UNIVERSITY FOR DEVELOPMENT STUDIES

EFFECT OF INCORPORATION OF LEMONGRASS OUTER LEAF POWDER ON QUALITY OF BEEF SAUSAGES

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2022

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BY

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[LONG ESSAY SUBMITTED TO THE DEPARTMENT OF AGRICULTURAL MECHANISATION AND IRRIGATION TECHNOLOGY, FACULTY OF AGRICULTURE, FOOD AND CONSUMER SCIENCES, UNIVERSITY FOR DEVELOPMENT STUDIES, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE (MSc) DEGREE IN POSTHARVEST TECHNOLOGY]

MARCH, 2022

DECLARATION

Student

I hereby declare that this thesis is the result of my original work and that no part of it has been presented for another degree in this University or elsewhere:

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I hereby declare that the preparation and presentation of the thesis was supervised following the guidelines on supervision of thesis laid down by the University for Development Studies.

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ABSTRACT

The extensive use of artificial additives and preservatives in foods and meat products in particular, has several health implications on consumers. Natural spices such as lemongrass have the potential to enhance sensory and nutritional qualities of food, including beef sausage. The objective of this study was to assess the effect of lemongrass powder produced from dried outer leaf on sensory, nutritional, physicochemical and microbial qualities of beef sausages. The lemongrass outer leaf samples were harvested 120 days after planting, and analyzed for their proximate, water activity, colour, mineral and active compounds in the fresh and dry forms. Overall, lemongrass powder samples (T2, T3, and T4) obtained from dried outer leaves and harvested at 120 days performed better than the Adobo spice (T1) as far as the afore-mentioned parameters were concerned. It was then used for sausage development at 0g (T1), 4g (T2), 8g (T3) and 12g (T4) per kg beef. The peroxide value of the lemongrass sausages ranged from 0.49±0.03 (T3) to 2.82±0.0002 (T1), pH ranged from 5.65±0.006 (T2) to 6.11±0.079 (T2), water activity ranged from 0.52±0.433 (T3) to 0.84±0.004 (T1). For colour, lightness ranged from 58.19±3.263 (T1) to 63.11±1.279 (T3), redness ranged from 5.61±0.871 (T3) to 10.61±0.928 (T1), and yellowness ranged from 14.20±0.542 (T4) to 17.03±0.993 (T3). The moisture (%), ash (%), fat (%), protein (%) and carbohydrate (%) of the lemongrass beef sausages ranged from 66.95±1.510 (T2) to 67.80±1.377 (T4), 1.88±0.114 (T3) to 2.17±0.107 (T2), 12.43±0.208 (T3) to 13.38±0.333 (T2), 14.32±0.016 (T4) to 18.32±0.211 (T1), and 0.14±0.010 (T2) to 2.44±0.1528 (T4) respectively. Also, flavonoids (mg/g), beta carotene (mg/g), total carotene (mg/g), total phenol (mg/g), anti-oxidant (%) and ascorbic acid (mg/g) ranged from 0.001±4.4E-05 (T1) to 0.03±0.001 (T4), 3.857E-04±4.7E-06 (T1) to 6.599E-04±1.7E-05 (T2),0.14±0.007 (T4) to 0.21±0.007 (T1), 2.84±0.215(T2)to 4.08±0.018 (T1), 39.74±0.738 (T1) to 54.25±0.567 (T2), and 20.76±0.952 (T1) to 51.92±0.968 (T3), respectively. The lemongrass beef sausages were scored as 6.20±1.831 to 7.28±1.568 for appearance, 6.16±1.573 to 7.08±0.954 for colour, 6.36±1.036 to 7.52±1.194 for texture, 6.12±1.301 to 7.60±0.743 for taste, 6.40±1.242 to 7.64±1.221 for mouthful and 6.88±1.092 to 8.44±0.826 for overall liking. The microbial count ranged from 1.89±0.142 (T3 on day 7) to 3.15±0.221 (T4 on day 1). The incorporation of lemongrass (outer leaf) powder in the production of beef sausage improved the flavonoids, beta carotene, antioxidant and ascorbic acid content of the beef sausages.

ACKNOWLEDGEMENTS

My deepest appreciation goes to my supervisor, Prof. Frederick Adzitey for his support, advice and encouragement in the course of doing this work. I can only say God richly bless you.

I thank my HoD, Dr. Joseph Kudadam Korese, a leader of Work Package 3 of UPGRADE Plus project, University for Development Studies for his great support through this far, God bless you Dr.

I am grateful to Mr. Alexander Abu and all the workers at UDS Meats Processing Unit who helped in making this work a success.

Marvelous appreciation goes to all my laboratory mates, Albert Abugri and Matthew Atongbiik Achaglinkame for their motivational support through it all.

My final thanks goes to my enter family especially Prof. Josephine Nketsia-Tabiri for her financial support, prayers and sacrifices. Your advice was a key to the successful completion of this work.

DEDICATION

This work is dedicated to my late grandmother Margaret Biney and my daughter Stephanie Nyameyie Aba Bentsiwa-Biney and my lovely Esther Gadzi.

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LIST OF ACRONYMS

LG	Lemongrass
BH	Butylated hydroxytoluene
BHA	Butylated hydroxyanisole
FG	Fever Grass
MC	Monocotyledonous
AMPRS	Aromatic and Medicinal Plants Research Station
CIMA	Central Institute of Medicinal and Aromatic Plants
RRL	Regional Research Laboratory
CWCP	Crop-weed Competition Period
KG	Kilogram
VAM	Vesicular Arbuscular Mycorrhiza
EO	Essential Oil
IW	Irrigation Water
CPE	Cumulative Pan Evaporation
CWC	Crop-Weed Competition
LO	Lipid Oxidation
WOF	Warmed Over Flavor
A.O.A.C	Association of Official Analytical Chemists
NaOH	Sodium Hydroxide
FAAS	Flame Atomic Absorption Spectroscopy
HCL	Hollow Cathode Lamp
BAC	Bioactive Compound
OD	Optical Densities
CIE	Commission Internationale de l'Eclairage
BSI	British Standard Institution Guidelines
a_w	Water Activity
PDA	Potato Dextrose Agar
PCA	Plate Count Agar
DR	Drying Rate
MC	Moisture Content
L*	Whiteness
a*	Redness
h*	Hue
b*	Yellowness
C*	Chroma
ΔE*	Overall Colour Change

