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Evaluation of the Effects of Ginger Addition on the Quality of Cooked Turkey Sausages

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Abstract

Sausage consumption worldwide is increasing every year. The aim of this research was to investigate the possibility of producing ginger-flavored turkey sausages with an improved nutritional profile. Three batches of sausage were subsequently produced: a control formulation containing 0% ginger (F0), and two batches, including F1 (containing 1% ginger) and F2 (containing 2% ginger). The survey results revealed that there are five (5) types of sausages sold in Conakry supermarkets: chicken, beef, pork, mutton, and turkey sausages. These sausages come from France, Italy, Belgium, Morocco, Spain, and Egypt. Supermarket managers indicated that the main requirements with suppliers of these products are strict compliance with hygiene rules, maintaining the cold chain, a long use-by date and correct. The manufacturing technology made it possible to produce 18 cooked turkey sausages, including 6 sausages for manufactured batches. Physicochemical analyses showed that the addition of ginger led to a variation in the levels of moisture, protein, pH, fat, and peroxide value, since a significant difference ($p < 0.05$) was observed between the control batch and those containing ginger (F1 and F2). The results of the microbiological analyses were satisfactory, since among the germs tested, only total aerobic mesophilic flora and fecal coliforms were found, but in numbers lower than the established microbiological criteria. Sensory analyses revealed that the manufactured sausages were of acceptable quality. From this study, it can be concluded that the addition of ginger at a 2% level not only increased overall acceptability but also yielded satisfactory physicochemical and microbiological results.

Keywords: Contribution, Formulation, Sausage, Turkey, Ginger

1. Introduction

Nowadays, consumers pay a lot of attention to the relationship between food and health. Although the food industry is increasingly focused on producing foods that meet high organoleptic standards, have a long shelf life, and adequate nutritional values, consumers increasingly prefer foods that have undergone less radical technological treatments, are prepared with little or no chemical additives, and are low in sugars, salts, and fats [1]. As a result, the market for foods with health-promoting properties, known as functional foods, has experienced remarkable growth in recent years. Meat products constitute an important part of the daily human diet [1, 2, 3]. For instance, in some countries such as France, purchases of meat products by metropolitan households for home consumption were estimated in 2020 by the Kantar Worldpanel consumer panel at approximately 2.2 million tons of finished products, an increase of 6.5% compared to 2019 [4]. Meat products are considered excellent sources of nutrients, such as proteins, minerals, and vitamins. Traditionally, to produce charcuterie products, pork back fat is widely used due to its technical advantages, such as the organoleptic characteristics (flavor, texture) of the final meat products [5]. However, the high fat content of charcuterie products has been shown to increase the risk of diseases such as obesity, hypertension, and cardiovascular diseases [6]. For these reasons, consumers are increasingly interested in cured meat

products low in saturated fat. Therefore, there is a demand for new fat substitutes that improve the nutritional quality of low-fat meat products. In this context, many strategies have been tested to develop low-fat cured meat products without diminishing their sensory, textural, and technological properties. Similarly, protein-based fat substitutes, such as wheat flour, soy flour, and milk-derived proteins, are widely accepted in low-fat sausages due to their nutritional and functional properties, including solubility, viscosity, etc. [7]. Despite the use of many plant-based products in sausages, to our knowledge, very few researchers have focused on the incorporation of ginger into turkey sausage. However, ginger has been shown to have anti-inflammatory properties due to its content of certain bioactive compounds, such as gingerols and shogaols [8]. Furthermore, ginger can aid digestion, as it is well known for its carminative properties, meaning it can help relieve bloating, gas, and digestive issues. Furthermore, it stimulates bile production and promotes gastric emptying, which is believed to help calm nausea and improve digestion. It is also reported that ginger can help relieve morning sickness in pregnant women and chemotherapy-induced nausea [8]. Furthermore, in recent years, turkey meat consumption has increased due to its low cost, accessibility, and high nutrient content. Several studies have shown that turkey meat has a very high nutritional value [9]. Based on the information cited above, it is interesting to incorporate ginger into cooked turkey sausage to improve its nutritional profile. Thus, the objective of this study is to produce cooked turkey sausages with ginger and evaluate their physicochemical, microbiological, and sensory quality.

2. Materials and methods

2.1 Presentation of the study area

This study was carried out in the city of Conakry from August 1, 2024 to January 30, 2025. The sensory evaluation was carried out at Gamal Abdel Nasser University in Conakry and those of physicochemistry and microbiology were carried out at the National Office of Quality Control in Matoto. The Fig 1 shows the city of Conakry, where our research sites are located. Indeed, the city of Conakry developed on the former island of Tombo with an area of 450 km^2 and on the Kaloum peninsula which opens to the continent, 36 km long and 5 km wide. It is located between 9° 32′ 53″ north latitude 13° 40′ 14″ west longitude. Its urban area runs from southwest to northeast, passing through the Gbassikolo Canal, and constitutes the capital's land and property potential. It is bordered to the east by the Coyah prefecture, to the west by the Atlantic Ocean, to the north by the Dubréka prefecture, and to the south by the Forécariah prefecture. Most industries are located along the sea. Industrial waste is always drained into the sea, and this can be detrimental to resources, especially to larvae, which are fragile at this stage of their development.

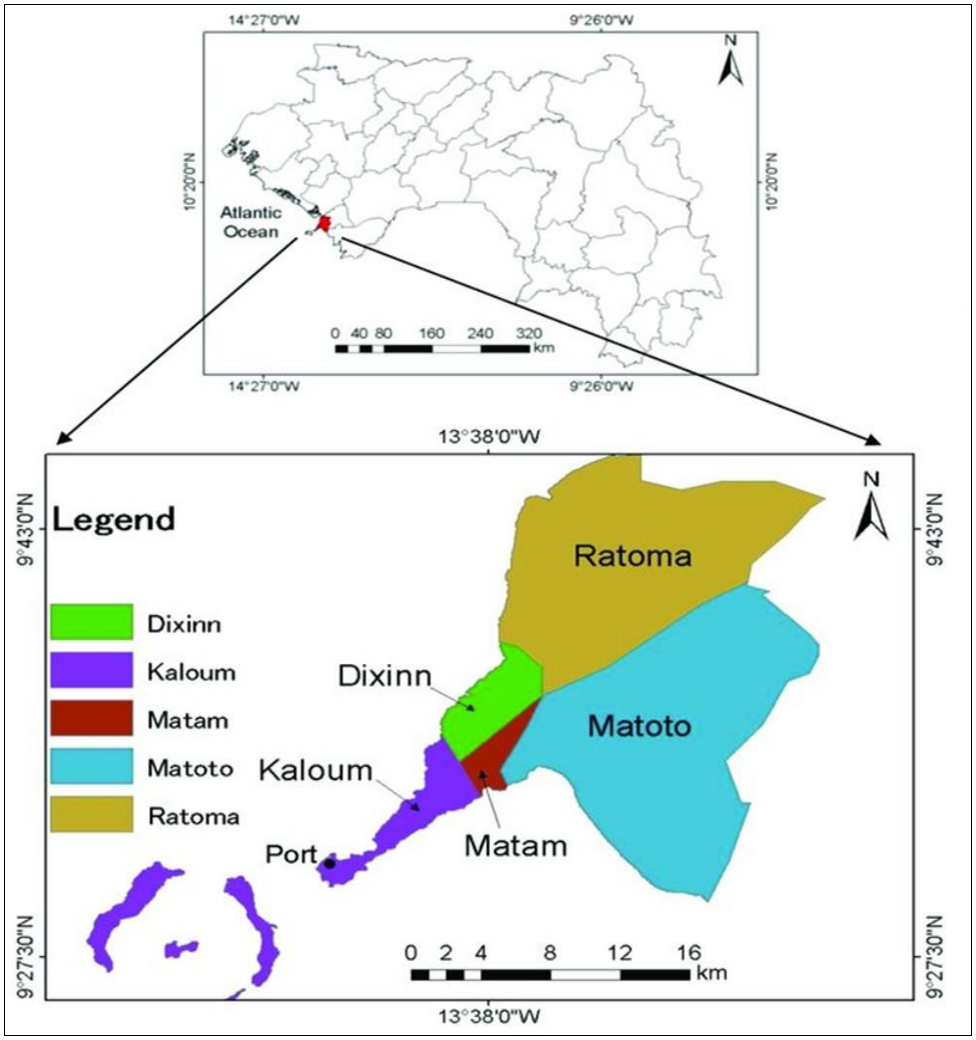

Fig 1: Map of the city of Conakry (Traore, Mawenda, & Komba, 2018)

2.2 Materials

The materials used in this study are presented in Table 1a. These materials are subdivided into five groups: material for sensory investigation and analysis, material for sausage manufacturing, material for laboratory analysis, chemicals and culture media. The food materials used are fresh local ginger (Zingiber officinale), natural casings (large intestine of N'dama beef) and various food ingredients. Chemicals and culture media were also used.

