquots of methanol and chloroform were added, and the bottles were capped and shaken for 2 hours. Another aliquot of chloroform was added, and the bottles were shaken again for 30 minutes. Finally, an aliquot of water was added, and the bottles were shaken a final time for 30 min.

Centrifuge tubes that had been dried and massed were used to hold 20 ml aliquots of the chloroform layer. These are then centrifuged for 10 min and allowed to set in a 25°C water bath for 15 minutes. The samples were then evaporated to dryness under a nitrogen blanket, heated in a drying oven for 30 minutes, and cooled in a desiCooler (Desert, JBMR, and India) for at least 30 minutes. Finally, they were massed, and the total lipid content was determined by:

Total lipid (g/100 g wet weight) = $\frac{(W2-W1)\,Vc.100}{VA.SW}$ (Katherine et al 1997)

Where W_2 is the weight of the glass tube and dried extract (g), W_1 is the weight of the empty dried glass tube (g), VC is the total volume of chloroform (ml), VA is the volume of extract dried (ml), and SW is the weight of food sample assayed (g).

2.6. Weight loss determination

All ingredients used were measured before meatballs processing, and the weight of meatballs products was also weighed. The total weight loss was determined by taking the difference between the above measures.

2.7. Statistical Analysis

The data were analyzed in excel 2010 as well as the graphs were constructed there. The results of three replicates were expressed as mean ± standard errors.

3. Results

3.1 Temperature of meat and Meatballs

The results have shown that the temperature decreased with time till to the constant temperature and the constant temperature was 22 °C.

Table 1 Temperature of fresh and cooked meat with the variation of time.

Time (min)	0	30	60	90	120
Temperature (°C) - Fresh meat	30 ± 0.01	26 ± 0.00	24 ± 0.00	22 ± 0.00	22 ± 0.00
Temperature (°C) - Cooked meat	48 ± 0.00	31 ± 0.01	25 ± 0.00	22 ± 0.00	22 ± 0.00

For both meatballs before and after they cooked, the temperature was decreased with the increase in time till the constant temperature. The constant temperatures before cooking both meatballs were the same, and also the constant temperatures after cooked of both meatballs were similar. Still the constant temperatures before cooked and after cooked were different.

Table 2 Temperature of meatballs before and after cooking.

Time (min)	0	30	60	90	120
Temperature (°C) (A)	21.5 ± 0.01	19 ± 0.00	19 ± 0.00	19 ± 0.00	19 ± 0.00
Temperature (°C) (B)	22.5 ± 0.01	19 ± 0.00	19 ± 0.00	19 ± 0.00	19 ± 0.00
Temperature (°C) (C)	64 ± 0.01	26 ± 0.01	21 ± 0.00	20 ± 0.00	20 ± 0.00
Temperature (°C) (D)	69 ± 0.01	29 ± 0.00	22 ± 0.00	20 ± 0.00	20 ± 0.00

Notes: (A); (B); (C); and (D): of meatballs without *A. caudatus* before cooked; with *A. caudatus* before cooked; without *A. caudatus* after cooked; and with *A. caudatus* after cooked, respectively.

Normally the meatballs with *A. caudatus* showed a lower upper temperature than those without *A.caudatus*. Figure 2 explains the temperature of those meatballs.

Here the temperature of meatballs with *A. caudatus* in red varied from the highest to the lowest as the temperature of meatballs without *A. caudatus* in blue color; the same both represent the equally constant temperature but the average temperature of meatballs with *A. caudatus* represents the greater number.

The greater temperature of meatballs with *A. caudatus* is influenced by the high water activity of amaranths and its lactic acid, which is miscible with water as water activity increases as the temperature of the sample increases. The low-fat content of meatballs with *A. caudatus* can also influence the increase in temperature.

3.2 Hydrogen potential (pH)

With the P^H of wheat flour of 6.1, raw *A. caudatus* leaves of 7, and the cooked meat after two hours 5.9, the pH of meatballs with *A. caudatus* and without *A. caudatus* before and after cooked was measured as represented in Table 3.

Table 3 Hydrogen Potential of meatballs.

Time (min)	0	30	60	90	120
P^H value (A)	6.5 ± 0.00	6.5 ± 0.00	6.5 ± 0.00	6.5 ± 0.00	6.5 ± 0.00
P^H value(B)	6.5 ± 0.00	6.5 ± 0.00	6.5 ± 0.00	6.5 ± 0.00	6.5 ± 0.00
P^H value (C)	6.3 ± 0.001	6.4 ± 0.001	6.5 ± 0.00	6.5 ± 0.00	6.5 ± 0.00
P^H value (D)	6.1 ± 0.001	6.3 ± 0.001	6.4 ± 0.00	6.4 ± 0.00	6.4 ± 0.00

Note: (A), (B), (C), and (D): Meatballs before being cooked without *A. caudatus*; with *A. caudatus*; after being cooked without *A. caudatus*; and with *A. caudatus*, respectively.