CHAPTER ONE

INTRODUCTION

Lemongrass is a perpetual grass plant generally appropriated around the world, and most particularly in tropical and subtropical nations (Olorunnisola *et al*., 2014). As the name recommends is plant distinguished by its trademark light lemon aroma due to the unstable oils found in the plant (John and Mujaffar, 2018a). It is developed over an area of 16,000 ha all through the world and produces around 1000 tons of rejuvenating ointment each year (Haque *et al*., 2018; Thomas, 2016). The bulbous stem of lemongrass comprises of terete and glabrous leaf sheaths with direct edge, restricted base and intense peak, comparing 100cm long and 2 cm in width (Saleem *et al*., 2003). At the point when the new leaves of lemongrass are pressed, they produce yellow or golden shaded fragrant natural ointment (Agbaje *et al*., 2007). The contents of this oil vary with the age of the grass. According to Bleasel *et al.* (2002) and Rashid *et al*., (2016), fresh lemongrass contains 0.67% of essential oil, which has substantial amount of citral, and dry lemongrass yields 0.4% essential oil containing 72.3% citral. The broad utilization of counterfeit added substances and additives in food varieties and meat items is getting bunches of blended sentiments from purchasers for wellbeing reasons. Malignant growth, hypertension and corpulence are noticed to be related with a percentage of these added substances and additives due to the existence of manufactured cancer prevention agents, for example, butylated hydroxytoluene and butylated hydroxyanisole (Lawrie *et al*., 2006). Albeit manufactured cell reinforcements have proactively been utilized yet lately, the interest for normal cancer prevention agents have expanded essentially as a consequence of antagonistic impacts of engineered cell reinforcements (Shah *et al*., 2014).

Removes from plant materials are wealthy in phenolics and give a decent option in contrast to manufactured cancer prevention agents. Grape seed, green tea, pine bark, rosemary, pomegranate, vex and cinnamon have displayed comparative or better cancer prevention agent properties contrasted with a few engineered ones (Shah *et al*., 2014). Regular cell reinforcements from plant extricates have been gotten from various sources like natural products (grapes, pomegranate, date, kinnow), vegetables, (broccoli, potato, pumpkin, curry), and spices and flavors (tea, rosemary, cinnamon, ginger) (Carthy *et al*., 2001; Kanatt *et al*., 2008; Mansour and Khalil, 2000; Mccarthy *et al*., 2001; Shah *et al*., 2014). Regular plants can hinder oxidative rancidity and postpone the improvement of off-flavor in certain items (Zaki *et al*., 2018). Sausage are meat items ordinarily produced using minced meat, either hamburger, pork or chicken with flavors, salts, flavors, extenders in addition to fillers (Abdolghafour and Saghir, 2014). In Ghana, local spices, herbs and extract from plant have been incooperated towards the creation of sausages (Abu *et al*., 2020). Since the last five years, lemongrass has already been used to replace lemon-peel in sausage industries in Germany (Malenica and Bhat, 2020). This as a result of the fact that lemon-peel has high pesticide residue which is absent in lemongrass because of its powerful natural aroma(Khan *et al*., 2014).Lemongrass also contains several important bioactive chemicals discovered in the leaves (Olorunnisola *et al*., 2014). Such mixtures incorporate phenolics and flavonoids are two types of flavonoids that have wide natural movement with relevance in a small regions due to their belongings as cancer prevention agents, antitumor, antiviral, calming, anti-microbial and allopathic (Boeira *et al*., 2018). These advantages can be harnessed when lemongrass is use in making sausage production(Bosch *et al*., 2018)

1.1 Problem Statement and Justification

Consumers worldwide enjoy meat and meat products. However, this is hampered by the health-related issues such as hypertension and cardiovascular diseases, which are linked to the consumption of meat products. These health-related concerns It is possible to reduce the amount of meat consumed significantly by producing health benefit meat products. This can be achieved by incorporating antioxidants and other beneficial nutrients to meat products. The leaves of lemongrass (Cymbopogon citratus) are known to possess phenolic compounds with strong antioxidant properties (Anggraeni *et al.*, 2018). It has therapeutic characteristics and can be used in Ghana to treat fevers, malaria, and other health problems (Rashid, 2016). Also, Thorat *et al*. (2017) reported that lemongrass has an exceptionally wide interest in healthful, therapeutic and seasoning industry, yet it isn't put away as new for long time at surrounding condition since it decays after extensive stretches. Drying is an important step in protecting lemongrass leaves and transforming them into value-added products (Mujaffar and John, 2018). Drying spices preserves their flavour by reducing moisture content, which inhibits the growth of microbes and allows for synthetic modifications during the drying process (Díaz-Maroto *et al.*, 2004). Lemongrass' cancer-prevention characteristics and medicinal benefits justify its use in the production of potentially healthy beef sausages, which is the study's goal.

1.2 Main Objective

- To determine the impact of lemongrass powder produced from dried lemongrass outer leaf on sensory, nutritional, physiochemical and microbial qualities of beef sausages.

1.3 Specific Objectives

i. To determine the tactile properties of beef sausages incorporated with lemongrass powder made from dried outer leaf.

ii. To determine the nutritional qualities of beef sausages prepared with dried lemongrass outer leaf powder.

iii. To determine physiochemical properties of beef sausages prepared with dried lemongrass outer leaf powder.

iv. To determine the total microbial load of beef sausages prepared with dried lemongrass outer leaf powder.

CHAPTER TWO

LITERATURE REVIEW

2.1 Lemongrass (Cymbopogon citratus)

Lemongrass is a fragrant herb notable for its flavoring or culinary, restorative and helpful uses (Wifek *et al*., 2016). The name lemongrass was coined from the ordinary lemon-like smell of the rejuvenating oil found in the shoot (Preedy, 2016). The spice started from Asia and Australia (Sakulnarmrat and Konczak, 2012); and it is best observed throughout Asian, Thai and Vietnamese culinary (Daniel, 2006). Lemongrass is announced to be one of the spices that has gone along the flavor course from Asia to Europe (Joy *et al.*, 2006). Lemongrass can be used new, dried, or powdered for flavors and teas. In the Caribbean, lemongrass (Cymbopogon citratus) is alluded to as "fevergrass" since the new leaves is utilized as tea to prevent fevers (Shahzadi, 2017). Lemongrass leaves are wealthy in aldehyde citral, which is estimated to be about 78 to 83% (Daniel, 2006). It contains rejuvenating ointment that has a lot of restorative purposes, and can likewise be used as a bug repellent (Mujaffar and John, 2018). Lemongrass oil is famously known as Cochin oil on the planet exchange, since 90% of it is sent from Cochin port (Jimayu, 2017). According to Nambiar and Matela (2012), lemongrass leaves contain phenol compounds which are rich in antioxidants. The plant creates from the vegetative to the regenerative stage towards development (Joy *et al*., 2016).