Table 1a: List of Materials

S. No	Names of materials	Quantity
	Sensory investigation and analysis equipment	
1	Disposable cups	30
2	Survey sheets	11
3	Scoring sheets	30
4	Disposable plates	30
5	Spittoons	30
	Sausage manufacturing equipment	
1	Blender	1
2	Funnel	1
3	Stainless steel knives	2
4	Rolled fissel	1
5	Bowls	2
6	Steamer	1
7	Plastic wrappers (pack)	1
8	Scale	1
9	Cooler	1
	Physicochemical and microbiological analysis equipment	
1	Ovens	4
2	Muffle Furnace	1
3	Analytical Balance	1
4	pH Meter	1
5	Magnetic Stirrers	3
6	Crucibles	6
7	Petri Dishes	6
8	Tongs	1
9	Kjedahl Apparatus	1
10	Digestion Matrax	4
11	Distillers	2
12	Graduated Burettes	2
13	Soxhlet Apparatus	1
14	Filter Papers	6
15	250 mL Cylinders	3
16	150 mL Erlenmeyer Flasks	4
17	Volume Flasks	3
18	Micropipette	1
20	Magnetic Stirring Bars	1
21	Pair of Gloves	3
22	Freezer	1
23	Stomacher	1
24	Colony Reader	1
25	Dishes	6
26	Wash Bottles	1
	Chemical products	
1	Distilled water	1 L
2	Petroleum ether	400 mL
3	Catalyst (sodium sulfate anhydride)	3 g
4	Boric acid 4% with color indicator	240 mL
5	Soda ash (33%)	50 mL
6	Soda ash (40%)	50 mL
7	Sulfuric acid (0.1N)	50 mL
	Culture media	
1	Buffered Peptone Water	500 mL
2	Violet Reed Bile Agar	300 mL
3	Meat Liver	500 mL
4	Plate Count Agar	500 mL
5	Rappaport Vassiliadis Soy	200 mL
6	Brilliant Green Phenol Red	100 mL
7	Lysine Iron Agar	300 mL

2.3 Survey in Conakry supermarkets

During this phase of the investigation, managers of supermarkets in Conakry were consulted to inquire about the types of sausages sold, their origins, requirements, current regulations, etc. To obtain this information, we developed survey sheets using the Sphinx Plus software. The supermarkets were chosen randomly. The municipalities of Matoto, Ratoma, Dixinn, Matam and Kaloum were selected given the strong presence of commercial establishments in these municipalities. The questions asked to the managers of these commercial establishments concerned the availability and typology of sausages, suppliers, supply and sales conditions, customer requirements and complaints, etc. The questionnaire was completed during discussions with the managers of the delicatessen departments.

2.4 Sampling

In this study, the raw materials used were turkey meat and fresh ginger. Ten (10) kg of turkey meat, two (2) kg of raw ginger, and two (2 kg) of natural casings (large beef intestine) were purchased, respectively, from the Bobo supermarket, the ENTAG market, and the Matoto slaughterhouse in Conakry. The samples were placed in a cooler and quickly transported to the food technology workshop at Gamal Abdel Nasser University in Conakry for sausage production. When purchasing these products, only those with the required organoleptic qualities were selected and purchased.

2.5 Microbiological analyses of raw materials (turkey meat and ginger)

The microbiological analyses were carried out on turkey meat and ginger in order to ensure their quality in order to use products that comply with microbiological criteria. Thus, 50 g of turkey meat and ginger were taken and sent to the National Office of Quality Control (ONCQ) of Matoto for the counts of Total Aerobic Mesophilic Flora (FMAT), Total Coliforms (CT), Fecal Coliforms (CF), *Staphylococcus aureus*, and Sulfite-Reducing Anaerobes (ASR). These analyses were carried out in four (4) stages which are: the preparation of culture media, the preparation of stock solutions, the preparation of decimal dilutions and the actual count.

Preparation of culture media

The culture media used in this study (Table 1a) were prepared following the manufacturer's instructions. For this purpose, a quantity of dehydrated media was taken waith the help of a spatula in an erlenmeyer, to which a corresponding quantity of distilled water was added, then stirred on a hot-plate magnetic stirrer until complete dissolution; then the mixture was rendered sterile using the autoclave in accordance with the requirements on the notice (ISO 4833 standard).

Preparation of working solutions

La préparation de la suspension mère a été réalisée selon la norme (NF V08-010, 1996). Elle a consisté à prélever de manière aseptique 26 g de viande de dinde et 26 g de gingembre dans un sachet stomacher stérile, puis ajouter 234

mL d'Eau Peptonée Tamponnée (EPT) préalablement stérilisée. Ensuite, le mélange a été homogénéisé au stomacher pendant une minute. La solution obtenue est appelée solution ou suspension mère titrant 10^{-1} et cette solution a été laissée au repos pendant 30 minutes pour la revivification des bactéries stressées lors du broyage.

Preparation of decimal dilutions

The preparation of the suspension was carried out according to the standard (NF V08-010, 1996). She consisted in aseptically removing 26 g of turkey meat and 26 g of ginger in a sterile stomacher bag, then adding 234 mL of pre-sterilized Buffered Peptone Water. The mixture was homogenized at the stomach for one minute. The solution obtained is called titrant mother solution or suspension 10^{-1} and this solution was left at rest for 30 minutes for revival of stressed bacteria during browning.

Denomination of germs

- Total Aerobic Mesophile Bacteria Denomination (FMAT)

The FMAT was denominated according to ISO standard 4833. The culture medium used is Plate Count Agar (PCA) medium. This technique consists of taking 1 mL of the mother suspension from each tube of dilutions from 10^{-1} to 10^{-5} in sterile Petri dishes under a laminar flow hopper. The PCA medium, thawed and cooled in a marine bath at 45 °C was added to the inoculum at a rate of 15 to 20 mL. Next, the mixture was homogenized by rotary movements. After solidification, the Petri dishes were incubated while turning the lids towards the stove key at 30 °C for 24 hours. Colonies were denominated using a muni colony counter of a magnifying glass or the naked eye. The reading was done on the 2 boxes seeded with successive dilutions (- from 300 colonies and more than 10 colonies on 1 box).

For the germ set investigated, the formula below was used to calculate the number of germs per gram (N) of product:

$$Ng = \frac{\Sigma c}{V(n1 + 0.1\,n2)\,d}$$

Where

Ng: number of germs per gram of product;

ΣC: Sum of characteristic colonies over the two retained boxes;

V: volume of inoculum applied to each box (in ml);

d: dilution rate corresponding to the first retained dilution;

n1: retained box number at the 1st retained dilution;

n2: retained box number at the 2nd retained dilution.