The P^H values were under the neutralization zone (P^H: 7); by this value, all meatballs were acidic, but the acidic degree is different in meatballs without *A. caudatus* to meatballs with *A. caudatus* where the last are more acidic. The change occurred only in meatballs after cooking, and for any time, the P^H was not changed. This information is explained in Figure 3, where the P^H value each time, the P^H value of meatball with *A. caudatus* each is always less than the P^H value of those without *A. caudatus,* but both reached the same constant P^H value.

Figure 3 shows the P^H variation of both meatballs in the function of time; the red color shows the P^H variation of meatballs with *A. caudatus,* and the blue color represents the P^H variation of meatballs without *A. caudatus*.

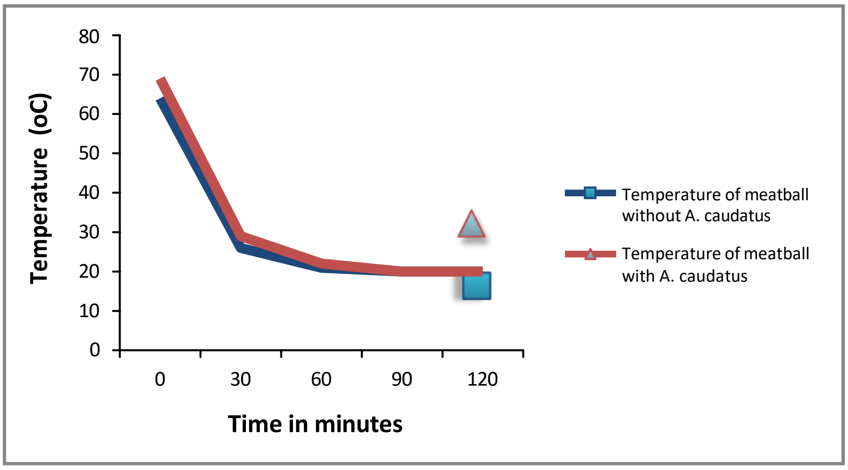

Figure 2 Temperature of meatballs after cooked.

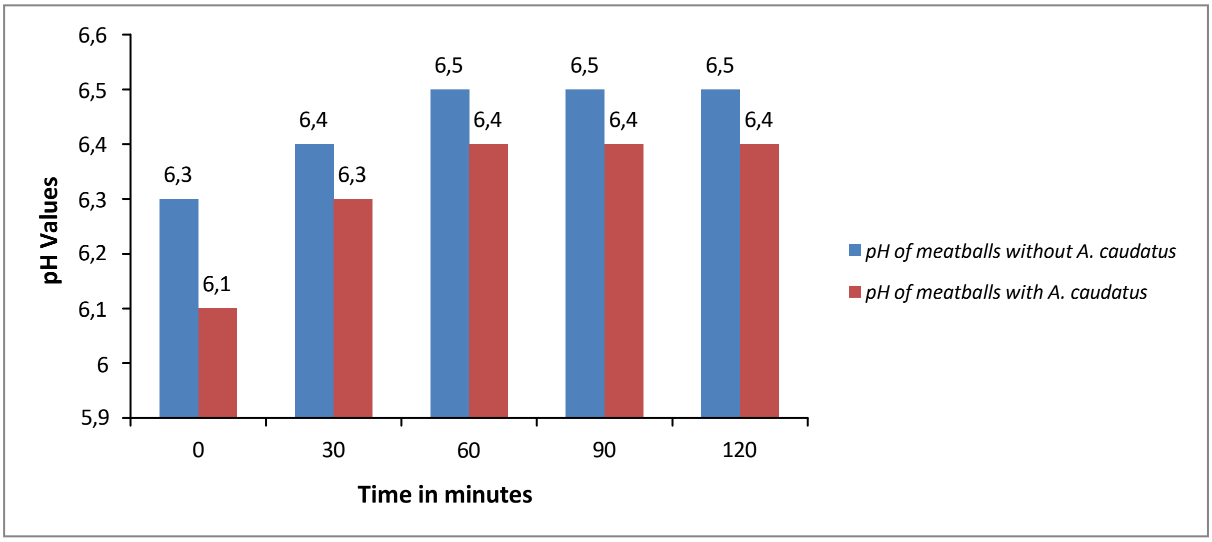

Figure 3 pH of meatballs after cooked.

The most commonly measured chemical attribute of water is its acidity or P^H. The P^H scale ranges from 1 to 14, with 1 being the most acidic and 14 being the most basic. The P^H value of meatballs without *A. caudatus* is greater than that of meatballs with *A. caudatus*; the cause is the lactic acid concentration of meatballs with *A. caudatus* that reduces the P^H value for increasing the acidity.

3.3 Titratable acidity

The titratable acidity of two meatballs was measured by following the procedures described in the methods. The measured titratable acidity in meatballs without *A. caudatus* by 7.2 ml of NaOH was 0.26%, whereas the titratable acidity measured from meatballs with *A. caudatus* by 50 ml of NaOH was 1.8%. This great acidity is more pronounced in meatballs with *A. caudatus* according to the P^H values.