2.2 Botanical and Taxonomical Description of Lemongrass

Lemongrass is a monocotyledonous perennial grass which can grow up to 1.38 m in height, 1.22 m in thickness and in clusters (Nambiar and Matela, 2012). The leaves are bright green, long, slender, and drooping which measures about 0.013-0.025 cm in width and 0.91 m in length (Ranade, 2015). Lemongrass has simple leaves with entire margins. The flowers grow on spikes and has long inflorescence between 0.03-0.06 m in length (Gawali and Meshram, 2019). The name 'Cymbopogon' was obtained from its floral arrangement (Ravinder *et al*., 2010; Shah *et al.*, 2011; Srivastava *et al.*, 2013).

Taxonomic details of lemongrass as stated by Shah *et al*. (2011) is shown below:

Kingdom: Plantae

Division: Magnoliophyta

Class: Liliopsida

Oder: Poales

Family: Poaceae

Genus: Cymbopogon

2.3 Morphological Description of *Cymbopogon citratus*

Cymbopogon citratus is also referred to as West Indian or American lemongrass (Peter, 2012). It's a non-stemmed, long-lasting grass, but with various firm turners which arise from short rhizomatous rootstock, making huge tussocks (Olorunnisola *et al*., 2014). Occasionally, lemongrass flowers under cultivation(Silva *et al*., 2008). It has a limited

width leaf blade, straight, glaucous, hanging with unpleasant edge, ligule shorten, inflorescence seldom created, and a huge free panicle (Joy *et al*., 2001).

2.4 Varieties of Lemongrass Released

Patra *et al*. (2000) reported the release of SB-9. Subsequently, Farooqi and Sreeramu (2001), reported lemongrass assortments delivered for development. Sugandhi, Pragati, Praman, RRL-16, CKP-25, RRL-39, Kavery, Krishna, SD-68 are among them and GRL-1. Sugandhi (OD-19) was delivered by Odakkali, Kerala, India's Aromatic and Medicinal Plants Research Station (AMPRS). It's a red stemmed variety adapted to a wide range of soil and climatic conditions, and it's especially popular in India. It is accounted for that under downpour took care of conditions the plant can accomplish a tallness of 1-1.75 m with bountiful tillering whiles yielding around 35-40 t/ha/year spice consisting 0.4% oil (125 kg/ha) with 75-95% citral (Farooqi and Sreeramu, 2001).

The variety, Pragati (LS-48) is said to have advanced through clonal determination from OD-19, the Central Institute of Medicinal and Aromatic Plants (CIMAP) is a research institute dedicated to the study of medicinal and aromatic plants, Lucknow, India (Prajapati *et al*., 2020). It is depicted as a tall developing spice with dim purple leaf sheath, adjusted to subtropical and heat and humidity (Hyun *et al*., 2019). It is reported to have an normal oil content of 0.72% with 95% citral content (Thekkan and Paulsamy, 2018). Another variety developed from CIMAP is Praman Clone 29, it developed through clonal determination and has a place with animal groups Cymbopogon pendulus (Gupta *et al*., 2018). It is a tetraploid which tillers profusely (Alamgir, 2017). The leaves stand upright and minimum in size (Singh and Katoch, 2020). Oil yield is assessed to be about 227 kg/ha/annum with 82% citral content (Tuttolomondo *et al*., 2020). In addition, the

CIMAP Reginal Station in Bangalore, india, released Kavery and Krishna varieties (Prajapati *et al*., 2020). RRL-16 is one more Cymbopogon pendulus-inferred assortment that was delivered for development by the Regional Research Laboratory (RRL) in Jammu, India. (Sharma *et al*., 2017). It creates a normal spice creation of 15 to 20 t/ha each year, yielding 100 to 110 kg oil (Prajapati *et al*., 2020). The oil focus goes from 0.6 to 0.8 percent, with around 80% citral content.(Viktorová *et al*., 2020). SD-68, created by S.C. Datta with the assistance of ionizing radiation, is fit for delivering up to 375 kg of oil for each hectare each year, with a citral content of 90-92 percent. (Kasi and Ramasubbu, 2021; Kassahun and Mekonnen, 2017; Li *et al*., 2020; Olorunsanya *et al*., 2014). It is one more high yielding assortment, created by efficient rearing for hereditary improvement at Pantnagar, Chirharit, India. It is impervious to ice, and the rejuvenating balm contains 81% citral. There are about 406 accessions of lemongrass germplasm conserved at AMPRS, Odakkal (Adhikari *et al*., 2015; Skaria, 2015). Moreover, it is reported by Joy *et al*. (2006) that there are 17 unique germplasms in which citral isn't the fundamental element of the oil.

2.5 Cultivation of Lemongrass

Generally, lemongrass is known to be propagated by seed (Rochfort *et al*., 2008). According to Mao (2019), the seed is mixed in a 1:3 proportion with dry stream sand and cultivated at a pace of 20 to 25 kg/ha in the field. Seedlings can likewise be developed in a nursery for 45 days prior to being relocated. This technique requires around 3-4 kg seeds for each hectare and is great for accomplishing a uniform stand and higher plant development. (Moore *et al*., 2013). Joy *et al*. (2006) reported that seeds are utilized to proliferate Cymbopogon flexuosus, while tussock division is utilized to spread

Cymbopogon citratus. When contrasted with seed spread, vegetative engendering by picked clones is believed to be unrivaled (Essola *et al*., 2017). Seed spread considers huge hereditary inconstancy, which prompts an abatement underway and oil quality(Sudarić *et al*., 2019). In the spread of lemongrass, clonal multiplication is exceptionally critical. Lemongrass seeds go torpid following half a month and lose reasonability following a couple of months(Meerow and Broschat, 2017). Subsequently, seeds reaped in January-February are regularly planted in the nursery in April-May. Seeds are scattered consistently over nursery beds at a pace of 3-4 kg/ha and covered with a flimsy layer of soil. The seed bed is habitually wateredfor 5-7 days(Joy *et al*., 2006). During the dry season, inundate the harvest each and every day for about a month in the wake of planting. For ideal yield, 4 to 6 water systems are informed between the months concerning February to June in tropical circumstances. Crop advancement, herbage, and rejuvenating balm yields were significantly helped when soil dampness systems were supported at 0.80 IW: CPE proportion. The nature of rejuvenating balm, then again, is unaffected by soil dampness systems(Joy *et al.*, 2006).