- Denomination of thermotolerant fecal coliforms and total coliforms (CT and CF)

The method NFV08-060-1996 was adopted by the denomination of CTs and CFs. The principle of this method is based on the enumeration of coliforms appearing on crystalline blue, bile neutral red and lactose (VRBL) jelly medium after incubation at 37 °C for feces and 44 °C for totals for 24 to 48 hours. This method consists of aseptically transferring 1 mL of the mother suspension into sterile Petri dishes (10^{-1} to 10^{-3} dilutions) under a laminar flow hot. The VRBL medium, thawed and cooled in a marine bath at 45 °C was added to the inoculum at a rate of 15 to 20 ml per box. Next, homogenize the mixture with rotary motions. After solidification, the boxes were incubated while turning the lids towards the stove key at 30 °C for 24 hours for total coliforms and 44 °C for fecal coliforms. After this time, colonies were identified using a magnifying glass or to the naked eye and the 2 boxes seeded with successive dilutions were retained. The coliforms presented red colonies of diameter equal to or greater than 0.5mm, after 24h incubation.

- Denomination of anaerobic sulfite-reducing bacteria (ASR) (ISO 15213)

ASRs are spore-forming bacteria. The seeding accomplished in liver meat (VF) medium is used for denomination of ASRs using tubes. The melted and bath-cooled VF medium was duly poured 20 mL into a sterile tube and 1mL mother suspension at 10^{-1} was added then homogenized. After homogenization and solidification, the tubes were incubated in anaerobiosis at 46 °C for 24 hours. Characteristic black colonies of ASRs appear in the incubation tubes.

- Search and denomination of presumed pathogenic staphylococci

Staphylococci were denominated according to the method of Standard NF V 057-1-2004). The principle of this method is based on the isolation and identification of *staphylococci aureus* after culture on Baird Parker (BP) medium. The method consists of surface seeding 0.1 mL of the mother solution and 0.1 mL of the 10^{-2} dilution into Petri dishes into which the BP medium is previously poured. Next, the boxes are incubated at 37 °C. After 24 hours, the boxes are lues. The characteristic colonies are marked on the back of the box and the boxes are freshly incubated for 24 hours at the same temperature. After this second incubation, 03 characteristic or uncharacteristic colonies are picked for later stages (catalase assay, culture on CC broth, coagulase assay). The characteristic colonies of coagulase positive staphylococci are black or gray colonies (reduction of tellurite to telluride), surrounded by a halo of lightening (corresponding to a proteolysis), within the halo, an opaque area may also appear due to action of a lecithinass.

2.6 Production techniques of cooked turkey sausages

The baked turkey sausages were manufactured at the UGANC Food Technology Workshop. The method described by Sangaré *et al*. [10] was adopted with a slight modification. The sausage manufacturing steps are presented in Fig 2. At reception, the turkey and ginger were carefully washed with tap water and drained. Subsequently, an initial weighing was performed followed by parage operations (denervation, debossing and decoupling); these techniques have allowed meat devoid of waste (lean) to be obtained. Thus, the lean obtained was to obtain the uniform brush on which the ingredients presented in Table 1b were added. The obtained mixture was divided into three batches: i) the first batch noted F0 is the control sausage, that is containing 0% ginger, the second batch (F1) consists of 1% ginger and the third batch (F2) contains 2% ginger. The three batches were embedded in natural buoys (large intestine of N'dama breed beef) and left to rest (ripen) for 20 minutes. Next, a steam bake (100 °C for 10 min) and an oil bake (100 °C for 2 min) were performed respectively followed by cooling. The obtained cooked sausages were packed in plastic bags and stored at +4 °C. The physicochemical, microbiological and sensory analyzes were performed.

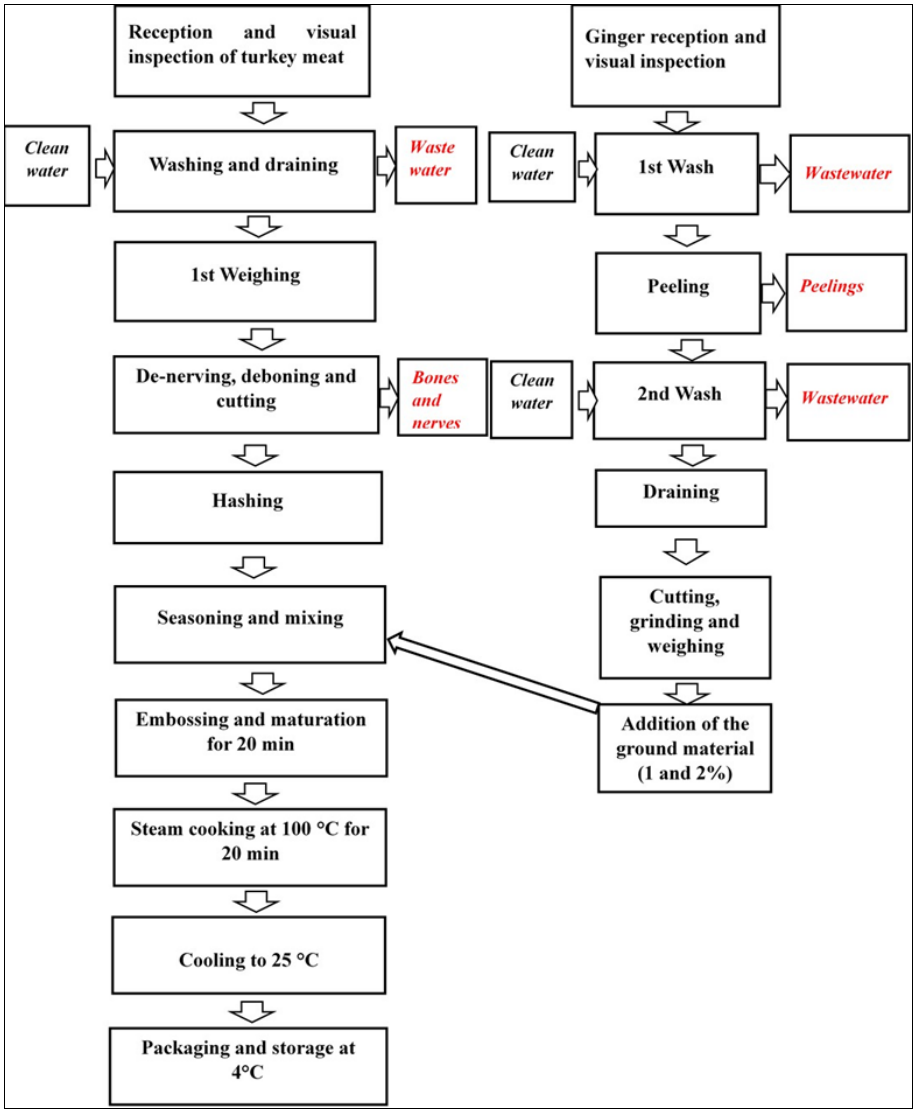

Fig 2: Processing flow chart for cooked turkey sausage

Table 1b: List of ingredients used

Ingredients	Formulations		
	F0	F1	F2
Lean turkey meat (g)	3000	2970	2940
Mixed ginger (g)	-	30.00	60.00
Water 0.5% (g)	15.00	15.00	15.00
Table salt 1% (g)	30.00	30.00	30.00
Garlic powder 0.5% (g)	15.00	15.00	15.00
Black pepper powder 0.3% (g)	09.00	10.80	10.80
Chili powder 0.2% (g)	06.00	06.00	06.00
Tomato powder 1% (g)	30.00	30.00	30.00

F0: Sausage with 0% ginger; F1: Sausages containing 1% ginger; F2: Sausage containing 2% ginger

2.7 Physicochemical analyzes of cooked turkey sausages

The samples of ginger cooked turkey sausages were analyzed at the Matoto National Quality Control Office physicochemical laboratory. The evaluated physicochemical parameters bear on the determination of moisture, total ash, total protein, fatty matter and pH.