3.4 Fat content

The lipids calculation using Simplified Gravimetric after chloroform-methanol extraction method (Katherineet al 1997), represents the meatball fat content without amaranthus of about 3.7% and the meatball fat content with *A. caudatus* of about 2.9%. This lower lipid level in meatballs with *A. caudatus* compared with the meatball without *A. caudatus* is explained by the reduction of meat, and the addition of *A. caudatus* leaves normally containing the high lactic acid than meat.

3.5 Weight loss

The weight variation was measured in all steps of meatball processing, where the wheat flour, the cooked meats, and the *A. caudatus* leaves were weighed before starting meatballs making. The measures were also taken during the processing of meatballs and finally, the measures of the weight of meatballs produced. The weight of the mixture for meatballs made without *A. caudatus* was 1,187g, and after their processing, the meatballs weighed 1,150g, whereas the weight of all meatballs was 1,065g being cooked. The weight loss in meatballs without *A. caudatus* was 122g.

The same measures of the weight of the meatballs with *A. caudatus* were done. The weight of the mixture was about 1,509g, while the balls weighed 1,495g, and finally, 1,328g of the meatballs weighed after being cooked. The weight loss of meatballs with *A.caudatus* was equal to 181g, and here is the difference in weight loss format balls with and without *A. caudatus* is that the *A. caudatus* found in meatball processing lost a high amount of water than the meatballs without *A. caudatus.*

The total weight loss of both meatballs was 303g (100 %); by this, the difference in weight loss between those meatballs of about 59g is 19.47%, and the weight loss in meatballs without *A. caudatus* was 40.26%, and the weight loss of meatballs with *A. caudatus* was equal to 59.74%.

4. Discussion

The production of meatballs from pork meat and wheat flour mixed with *A. caudatus* was possible, but the meatballs took a color like that of *A.caudatus*. The effect of *A. caudatus* on meatball production is explained by the decrease in P^H corresponding to the production of acidity. Water removal by drying has high chemical component values, such as vitamin C and beta carotenes than in fresh samples.

As discussed by Sureshkumar et al (2006), not only is the acidity increasing influenced by the *A. caudatus* on meatballs production, but also the temperature is first increased, then it starts to decrease up to the constant based on time.

The incorporation of *A.caudatus* into meatball production is different from the study of the quality of low-fat meatballs containing legume flours as extenders which all meatballs incorporated legume flours were tougher (Serdaroğlu 2005).

These parameters, such as the temperature, $P^{H,}$ and weight, decreased in the time increase function. The comparison of temperature for both meatballs shows that the meatballs with *A. caudatus* had greater temperature than meatballs without *A. caudatus,* but both meatballs had a constant temperature (Figure 2).

In terms of fat content, the meatballs with *A. caudatus* had lower lipids (2.9%) than those found in meatballs without *A. caudatus* (3.7%). The fat level in *A. caudatus* (10%) affected the fat content of meatballs. The decrease in fat content from 3.7% to 2.9% significantly increased the cooking yield and fat retention. This point is very similar to the study of the effects of fat level (5%, 10%, and 20%) and cornflour (0%, 2%, and 4%) on some properties of Turkish-type meatballs (koefte) (Meltem and Ozlem 2004).

Based on the study of the effect of wheat flour, whey protein concentrate, and soy protein isolate on oxidative processes and textural properties of cooked meatballs showed that whey protein concentrate and soy protein isolate were inhibitory toward oxidation in cooked meatballs, the *A. caudatus* also explains this hypothesis (Ulu 2004).

The weight loss between the two meatballs was different, 59g. The difference can be defined by the water activity of *A. caudatus*. During meatball processing, the meatballs containing amounts of *A. caudatus* were those that showed greater weight reduction than the others, and their cooked characteristics took a long time. Ambient storage conditions can be due to the decrease in P^H and water activity (Sureshkumar et al 2006). The production of induced lactic acid decreases in P^H from 6.5 to 6.4/6.5 to 6.1 (Table 3).

Lactic acid production and subsequent drops in P^H influence the organoleptic properties of meatballs (Lucke 1986). Lactic acid has the potential to enhance saltiness, and the low P^H values may change the flavor by restricting proteolytic and lipolytic enzyme activity (Lucke 1986).

5. Conclusion

The meatballs with *A. caudatus* were more acidic (less P^H value) and had lower lipids than those without *A.caudatus*. However, the meatballs with *A. caudatus* represent the food quality compared to others by their greater acidity in which the sugar content is in low concentration. The acid concentration of both meatballs has significant for consumers and the loss of weight means that the lowering of water content is an indication of a good storage process. It is recommended to use *A. caudatus* meatballs containing good nutritional values, antioxidants, and vitamins for human life in preventing diseases.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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