The initial 25-30 days in the wake of planting is named crop-weed contest period (Neve *et al*., 2003). During an effective harvest foundation, the field ought to be without weed for the initial 3-4 months following planting(Kruidhof *et al*., 2008). After the establishment stage, crop can compete well with weeds (Ahmed *et al*., 2021). Within a year, generally, weeding 2-3 times is necessary (Butsenko *et al*., 2021). During the summer, from December to May, The field gives off an impression of being evaporated under rain-fed conditions (Cui *et al*., 2021). The dry grass and stubbles of the harvest is scorched before the beginning of stormy season (Goulding *et al*., 2021). The termites are

killed because of this training attacking crop stubbles and for the old clumps, an avenue for rejuvenation (Joy *et al*., 2006; Kruidhof *et al*., 2008). The plant is intolerant to shade and when grown under diffused light, oil yield is reduced drastically (Teles *et al*., 2021).

2.6 Growth Conditions

Lemongrass is known to grow well in bright, warm, sticky states of the jungles (Balakrishnan *et al*., 2014). According to Utara (2017), it produces most noteworthy oil yield per ton of herbage where the precipitation midpoints 2500-3000mm every year, but *Cymbopogon citratus* is likewise dry spell lenient. In regions where precipitation is poor, it very well may be developed with supplemental water system. Day temperature of around 25-30°C is viewed as ideal for greatest oil creation, without incredibly low night temperature (Mukamuhirwa *et al*., 2019).

Lemongrass thrives in various kinds of soil going from rich topsoil to unfortunate laterite (Prajapati *et al*., 2020). In sandy topsoil and red soils, it requires great manuring (Cai *et al*., 2018). It can't be developed on soils that are excessively calcareous or excessively wet as reported by Farooqi and Sreeramu (2001).

The two species of lemongrass (*Cymbopogon citratus* and *Cymbopogon flexuosus*). It is expressed that legitimate waste is the main part in developing it on a scope of soils (Ullah *et al*., 2020). Lemongrass leaf oil yield and citral fixation are expanded in sandy soils. Even though *Cymbopogon flexuosus* prospers in very much depleted sandy loamy soils, it is filled in essentially a wide range of land accessible from extremely light sandy soil to upland laterites in India. Soils of pH from 5.5 to 7.5 are utilized. *Cymbopogon citratus* is for the most part developed on soils more acidic than *Cymbopogon flexuosus*. In India, it reported that the highest grass yield and oil yields per hectare of *Cymbopogon flexuosus*

are accomplished in soils of pH 7.5 (Atawodi *et al*., 2017; Munda*et al*., 2020). On highly saline soils, lemongrass produces an average herbage and oil yields (Ghasemi Pirbalouti *et al*., 2019). In a pot experiment, *Cymbopogon flexuosus* developed in soils with electrical conductivity of 11.5, 10 and 5.5 mmhos/cm showed no critical lessening in spice and oil yield (Pandey *et al*., 2020). The citral content was likewise not impacted by expanding saltiness levels up to 15 mmhos/cm (Joy, Skari *et al*., 2006).

2.7 Growth Stage or Harvest Time of Lemongrass on Biomass and Essential Oil Yield

In fragrant yields, the substance organization of the rejuvenating ointment is connected with the age of the leaves, in this manner focusing on the significance of the development stage at which they are collected (Motsa *et al*., 2006). Gora *et al.* (2002) and Sangwan *et al.* (2001) reported that medicinal oil yield and sythesis change with formative phase of the entire plant, plant organs and cells. In harmony with this report, Ramezani *et al*. (2009) additionally revealed that reaping phase of the plant impacts the amount and nature of rejuvenating oil in most medicinal balm bearing plants. For biomass yield of *Ocimum tenuiflorem*, Kothari *et al.* (2004) proposed that it was more noteworthy in the main collect and steadily declined in ensuing harvest. They likewise added that the techniques for reaping had no critical impact on the yield of biomass. Going against the norm, the oil content is lower in the main reap with expanded biomass yield. In any case, the medicinal ointment expanded slowly in the ensuing harvests to arrive at most extreme in the fourth gather. Research by Motsa *et al.* (2006), showed that the sweet-smelling plant oil arrangement and creation are oftentimes modified during the reaping and post-collecting tasks. The reaping age significantly affected new biomass (g/plot), new

herbage yield (kg/ha), dried herbage yield (kg/plot), and medicinal oil yield (kg/ha), as per the review. What's more, the age at which lemongrass was gathered considerably affected the quantity of turners/plants. Assortments altogether affected the quantity of turners/plants, longest leaf length, new biomass/plant, new herbage yield kg/plot, dry herbage yield kg/plot, and natural oil yield kg/ha, as well as rejuvenating ointment content, as indicated by an examination of change. The base rejuvenating ointment yield was estimated at 45 days subsequent to planting for both lemongrass cultivars (Lomisar-UA and Lomisar-Java). (Maswal and Dar, 2014a). As the gathering age term delayed from 45 to 105 days subsequent to planting, the rejuvenating balm yield was expanded (van Beek and Joulain, 2018).

On fresh herbage, yield values recorded increased by 66.13% While reaping age span was reached out from 45 to 105 days in the wake of planting, the yield was 242% (Lomisar-UA) and 242 percent (Lomisar-Java) (Jimayu and Gebre, 2017). The most noteworthy worth of dry herbage yield was recorded at gathering age of 105 days subsequent to planting; though, the base worth was gotten from reaping age of 45 days in the wake of planting for the two assortments (Tufail *et al*., 2020). These results were attributed to the positive correlation between dry herbage yield and fresh biomass (Jimayu and Gebre, 2017).