Moisture measurement

The moisture content was determined based on the 1995 AOAC method. The principle of this technique consists of desiccation in a vacuum, of a test sample, at a temperature of 105 °C ± 2 °C, until a constant weight is obtained. The operative mode is as follows: it consists of washing and drying the capsule in a vacuum at 105 °C for 15 mn. Next place the capsule in a desiccator lined with a dehydrating agent (silica gel) for 2 min. With the help of a precision balance, weigh the empty capsule (Pv), then weigh 5g of the sausage sample into the capsule, strain and weigh again (Pe). Dry the sample-containing capsule in a vacuum set at 105 °C for 4 hours, then cool them after drying in a desiccator for 3 min. Finally, weigh the loaded capsule (Pc) after drying.

The formula below is used for the calculation:

$$H\% = \frac{(Pe-Pv)}{(Pe-Pc)} \text{ x } 100$$

Where

H%: moisture content;
Pe: weight of the capsule with the assay taking before drying;
Pc: weight of the capsule with the assay after drying;
Pv: weight of empty capsule.

Total ash measurement

Total ash was determined using the method of NF V 18-101-1977.

The principle of total ash rate determination is based on total incineration of the test sample at a temperature of 550 °C in a muffle furnace until white ash is obtained. The operative mode consists of washing the crucible with water, then heating in the oven set to 550 °C in a muffle oven for 5 min, followed by cooling in the desiccator for 15 min, weighing the vacuum (Pv) and tarrying, then weighing 5g of the sample (Also) in the same crucible and bake in a muffle oven at a temperature of 550 °C for 5 hours. Next, let the oven cool for 5 min, then take out the crucible containing the white ashes and place them in the desiccator for 15 min and note the weight (Pc) of the crucible plus the residue.

The formula below was used for total ash rate calculation:

$$\%C = \frac{P_c - P_v}{P_e} \times$$

Where

%C: Total ash content;
Pv: Weight knows the crucible;
Pe: Weight of the assay take;
Pc: Weight of the loaded crucible containing the white ashes.

Total protein measurement

The AOAC., (1995) method was adopted for total protein rate determination.

The principle consists in mineralizing a test sample by concentrated sulfuric acid in the presence of a catalyst. Thus, the nitrogen contained in the sample is converted into ammonium sulfate. The ammonia thus liberated is collected in a solution of boric acid, and titrated with a solution of sulfuric acid or hydrochloric acid. The operative mode of this technique consists of weighing 0.5 g of sample into a pre-numbered mineralization tube. Next, place the tubes in the mineralizing block, then add the catalyst (about 10g), then add 15 mL of concentrated sulfuric acid. Allow to mineralize for 1h until complete disappearance of white sulphurous vapors. Set the apparatus under voltage, then connect the tube containing the mineralized sample to the distillation unit connected to bottles of 32 % baking soda and distilled water. Next place a 250 mL erlenmeyer containing 30 mL of boric acid on the terminal plate of the distillation unit. Watch as the tube is immersed in the boric acid solution. Open the water faucet connected to the appliance. Check after the parameters such as the volumes of soda and water to be dispensed as well as the distillation time and finally, start the distillation. The titration is carried out using 0.1 N hydrochloric acid up to the turn from green to dirty pink.

The following formula is used to calculate nitrogen rate and total protein rate:

$$\%N = \frac{(V-V0)x14}{P_e} \times 100$$

%Protéines = %N x 6,25

Where

%N: percentage nitrogen content
V0: Blank titration volume in mL;
V: Sample titration volume in mL;
N: Exact normality of hydrochloric acid;
14: Molar mass of nitrogen in g/mol;
F: Protein nitrogen conversion factor set to 6.25
Pe: Essay pricing in g

Measurement of fat

The fat content was evaluated according to the AOAC., 1992 method. The principle consisting of this method is based on lipid release by extraction using a solvent, N-hexane or petroleum ether. This extraction is followed by evaporation of the solvent. The lipid extract is then weighed after desiccation at 150 °C, then reported as a function of sample mass. The operative mode consists of weighing the vacuum cups (Pv) and taring; next weigh 5g of sample into the cartridge (Pe). Then, add 150 ml of hexane to the beakers, so that the cartridge containing the sample is immersed in the solvent, then adapt the cartridges to the beakers. Insert the cups into the extractor. Open the tap to feed the extractor refrigerants. After extraction, incubate the beakers at 105 °C for 1h to remove traces of solvent, then weigh the beakers again (Pc).

The lipid content was calculated according to the following formula:

$$\%MG = \frac{P1 - Pv}{Pe} x100$$

Where

%MG: Fat content;
Pc: Weight of the cup with the fatty matter extracted after drying;
Pv: Weight you cup empty;
Pe: Weight of the test take.

Determination of pH

The method described by El-Nashi *et al*., [11] was adopted with modification to measure the pH of the samples. In our case, the pH-meter (3110, Germany) was used. Thus, 10 g of ginger cooked turkey sausages broth were dissolved in 50 ml of distilled water, thoroughly homogenized. Before the measurements, the pH meter was calibrated with known standard pH standard solutions (pH of 4.00 and 7.00. The pH meter electrode was rinsed with distilled water, then immersed in the mixture and the value obtained was read on the screen. Three (3) repetitions were realised for each sample.

Determination of peroxide value

The method described by Sam *et al*., (2021) was adopted with a slight modification to determine the peroxide value (PV). This technique was performed by weighing 1 g of finely browned sausage into 250 mL Erlenmeyers. Next, fifteen milliliters (15 mL) of acetic acid-chloroform solution (480 mL acetic acid and 320 mL chloroform) were added to each Erlenmeyer and stirred. Then, a saturated solution of potassium iodide (500 mL) was added to each Erlenmeyer by means of a 1 mL pipette. Of the deionized water (20 mL) was added to each Erlenmeyer. They were then titrated by sodium thiosulfate solution (0.01 N) with 1 % starch solution as indicator. The procedure mentioned above was used without sausage sample to obtain the blank. The formula below was used to calculate PV:

$$PV = \frac{(S) \times N}{\text{PWeight of the sample (g)}} \times 100$$

Where

S: Titration volume;

N is the normality of sodium thiosulfate (0.01 N).

2.8 Microbiological analyses of cooked turkey sausages produced

The sausages were manufactured to denominate total aerobic mesophilic flora, coliforms (total and fecal), sulfito-reducing anaerobes and staphylococcus aureus. The methods realized on the raw materials were used to denominate these germs.

2.9 Sensory analysis of manufactured sausages

The sensory analysis was performed using the hedonic method according to the method described by ACTIA, [12] with slight modification. This method consists in evaluating on a scale, the pleasant character of the products presented to the subjects. In our study, sensory attributes bear on taste, color, texture, odor, aroma and overall acceptability. Thus, thirty (30) persons (naïve subjects) whose age is between 30 and 60 years were selected from the students and staff of Gamal Abdel Nasser University of Conakry (UGANC). This tasting took place in a classroom at the UGANC. The samples were presented blindly in a disposable plate by assigning each a code. The researched information and the aim of the study were then explained to the tasters. Each taster was provided with a tasting sheet, a pen and a disposable mug containing Coyah brand mineralized water. Each taster was asked to tick the boxes corresponding to their perception.

2.10 Statistical analyzes of data

The survey data were performed on SPHINX Plus2. The analysis of variance (ANOVA) was applied using XLSTAT 2019 software, and Fischer's test was used to compare the means of the three formulations (F0, F1 and F2). The Excel spreadsheet (Microsoft Office, 2019) was used for the graphs. We considered that an observed difference was not statistically significant except when $p<0.05$ at a 95% confidence level.

3. Results and Discussion

3.1 Supermarket Survey Results

The survey conducted in commercial establishments in the city of Conakry covered eleven (11) supermarkets, namely Imperial, Bobo supermarket, Garaya, Leader Price, CocciMarket, Prima Center Conakry, SDF supermarket, GARAYA supermarket, City Market, Kimaf supermarket and ZCO supermarket. As mentioned in Table 2, interviews with managers of commercial establishments show that supermarkets sell chicken, beef, pork and mutton sausages, but not turkey sausages with ginger. These sausages come from France, Italy, Belgium, Morocco, Spain and Egypt. They told us that their requirements with sausage suppliers are strict compliance with hygiene rules, maintenance of the cold chain, distant and legible use-by date and timely supply of sausages. Sausages are supplied to supermarkets using refrigerated trucks with a temperature set at +4 °C. In addition, the survey revealed that rare customer complaints are recorded and generally concern defects in organoleptic characteristics (packaging defects, bad smell, firmness, etc.) which are reported to suppliers for corrective measures. In addition, the results revealed that no specific control of sausages is carried out in Conakry supermarkets. These results are different from those obtained by Diouf, [13] who reported that sausages sold in Dakar supermarkets are subject to specific control. The latter also indicated that sausages are highly perishable foods that must be subject to specific regulations to protect consumer health.

Table 2: Results of surveys conducted with supermarket managers

Supermarkets	Types of sausages	Origin	Requirements	Customer Complaints
Imperial, Hypermarket Bobo, Garaya, Leader Price, CocciMarket, Prima Center Conakry, SDF Supermarket, GARAYA Supermarket, City Market, Kimaf Supermarket and ZCO Supermarket	Turkey sausage, Dry chicken sausage, Beef sausage, Dry pork sausage and Mutton sausage	France, Italy, Belgium, Morocco, Spain and Egypt	Strict compliance with hygiene rules, maintenance of the cold chain, long, correct and legible use-by date and timely supply.	Packaging defect, bad odor, change in firmness

3.2 Results of microbiological analyzes of turkey meat and ginger

Turkey meat is a favorable medium for the development of numerous microorganisms. Thus, the results of microbiological analyzes performed on turkey and ginger meat samples are presented in Table 3. Among the named germs, only FMAT, total coliforms were encountered in these meat samples, but in numbers below microbiological standards recommendations. No fecal coliform, *Staphylococcus aureus*, sulfite-reducing anaerobes and Salmonella germs were encountered in the samples. These results confirmed that turkey meat was suitable for sausage production. These results are similar to those found by Amira *et al*. [14], who after denominating total aerobes in turkey meat, did not encounter any germs above recommended microbiological standards. As far as ginger is concerned, except for FMATs, no germs have been identified, confirming the hypothesis according to which ginger has antibacterial property. These obtained results confirm that turkey meat and ginger are suitable raw materials for the production of turkey sausages.

Table 3: Results of microbiological analyses of turkey meat and ginger

Germs wanted	Turkey Meat	Gingember	Microbiological Criteria (CFU/g)
FMAT (CFU/g)	500	2	$5x10^5$
Fecal coliforms (CFU/g)	0	0	5000
Fecal coliforms (CFU/g)	20	0	500
Staphylococcus aureus (CFU/g)	0	0	500
ASR (CFU/g)	0	0	100
Salmonella (CFU/g)	Absence	Absence	Absence in 25g
Appreciation	Satisfying	Satisfying	

FMAT: Total Aerobic Mesophilic Flora; CFU: Colony Forming Unit; ASR: Anaerobic Sulfite-Reducing

3.3 Physicochemical analyzes of manufactured sausages

The physicochemical analyzes of ginger cooked turkey sausages bear on the determination of moisture, total ash, total protein, fat and pH and peroxide value.

Moisture contents

The Fig 3a presents the moisture content of different manufactured sausages. The moisture content varied significantly with the level of ginger incorporation ($p < 0.05$). The moisture contents in recipes F0, F1 and F2 were 46.66 ± 0.14 %, 48.05 ± 0.19% and 49.88 ± 0.18 %, respectively. This difference would be due to the high moisture content of the ginger; this could explain the higher moisture level in F2 ($p < 0.05$), compared to F0 and F1 formulations. Similar results were reported by Devatkal *et al.* [15], who found an increase in the moisture content of vegetable bread with buffle liver incorporated to from carrot paste. Furthermore, Bhosale *et al.* [16] reported that with increasing level of incorporation of carrot and sweet potato puree, the moisture content increased. On the other hand, Naveen Kumar Reddy *et al.* [17] reported that water content increased significantly ($p<0.05$) with increasing levels of raw carrot paste (namely 5, 10 and 15 %). The results obtained in our study confirm that the incorporation of ginger, due to 1 and 2%, presents a significant impact on the water content of turkey sausages. According to the Code of Charcuterie Uses and Requirements [18], the moisture content of a sausage is much higher if the product is rich in lean or abates since the water content of these products is 5 to 10 times higher than that of fats. However, the determination of total moisture remains indispensable for the screening of certain frauds in charcuterie products, in particular, Moisture of defatted products (HPD), moisture of defatted and de-starched products (HPDA) and moisture to protein ratio.

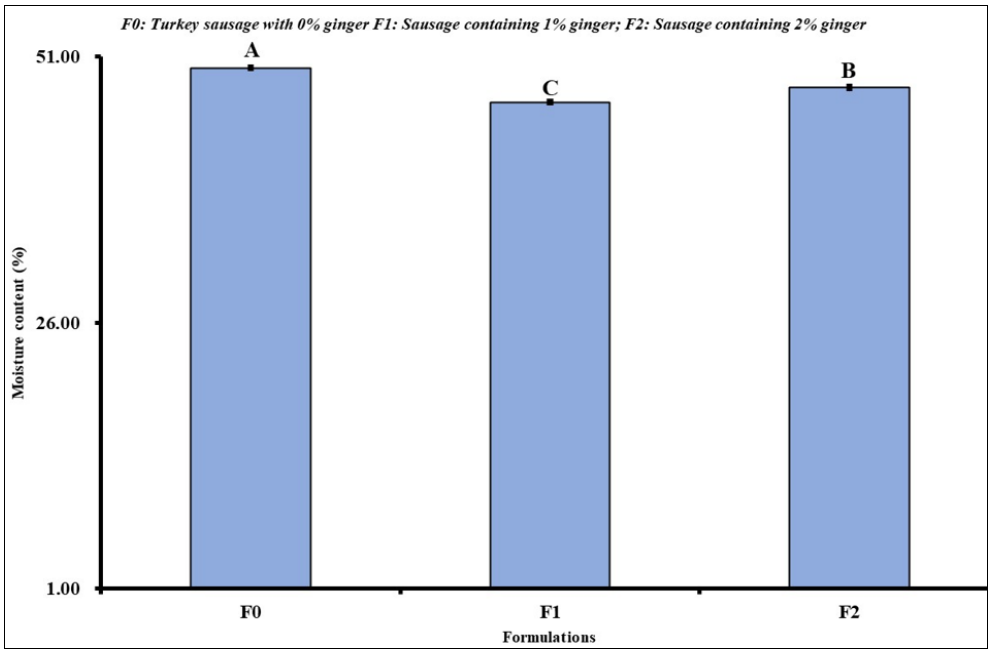

Fig 3a: Results of the determination of moisture value on manufactured sausages

Ash contents

The total ash contents determined on the sausage samples are mentioned on Fig 3b. The analysis of variance applied to the ash content showed a significant difference between the three formulas (F0, F1 and F2) ($p < 0.05$), since the contents range from 2.47 ± 0.32 % in F0 formula to 3.46 ± 0.25 % in F1. As for F2, the content is 3.99 ± 0.39%. In effect, the results found in the Witness are similar to those reported by Reddy *et al.* [17] who found a total ash content of 2.22 ± 0.05 % in the Control saucers and 2.19 ± 0.01%, 2.16 ± 0.02%, and 2.11 ± 0.06 %, respectively in the sausages containing 5, 10 and 15 % of hacked carrots. Furthermore, the results corroborate those obtained by Ali *et al.* [19] who found a content of 2.50 ± 0.04 % and 2.36 ± 0.18 % in sausages containing 2 and 4 % ginger extract, respectively.