2.8 Pests of Lemongrass

Not many bugs are accounted for in lemongrass (Joy *et al*., 2006). Joy *et al*. (2006) reported the infestation of lemongrass because of the shaft bug (Clovia bipunctata). A Chilotrea stem-exhausting caterpillar has hurt sp. have been observed (Follak *et al*., 2016). Nematodes, for example, *Tylenchorhynchus vulgaris, Rotylenchulus reniformis*,

Helicotylenchus spp., and Pratylenchus spp. have been accounted for to contaminate grass (Ulrich and Ziebert, 2008). Table 2.1 shows the common diseases of lemongrass and their casual agents.

Table 2.1: Common dieases of lemongrasss and their causal agents

Disease	Causal organism
Little leaf malformation of inflorescence)	*Balensia sclerotic* (Pat) Hohnel
Smut	*Tolyposporium christensenni* *Ustilago andropogonis*
Root rot	*Botrydiplodia theobromae*
Leaf spot (eye spot)	*Helminthosporium saccharii,* *Helminthosporium leucostylum,* *Drechslera victoria* *Drechslera helm*
Leaf spot and clump rot	*Fusarium equiseti* *Fusarium verticillium*
Leaf spot	*Curvularia andropogonia* (CLS)
Leaf spot	*Curvularia veruciformis,* *Curvularia trifolii* *Collitotrichum graminicola*
Leaf blight Leaf blight Grey blight	*Curvularia andropogonia* (CLB) *Rhyzoctonia solani* *Pestalotiopsis magniferae*

Source: Joy *et al*. (2006)

A physiological disease known as brown top disease is caused as a result of the low water content of the grass toward the finish of the dry season (Gutiérrez-Gamboa *et al*., 2020). The leaves affected become brown and curly (Kamyab *et al*., 2015). *Puccinia nakanishikii* is the causal organism of rust disease (Kassahun *et al*., 2014). Stretched appendages are one of the side effects, On the two sides of the leaf surfaces, there are striped, dull earthy colored flaws. (Poschenrieder *et al*., 2019). Root zone of lemongrass are intensely swarmed with various vesicular arbuscular mycorrhiza (VAM)(Eke *et al*., 2020). Moreover, brown septate hyphae of non-mycorrhizal parasite additionally existed together with VAM in half of root zone (Seerangan and Thangavelu, 2014). A common practice of warding off pests, diseases and weeds is burning of stubbles in summer (Hunt *et al*., 2016).

2.9 Harvesting of Lemongrass

Harvesting of lemongrass leaves was done for several purposes (Thakur *et al*., 2020). The grass is harvested by cutting it about 0.01 m with the guide of sickles or a blade, over the ground level (Jones and Tracy, 2018). The times the grass is collected in a year is subject to climatological factors like temperature, precipitation, dampness and level of soil ripeness (Karbivska *et al*., 2020). For the most part, the yield fills best in sticky condition (Martínez *et al*., 2017). Because wet grass ferments quickly when left for a period, cutting can start when the night dews have dissipated from the plants (Nilsson *et al*., 2017). It is however, preferable to harvest on sunny days, since shady and foggy circumstances will generally diminish leaf oil content (Joy *et al*., 2006). First collect might be at 90 days in the wake of planting (Ahmed *et al*., 2020).

In this manner, reaping can be at 50-55 days' span, up to 5-6 years from a similar harvest. During the main year of planting, three harvests are acquired and subsequently 5-6 reaps each year. The long stretch of May starts the gathering season and go on till the finish of January. Around, herbage yield of around 10-15 t/ha/gather might be acquired.

Lemongrass developed for seed intention is not cut, since the yield of seeds from plants consistently collected is exceptionally low (Beya *et al*., 2021). For the most part, November to December denotes the blooming of the plant and mature seeds are gathered during January or February (Kasi and Ramasubbu, 2021). A sound lemongrass plant might create 10 to 20 g of seeds. The entire inflorescence is gathered and dried in the sun. The seeds are then gathered by beating against the floor or hitting it with sticks. Seeds lose viability after six months of storage hence it is advisable for fresh seeds to be used in raising a plantation. Seed germination is supposed to be low until May, then, at that point, improves until July, then, at that point, declines. After October, germination is low(Joy *et al*., 2006).

2.10 Physicochemical Properties of Lemongrass

Lemongrass, whose natural balm is utilized as enhancing inferable from its lemon fragrance is boundless (Maswal and Dar, 2014). Among other compounds, natural oil, or citral, is the most predominant fixing in lemongrass (Tak *et al*., 2017). The amount of geranial (trans-citral or citral A) and neral (cis-citral or citral B) in this mixture determines the quality of essential oils. Essential oils build up in particular oil cells found in the parenchyma tissues of lemongrass leaves (Do Nascimento *et al*., 2020). The medicinal ointment is likewise utilized in scent and restorative enterprises (Manvitha and Bidya, 2014). According to Saroj (2018), the rejuvenating oil confined from flying parts

(leaves) of lemongrass is yellow to ruddy brown in shading and the aroma is strong lemon like. Factors like temperature, light force, soil dampness, compost, and development stage impact the medicinal ointment and citral substance (Mahmoud *et al*., 2018).

2.11 Medicinal Properties

Manvitha and Bidya (2014) reported that newly cut and to some degree dried leaves are utilized for medicinal purposes, and are the wellspring of the medicinal oil. Cymbopogon citratus has different pharmacological properties including hostile to amoebic, against bacterial, hostile to diarrheal, against filarial, against parasitic and mitigating properties. In East India and Sri Lanka, where it is designated "fever tea," lemongrass leaves in mix with different spices is utilized to treat fevers, sporadic monthly cycle and stomach throbs (Moosavi *et al*., 2015). In Brazil and the Caribbean, lemongrass is one of the most popular herbs for nervous and digestive problems (Tilaye *et al*., 2018). The indians lemongrass in a comparative design, to treat migraines, stomachaches, colds and rheumatic agonies (Poddar *et al*., 2020). The rejuvenating ointment is utilized in India to treat ringworm or in a glue with buttermilk to rub on ringworm and injuries (Zahara *et al*., 2020). It annihilates many sorts of biomaterial and growths, and is an antiperspirant (Azelee *et al*., 2020). Generally, it is taken as tea for fevers, hacks, colds, and as a charming tonic or drink (Van Wyk and Gorelik, 2016). It advances sweat and discharge of mucus, and facilitates stomach cramps (Periyasamy *et al*., 2020).