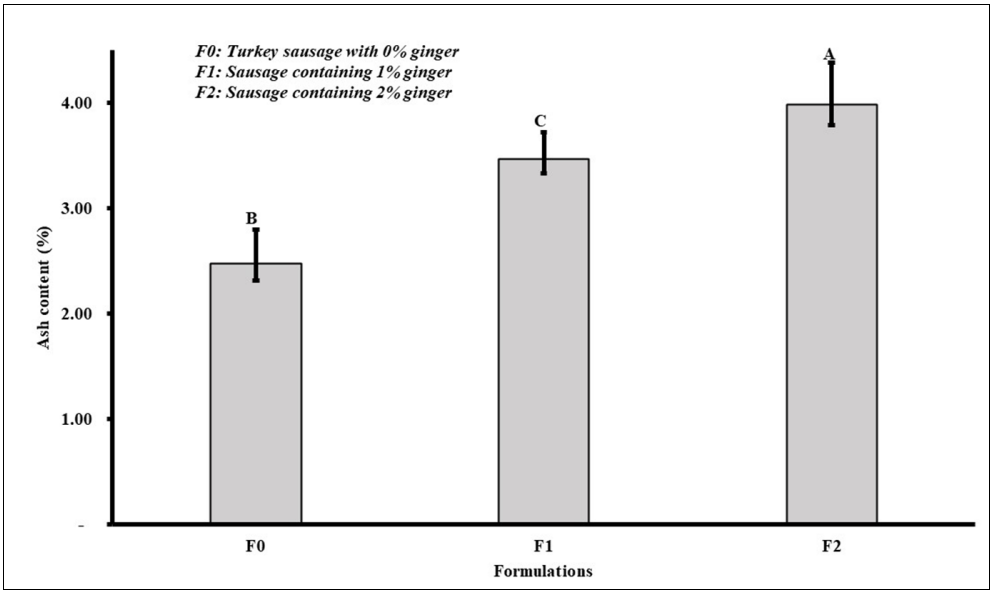

Fig 3b: Results of the determination of ash value on manufactured sausages

Total protein contents

As mentioned in Table 4a, the protein contents determined on the three recipes F0, F1 and F2 are 17.78 ± 0.37 %, 16.64 ± 0.60 %, and 14.39 ± 0.72%, respectively. There is no significant difference between protein contents of formulas F0 and F1 ($p > 0.05$) unlike formula F2 ($p < 0.05$). The protein contents of formulation F0 (17.78 ± 0.37%) are lower than those reported by Sanwo *et al*. [20] who found 18.40% protein in beef sausage. This difference could be attributed to the quality of the raw material used on the one hand, to the added ingredients, on the other hand. Moreover, our results differ from those found by Seong *et al*. [21] who by incorporating 1 % ground garlic in pork sausages obtained a protein content of 23.34 % compared to sausages without added spices. These observations show that the composition of sausages is highly variable. In short, this study shows that the incorporation of ginger in sausages entails a variation in protein content.

Table 4a: Results of physicochemical analyses of manufactured sausages

Parameters	Formulations		
	F0	F1	F2
Protein (%)	17.78 ± 0.37^{a}	16.64 ± 0.60^{a}	14.39 ± 0.72^{b}
Fat (%)	15.31 ± 0.55^{b}	16.48 ±0.60^{b}	18.72 ±0.35^{a}
pH	6.46 ± 0.01^{a}	6.41 ±0.005^{b}	6.37 ±0.01^{c}

F0: Sausage with 0% ginger; F1: Sausages containing 1% ginger; F2: Sausage containing 2% ginger; numbers represent means ± standard deviations; superscript lowercase letters represent statistical differences between formulations at a 95% confidence level.

Fat content

The fat contents determined in the manufactured turkey sausages are mentioned in Table 4a. These results show that F0 and F1 formulations present no significant difference ($p > 0.05$). On the other hand, the F2 had significantly higher contents (18.72 ±0.35) than the F0 (15.31 ± 0.55) and F1 (16.48 ±0.60) formulations. This variation could be explained by the addition of ginger; since at 2 % incorporation, a significant ($p < 0.05$) variation of fat levels was observed. The results obtained are lower than those reported by Seong *et al*, [21] who obtained 27.38 ± 0.65% and 27.75 ± 0.77% in control sausages and sausages containing 1% garlic powder, respectively. These results show that the fat content of sausages can be influenced not only by the quality of the raw material used, but also by the nature of the ingredients added during manufacture.

Measurement of pH

Such as presented in Table 4a, pH values in cooked turkey sausages were variable as a function of recipes. The highest values were observed in F0 (6.46 ± 0.01), compared to F1 (6.41 ± 0.005) and F2 (6.37 ± 0.01) formulations. Our results are similar to the work of Naveen Kumar Reddy *et al*. [17], who found a decrease in pH value following the incorporation of carrot in replacement of lean meat [16]. On the other hand, our results are lower than those reported by MS Ali *et al*. [19] who found that the pH value of sausages containing ginger extract was affected not only by the level of ginger incorporation, but also by the storage duration. Furthermore, in a similar study, Grasso *et al*. [22] noted that the addition of defatted sunflower seed meal in Frankfurt sausage decreased pH values; this notification is similar to our study where the addition of ginger entrained a variation of pH values. Moreover, it has been reported that a lower pH in meat and charcuterie products can inhibit microbial activities [23], by increasing acidity; which is detrimental to the development of microorganisms such as reported by Jamilah, Abbas, and Rahman [24]. According to this study, higher levels of ginger decreased the pH value, consequently, higher inclusions of ginger can improve the preservation and stability of ginger cooked turkey sausages.

Measurement of peroxide value

The peroxide value (PV) is a parameter used as an indicator of primary lipid oxidation products in meat products [25], it serves to measure the levels of fat degradation in food products [26]. In our case, the values of PV are presented on Fig 3c. The obtained results show that the addition of ginger presents a significant impact on PV, since these values go from 2.55 ± 0.12 meqO2/kg in the F0 formula to 2.04 ± 0.03 mEqO2/kg and 2.02 ± 0.01 meqO2/kg in the F1 and F2, respectively. respectively. A significant difference was

observed between F0 and the mixed formulations (F1 and F2), indicating that ginger is a source of antioxidants (phenols and other similar substances), which possess strong antioxidant and antibacterial properties thus preventing hemoglobin oxidation in the sausage [27]. Moreover, our results are similar to those reported by Sam *et al*. [25] who, in a similar study, examined the addition of carrot paste at 3 % (FI), 5 % (FII) and 10 % (FIII) levels as a potential antioxidant in Frankfurt-type sausages. The authors reported that of lower PV in FI (2.5 meqO_2/kg), FII (2.4 meq/kg) and FIII (2.2 meqO_2/kg) samples compared to the control (2.meqO_2/kg), thus demonstrating an antioxidant activity of 2,2-diphenyl-1-picrylhydrazyl (DPPH) superior to that of the control samples. Similar results were also found by Fernández-Fernández *et al*. [28], who obtained a PV level of 2.10 ± 0.32 meqO_2/kg lipid in Galician chorizo sausages. On the other hand, our obtained results are higher than those reported by Rahman *et al*. [26] who obtained 1.15 ± 0.13 meqO_2/kg in chicken sausages. Furthermore, it is important to clarify that our results are lower than the limit of acceptability set for charcuterie products (<6 meq O_2/kg); which means that our samples are of satisfactory quality from the oxidation point of view. The main reasons for these variations could be attributed not only to the nature of the raw materials used, but also, to the duration and storage conditions of the sausages [19]. In short, the results obtained in this study show that it is possible to produce high-quality sausages using ginger as a source of natural antioxidants; which is consistent with that reported by Lamya EL Sediek, Wafaa, M.M. Abozeid [27] who concluded that fresh ginger at the rate of 1.0 % can be used as a natural source of antioxidant to improve the quality and stability of sausages.

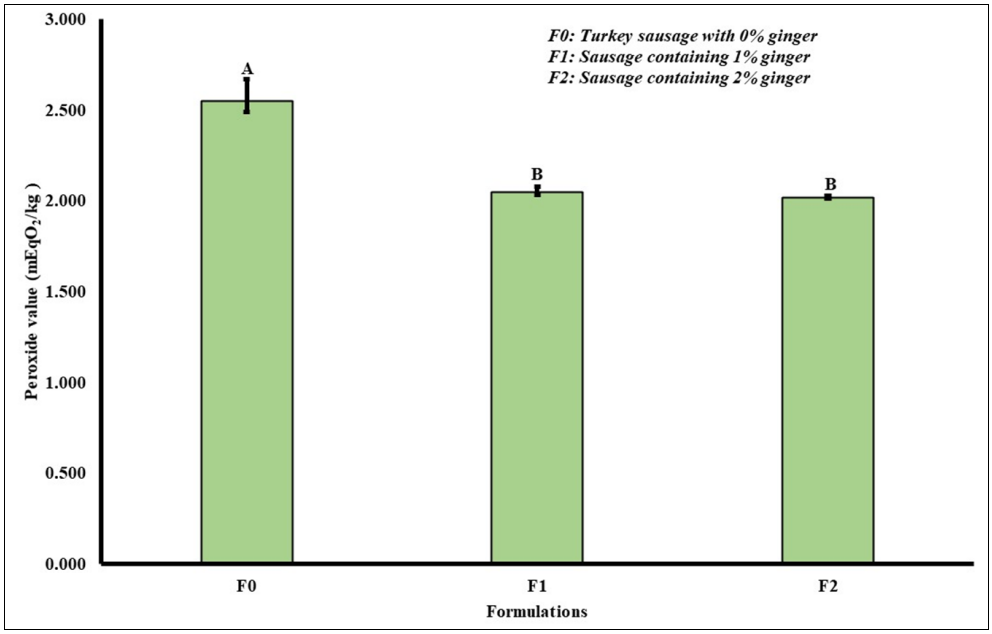

Fig 3c: Results of the determination of peroxide value on manufactured sausages

3.4 Microbiological analyzes of cooked turkey sausages

Sausages are perishable charcuterie products with a fairly high bacterial population [29]. Thus, the results of the microbiological analyzes performed on our samples are mentioned in Table 4b. These analyzes bear on the denomination of FMAT, fecal and total coliforms, *Staphylococcus aureus*, ASR and Salmonellae. The results obtained showed the FMAT and total coliforms are present in all formulations, but in amounts lower than the microbiological criteria set for cooked sausages. The amounts of these germs decreased with added levels of ginger; for example, the amounts of FMAT range from 210 CFU/g in the F0 formulation to 110 CFU/g in the F2 formulation. These results confirm the hypotheses according to which ginger presents an antimicrobial property. For instance, Beristain-Bauza *et al*. [30] reported that ginger is a plant used in traditional medicine against different diseases due to its diverse properties (antimicrobial, antioxidant, anti-inflammatory, anticoagulant, etc.). Moreover, a total absence of fecal coliforms, *Staphylococcus aureus*, ASR and salmonellae was recorded. This could be due on the one hand, to the quality of the raw materials and ingredients used, and on the other hand, to the observance of hygiene rules during manufacture. Also, this absence could be attributed to the antimicrobial effects of ginger. For example, it has been reported that ginger contains certain bioactive compounds (monoterpenoids, sesquiterpenoids, phenolic compounds and their derivatives, aldehydes, ketones, alcohols, esters) that offer a broad spectrum of antimicrobial activity against various microorganisms and make them an interesting alternative aux synthetic antimicrobial. In conclusion, the results obtained in this study show that the manufactured ginger turkey sausages conform to the set microbiological criteria and consequently, they can be consumed without the risk of bacterial contamination.

Table 4b: Results of microbiological analyses of manufactured sausages

Germs wanted	Formulations			Microbiological Criteria (CFU/g)	Appreciation
	F0	F1	F2		
FMAT	210	120	110	10000 CFU/g (RUE 2073)	Satisfying
Fecal coliforms	00	00	00	10^3 CFU/g (CUC)	
Fecal coliforms	05	01	01	5.10^2 CFU/g (RUE 2073)	
Staphylococcus aureus	00	00	00	10^3 CFU/g (CUC)	
ASR	00	00	00	30 CFU/g (RUE 2073)	
Salmonelles	Absence	Absence	Absence	Abs in 25g (CUC)	

3.5 Sensory analysis of manufactured sausages

The sensory characteristics evaluated on our sausage samples covered taste, color, odor, texture, aroma and overall acceptability. The results of the evaluation of salty flavor of cooked sausages, such as mentioned in Fig 4a, it springs that the highest rate (96.66) for conveniently salty appraisal was obtained for formula F2 compared to formulas F1 and F1 for which 90 and 93.34 % have been obtained respectively. The observed differences between these formulations would be attributed to the addition of ginger; since it's the same quality of salt that has been added in all the formulas. Furthermore, tasters' satisfaction for the salty taste would be due to the amounts of added salt on the one hand, and the ability of gingember to enhance the sensory attributes of sausage [27]. The results obtained in our study are similar to the work of El-Nashi *et al*. [11] who noted that enrichment is a factor to drive the variation of sausage flavor.

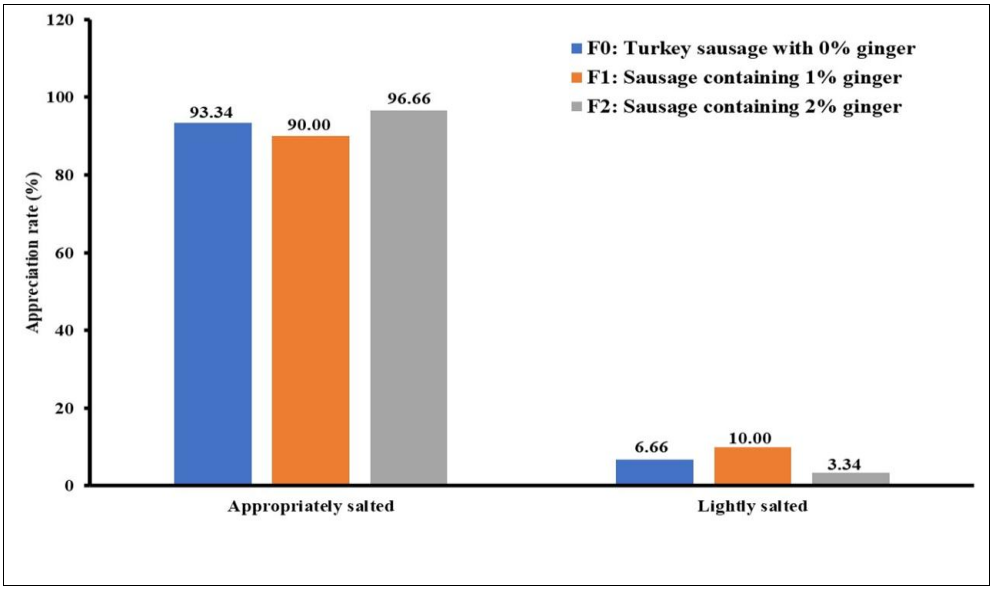

Fig 4a: Results of the evaluation of the flavor of the sausages produced

Evaluation of color

The tasting bearing on the color revealed that all the formulations were reddish in color, since all the tasters noted that they were reddish in color (Table 5a). This appreciation is quite normal and would be attributed to the added ingredients, in particular, tomato and pepper powder; which conforms to the characteristics of a normal sausage such as reported by El-Nashi *et al*. [11]. Furthermore, Paule, [18] who reported that the color of sausage can be modified by the ingredients used.