2.12 Harvest Time of Aromatic Plants on Biomass and Essential Oil Yield and Quality

A study by Gulcan *et al.* (2010) on the impact of reap time on medicinal balm creation, phenolic constituents and cell reinforcement properties of Turkish oregano (Origanum onites L.) showed that, the yield and carvacrol content of rejuvenating ointments and rosmarinic corrosive substance, absolute phenolics, decreasing/cancer prevention agent limit and free-extremist rummaging exercises of oregano separates recorded greatest qualities toward the finish of blooming to the start of organic product set stage. Finishing up on the review, Gulcan *et al.* (2010) reported that all yields, substance organizations, free extremist rummaging exercises and diminishing/cell reinforcement limits of concentrates and rejuvenating balms were influenced by the vegetative periods of growing season in Turkish oregan.

In lemon analgesic (Melissa officinalis L.), the impacts of gather stage and year had critical effect on new spice yield (Avci and Giachino, 2016). The composition of essential oils was significantly affected by the harvest stage, and harvest stage and year interaction (Emami Bistgani *et al*., 2017). The plant stature, new spice yield, dry spice yield, dry stem yield and rejuvenating balm content were fundamentally impacted by collecting stages. In the same study, it is reported that collecting at brilliance stage was the best stage for acquiring the most noteworthy medicinal oil content and new spice yield (Yanqun Li *et al*., 2020). Primary parts of the lemon not entirely set in stone as E-Citral, Z-Citral and Caryophyllene oxide (Kittler *et al*., 2018). Notwithstanding, it is recommended that the post-brilliance stage is not proper for reaping for the most noteworthy E-citral content (Avci and Giachino, 2016).

2.13 Drying of Plant Biomass

Drying is a typical and fundamental strategy for postharvest protection of therapeutic plants as it considers the speedy conservation of the restorative properties of the plant material in an unsophisticated way (Chen *et al*., 2016). Saving the dynamic fixings in restorative and zest plants by and large requires low drying temperatures (Jin *et al*., 2018; Karima *et al*., 2016). Due to this, the drying time becomes relatively long with low energy efficiency (Babu *et al*., 2018; Dolgun *et al*., 2020). Moreover, execution of drying has imposing effect on the quality of the product as well as its worth. Ideal blend of dryer plan, functional strategy, energy use and quality support of the item requires basic administrative choices (Müller, 2007). Restorative plants can be dried in various ways, including the outside (concealed from direct daylight); put in dainty layers on drying outlines, wire-screened rooms or structures; by direct daylight; in drying stoves/rooms and sun oriented dryers; by aberrant fire; microwave; or infrared gadgets (Müller and Heindl, 2006). Temperature and dampness should be controlled when conceivable to stay away from harm to the dynamic substance compounds (Chen *et al*., 2020). The technique and temperature utilized for drying may extensively affect the nature of the subsequent therapeutic plant materials. Substance changes are the most significant in the post-collect of restorative plants and can impacted by dry. Also, changes like the item appearance (shading) and smell, the last quality can advanced by drying (Aboltins and Kic, 2016).

To find the ideal drying span, it is important to get the vehicle instruments which happen inside and on the outer layer of the item (Feng *et al*., 2012). The drying system is portrayed by the presence of transport components like surface dissemination, unadulterated dispersion, slender stream, dissipation, thermo-dispersion, and so on (Xiao

et al., 2014). For lemongrass leaves, drying is a key stage in its protection and in the further handling of the leaves into esteem added items (Mujaffar and John, 2018). Kassem *et al*. (2006) and Lonkar *et al.* (2013) reported that there are restricted examinations on lemongrass which utilizes customary bureau or stove drying. Most works have zeroed in on the drying of leaves in a sunlight based dryer and different dryers, for example, fluidized bed dryer, heat siphon dryer, consistent temperature and dampness chamber, biomass dryer, and a decent bed dryer (Coradi and Melo, 2014; Fudholi *et al*., 2012; Kassem *et al*., 2006; Rahman *et al*., 2013; Waewsak *et al*., 2006).

According to Mujaffar and John (2018), expanding temperature from 40 to 60°C brought about an emotional decline altogether drying time, expansion in drying rate, and lessening in harmony dampness content of leaves. Expanding temperature from 40 to 60°C brought about a normal reduction altogether drying season of 71% (John and Mujaffar, 2018; Xiao *et al*., 2014). By and large, the normal harmony dampness upsides of leaves dried at 40°C were around 35% higher than the normal incentive for leaves dried at 50°C (Barbosa *et al*., 2008), and The average value for leaves dried at 60°C was 80% higher (Therdthai and Zhou, 2009).

2.14 Impact of Drying Temperature on Active Ingredients

Drying temperature ought to be decided to be pretty much as high as conceivable without diminishing the nature of the item as required (Kumar *et al*., 2014). Greatest reasonable temperatures rely basically upon the substance structure of the dynamic elements of the therapeutic and zest plant species being referred to (Aćimović *et al*., 2019). An example of the impact of drying temperature on decrease of aggregate essential oil content during convective drying is reported for *S. officinalis* (Hamrouni-Sellami *et al*., 2013).

Rejuvenating balm decrease versus dampness content during drying at 60 and 90°C (Farahmandfar *et al*., 2020). For drying at 90°C, rejuvenating ointment misfortunes of 11% happened when the dampness content came to 40%, and misfortunes were 90% when balance was reached (Müller, 2014). For drying at 60°C, no misfortunes of rejuvenating oil happened until a dampness content of 10% was reached, however expanded to half while moving toward balance dampness content (Yogendrarajah *et al*., 2015). Misfortunes of natural balm happened for arriving at a last dampness content of 11% and for arriving at balance dampness content (de Aquino Brito Lima-Corrêa *et al*., 2017). Clearly up to a temperature of 50°C no misfortunes in natural balm happened; even on account of over-drying to harmony dampness content (Müller, 2007).