Table 5a: Results of sensory analysis of texture, odor and color of manufactured sausages

Formulations	Sensory attributes (%)								
	Texture			Odor			Color		
	Firm	Soft	Hard	Pleasant	Very pleasant	Unpleasant	Bright red	Uniform red	Whitish
F0	93.33	3.33	3.33	10.00	90.00	0.00	3.40	96.60	0.00
F1	86.66	3.33	10	3.33	96.66	0.00	3.40	93.30	3.30
F2	83.33	0.00	16.66	3.33	96.66	0.00	0.00	90.00	10.00

F0: Sausage without ginger; F1: Sausages containing 1% ginger; F2: Sausage containing 2% ginger

Evaluation of odor

The results of the odor evaluation of the sausages are presented in Table 5a. The results show that the produced sausages have a very pleasant odor, since the majority of the tasters find the odor very pleasant. In fact, 27, 28 and 29 tasters rated formulations F0, F1 and F2 as very pleasant odor. This appraisal conforms to charcuterie standards which stipulate those sausages must have a characteristic and pleasant smell. These results are in accordance with the prescriptions made by Paule, [18] who noted that sausages should have a pleasant and characteristic smell. This conformity could be attributed on the one hand to the quality

of the raw materials, and on the other hand, to the ingredients added during production.

Evaluation of texture

The texture evaluation results (Fig 4b) show that the sausages are firm. But the highest firmness was observed for Witness formulation. Moreover, the hardness increased with the additional level of ginger; which can be attributed to the ginger constituents. These results are comparable to those obtained by El-Nashi *et al.* [11], who noted that the incorporation of certain plant products can improve the textural characteristics of sausages. In another similar study, Sangaré *et al.* [10] observed that the addition of sesame meal at the rate of 2% entrained a significant variation of textural characteristics of sausages during the fermentation stage.

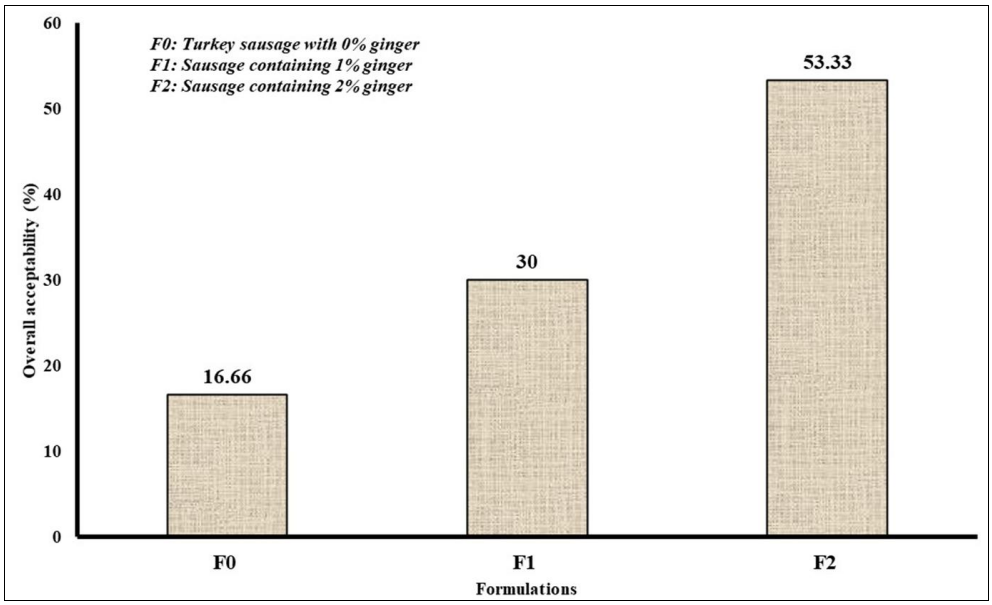

Fig 4b: Results of the evaluation of the overall acceptability of the sausages produced

Evaluation of aroma and overall acceptability of sausages produced

The results of the aroma evaluation are shown in Table 5b. It follows from this evaluation that the majority of the tasters appreciated the F1 and F2 formulations compared to the F0 formulation. These results show that the addition of ginger at 1 % and 2 % allowed to flavor the manufactured sausages, since ginger aroma was perceived by all the tasters. Similar results were found by El-Nashi *et al.* [11] who noted that the aroma of sausages is tributary to ingredients added during manufacturing. Regarding, the overall acceptability (Fig 4b), it emerges that 53.33% rated formula F2 as the best appreciated, followed by formula F1. These results show that the addition of ginger improved the overall acceptability of the sausages. These results are similar to those reported by El-Nashi *et al.* [11], who found that the overall acceptability of sausages was improved by the addition of ginger extracts. In addition, Lamya EL Sediek, Wafaa, M.M. Abozeid, [27] reported that the addition of fresh ginger at the rate of 1% entrained a significant improvement in the overall acceptability of sausages; which could be attributed to ginger's ability to preserve the sensory characteristics of sausages.

Table 5b: Results of sensory analysis of aroma of manufactured sausages

Formulations	Sensory attributes aroma (%)			
	Flavored	Unflavored	Other	Perceived Flavor
F0	26.66	56.66	16.68	Garlic and pepper
F1	98.00	2.00	0.00	Ginger
F2	99.00	1.00	0.00	Ginger

F0: Sausage without ginger; F1: Sausages containing 1% ginger; F2: Sausage containing 2% ginger

4. Conclusion

The present study was conducted in order to evaluate the feasibility of producing ginger-roasted turkey sausages with an improved nutritional profile. Within this objective three sausage formulations, including a Control formulation (0% ginger) and an F1 formulation (1% ginger) and an F2 formulation (2% ginger) were manufactured and characterized physicochemically, microbiologically and sensorially. The results of the surveys showed that there are several types of sausages in Conakry's supermarkets and that no specific controls on these products are carried out. Furthermore, the results revealed that there are no ginger turkey sausages in these supermarkets. The microbiological analyzes of the turkey meat and ginger revealed that they conformed to the set microbiological criteria. The results of physicochemical parameters bearing on the determination of moisture, fat content, pH, total ash, protein and peroxide index showed that the addition of ginger presents a significant impact, since an evolution of the quality of sausages was observed as a function of levels in addition. Furthermore, the results showed that ginger could be considered as a natural antioxidant source in turkey sausages, since formulations containing ginger presented the lowest peroxide index values. As far as the results of the microbiological analyzes are concerned, it turned out that only Total Aerobic Mesophilic Flora and Total Coliforms were detected in the sausage samples, but in amounts lower than the microbiological criteria set for cooked sausages. The numbers of these germs significantly decreased with added levels of ginger. All other germs (Staphylococcus aureus, sulfite-reducing anaerobes, fecal coliforms and Salmonellae) were absent in the samples. The sensory analyzes showed that the addition of ginger improved the

sensory properties of the sausages, since the best appraisals were obtained for the ginger-containing formulations (F1 and F2). Still, the F2 formulation had the highest acceptability score. Based on the results obtained in this study, we can conclude that ginger can be rightly used to improve the quality of turkey sausages.

Finally, in terms of perspectives, we envision pursuing these works by manufacturing ginger-fermented turkey sausages and characterizing them at the molecular scale and performing technological calculations.

5. Author Contributions

Conceptualization, M.S; R.K.; methodology, M.L.S.; validation, H.D.; N.T; investigation, H.D.; MS; writing—original draft preparation, M.S., M.L. S. All authors have read and agreed to the published version of the manuscript

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8. Data availability

The authors confirm that data will be made available upon request.

9. Conflicts of Interest

The authors have no conflicts of interest.

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