As a result of the volatile nature of medicinal balms, a positive connection between temperature of the drying air and loss of natural oils can be hypothesized (Müller, 2007). For *Chamomilla recutita, Cympogon citratus, Lipia alba* and *Rosmarinus officinalis* the losses of essential oils have been moderate even at a high temperature of 80°C (Luna *et al*., 2019; Mutlu-Ingok *et al*., 2020; Nieto, 2017). However, the misfortunes are not in all cases consistently expanding with temperature. Arabhosseini*et al.* (2006) reported a deficiency of 63% at 45°C which expanded to 75% at 60°C however diminished again to 36% at 90°C in Artemisia dracunculus. After capacity for a long time the misfortune at 90°C expanded to 74%, while the extra misfortunes during capacity were extensively lower for the lower drying temperatures (Arabhosseini *et al.*, 2007). This demonstrates that medicinal balms step by step dissipate from the plant framework during capacity after the oil organs have been impacted by high temperatures during drying (Haqqyana *et al*., 2020). Dynamic fixings other than natural oils show less aversion to temperature

(Ikbal and Pavela, 2019; Qin *et al*., 2017). Acemannan, a starch in Aloe barbadensis was just tolerably impacted by temperatures up to 80°C (Femenia *et al*., 2003). The same is reported that in *Hypericum perforatum*, parthenolide (a sesquiterpene lactone) in *Tanacetum parthenium*, and alkylamides in *Echinacea purpurea*, hypericin (an anthraquinone subordinate) is found (Hevia *et al*., 2001; Martinov *et al*., 2007; Rushing *et al*., 2002). As stated by Hevia *et al*. (2001), drying temperature and formative stage at collect impact the parthenolide content of feverfew leaves and stems. Low drying air temperatures of even 30° C resulted in spoilage of the product *E. purpurea* because of the deferred drying (Hodgkins *et al*., 2018; Ikbal and Pavela, 2019). Hence, high drying air temperatures were preferable (Shishir and Chen, 2017).

2.15 Impact of Drying Temperature on Colour

As numerous therapeutic plant species are utilized as tea and food additives, shading is a fundamental quality standard since it is straightforwardly clear to purchasers. The CIELAB system for shading estimation is habitually applied utilizing daintiness, chroma and tint as boundaries (Hejna *et al*., 2020). In a review where these boundaries were looked at, tint demonstrated best to address quality as far as shade of dried *A. dracunculus* (Arabhosseini, 2005). For *S. officinalis*, a particular tone degradation was apparent while the drying air temperature was expanded from 50 to 55°C, which was likewise perceived by a reduction of tone from 112 to 87 degrees (Munné-Bosch and Vincent, 2019). This implies that tint was transforming from the green to the red quadrant, demonstrating the cooking that was likewise outwardly obvious (Gómez *et al*., 2010). For Ocimum basilicum, a steady diminishing of tone from 96 to 91 was noticed for an expansion in drying air temperature from 35 to 50 °C (Le Anh Dao *et al*., 2020).

2.16 Lemongrass Agronomic and Chemical Characteristics as Influenced by Spacing and Variety

According to Jimayu *et al*. (2016), variety had a significant affected by the quantity of tillers/hill, number of leaves/tillers, leaf length, new biomass/slope, new herbage yield/ha, and dry herbage yield/ha are immeasurably significant variables to consider.. Similarly, spacing had a substantial impact number of turners/slopes, leaf length, new biomass/slope, new herbage yield/ha, natural ointment yield/ha, dry biomass/plant and dry biomass yield/ha. Communication of separating and assortment likewise impacted number of turners/slopes, on new herbage yield/ha, medicinal ointment content and natural balm yield/ha (Jimayu *et al*., 2016).

2.17 Meat Processing

Further handling of meat offers the occasion to add esteem, decrease costs, improve sanitation and broaden the timeframe of realistic usability (Santo *et al*., 2020). This can bring about expanded family pay and improved sustenance (Amaya-Lara, 2016). While meat consumption per capita is substantial in some developed countries, it is less than 10 kg in non-industrialized countries, which is seen as inadequate and frequently leads to malnutrition and hunger (Weis, 2013). Meat preparation is pointed toward overcoming any barrier in expense of meat items, increment in sizes and expansion of capacity of meat items (Barbut, 2020). Items from meat preparing ventures are broadly acknowledged by meat buyers because of the expanding interest for quick and advantageous dinners (Gómez *et al*., 2020; Thomas *et al*., 2020). The after job is of specific significance since both the utilitarian qualities displayed , meat protein can be substituted by recreated or thought about by some other food protein (Amaral *et al*.,

2018; Scollan *et al*., 2017; Zaini *et al*., 2020). It is estimated that there are 800 million malnourished people in the world (Pérez-Escamilla, 2017). Giving protected, nutritious, and healthy nourishment for poor and undernourished populaces is significant (Chibarabada *et al*., 2017). Protein-energy unhealthiness is among the most difficult issues looked by non-industrial nations today (Rahimmalek *et al*., 2013; Wells, 2012; Wells *et al*., 2018).

Meat is ready for utilization from multiple points of view, for example, meat that has been smoked, boiled, and dried like hamburger jerky, steaks in stews, Ham and sausage (Dong *et al*., 2020). Some meat are processed by smoking, salting or drying to increase it life span and usability (Fraqueza *et al*., 2020). Many additionally seasoned with flavors like cinnamon, garlic paprika and different flavors (Lorenzo *et al*., 2014; Lorenzo *et al*., 2014; Oswell *et al*., 2018). Comminution is the method of lessening entire muscle to little particles (Abrar *et al*., 2016). The degree of comminution shifts among different prepared items (Abdollahi and Undeland, 2019). It goes comminuted from coarse to fine, to frame a mixture or glue cheap expansion of flavors (Ong *et al*., 2020). Meat decorations, meat pieces and greasy tissues that would otherwise be discarded are comminuted and seasoned to create delicious meat products (Alter and Sharma, 2016).

2.18 Sausages

Of the multitude of different prepared meats, sausage also referred to as hotdog is the most tempting and generally used (Ghamrawy, 2019). The name "sausage" comes from the Latin word salsus, which meaning "salted meat." (Jaminyasa *et al*., 2017). A few elements added to make creation hotdog and atmosphere is the major significant factor for the advancement of district explicit new and dried wieners (Patel *et al*., 2018).

Districts with particular seasons utilized various methods to protect meat (Bersisa *et al*., 2019). The smoking cycle was created to safeguard hotdogs during the hotter seasons (McCurdy Sandra *et al*., 2009). Dry wiener, which does not need any refrigeration, was made in hotter areas (Liener *et al*., 2003). A few wieners got related with their nation or city of beginning. A genuine model is Bologna, which started in the northern Italian town of Bologna (Reynolds, 2019). Every culture has made its own trademark kind of frankfurter, for instance the Native Americans made hotdogs using a huge assortment a combination of meats and berries (Basic Sausage-Making, 2004).

2.18.1 Beef Sausages

Meat is the tissue gotten from a butchered creature that is eaten as food, and this might incorporate skeletal muscle, fats and different tissues (Lawrie andLedward, 2017; Ossom *et al*., 2020; Riley *et al*., 2020). Meat can be transformed into specialised goods such as beef sausages, pork sausages, frankfurters, and burgers, among others, by adding ingredients and/or mechanical action to match market demands. (Adzitey *et al*., 2015; Ansah *et al*., 2019). In the meat handling industry, the consideration of non-meat fixings is viewed as a significant system for decreasing by and large creation cost while keeping up with healthful and tactile characteristics of finished results (Heinz and Hautzinger, 2019). Spices such as lemongrass can be improve meat quality, it's used in meat products. particles forming and increase your dietary fibre intake to improve the texture of your food. As in the mission of diminishing expense of creation, lemongrass which is promptly accessible and generally less expensive than meat can fill in as a flavor in frankfurters s (Alirezalu *et al*., 2020). Hamburger wiener is one of the most customary meat items in Egypt and it is for the most part delivered from meat, fat tissues, dry rusk,

salt and flavors (Girgis *et al*., 2015; Lin and Huang, 2008). Consumers are increasingly showing preference for products with low – fat content with good flavor (Yang *et al*., 2007).

2.18.2 Pork Sausages

Pork is the most generally consumed meat on the planet with the greater part in the U.S. consuming pork as handled items, specifically ham, bacon and frankfurter (Demeyer *et al*., 2015). In the United States, 19.8% of pork is consumed as a hotdog item, like bratwurst, wieners and matured frankfurters (Baer and Dilger, 2013; Chris Novak, 2010). Pork hotdogs contain up to 30% fat, which is significant in the handling, textural and tangible attributes of frankfurter items (Yang *et al*., 2007). Besides, fat assumes a significant part in influencing tangible qualities (appearance, flavor and surface) and purchaser acknowledgment (Tomaschunas *et al*., 2013; Weiss *et al*., 2010). There is restricted examination accessible in regards with the impacts of fat quality on handling, textural and tactile attributes in various wiener items (Baer and Dilger, 2013).

2.18.3 Frankfurter Sausages

Frankfurters are cooked and smoked sausages (Wolfer *et al*., 2018). They are created from new meat that is restored during handling, completely cooked, and smoked (Chang *et al*., 2013). Sausages are ordinarily delivered utilizing a wide scope of fixings involved different creature or vegetable proteins, including vegetable and oleaginous seeds, basically soybean (Güemes-Vera *et al*., 2018). Wieners are ordinarily delivered utilizing a wide scope of fixings contained different creature or vegetable proteins, including vegetable and oleaginous seeds, mostly soybean (Anal *et al*., 2019). There are a few non-meat proteins utilized in the arrangement of wieners and other meat items which

incorporate starches, vegetable protein, dairy protein, cancer prevention agent, extenders, etc (Balestra and Petracci, 2018; Joshi and Kumar, 2015; Petracci *et al*., 2013).

2.18.4 Fermented Sausages

In Italy, customary aged frankfurters are notable and broadly consumed pork things In north-eastern Italy, Conventional aged frankfurters are made without the expansion of microbial starters to safeguard the sensitive sharpness, moderate acridity, and flexible consistency that these items are known for (Muzzin *et al*., 2020; Perez-baez *et al*., 2020). These dishes are made from 60% minced new pig tissue and 40 percent minced fat, along with sugar, sodium chloride, flavors, and different fixings (i.e., nitrate, nitrite) (Flores *et al*., 2019). Starter cultures are mostly utilised in large-scale manufacturing (Kavitake *et al*., 2018).

2.19 Controlling the Oxidation of Lipids in Meat and Products

Mielnik *et al.* (2008) reported on lipid oxidation, one of the serious issues happening during handling and capacity of meat and meat items. This cycle starts with a few changes, which adversely influences the items' tone, flavor, surface and healthy benefit. Pre-cooked items produced using turkey meat are generally helpless to WOF (warmed over flavor) i.e. improvement of an unfortunate rotten flavor in heat-treated meat, chill put away and ensuing warmed (Byrne, 2000; Shahidi and Oh, 2020). WOF is the significant reason restricting tactile quality in pre-cooked meat (Tikk *et al*., 2008). The control of WOF in meat is at present of extraordinary financial significance because of the expanded interest for pre-prepared comfort food things for home and institutional use (Huebbe and Rimbach, 2020). WOF can be decreased using any ordinary method for forestalling lipid oxidation among which phenolic cell reinforcements show up as the best

inhibitors (Lee *et al*., 2006; Namal, 2013). Since antiquated times, spices and flavors have been added to food to work on tangible properties and drag out time span of usability (Namal, 2013; Raeisi *et al*., 2016). Primary protests against the utilization of flavors as cancer prevention agents are the trademark flavor they provide for the meat items (Aziz and Karboune, 2018; Karpińska-Tymoszczyk, 2010). This could, however, be converted into a good new exiting sensory sense. Many polyphenol-rich plants and spices have antioxidative properties that scavenge free radicals, similar to synthetic phenolic antioxidants (Quideau *et al*., 2011; Stevanovic *et al*., 2009).According to Nambiar and Matela (2012), the leaves of lemongrass contain phenol compounds which are rich in antioxidants.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

The research was carried out at the University for Development Studies (UDS), Tamale The rainfall pattern is unimodal with an average rainfall of 118.61 mm, temperature of 27.15°C and humidity of 19% (Koranteng *et al*., 2020; Larbi *et al*., 2020). Field experiment was conducted at Farming-for-the-future at the University for Development Studies, Nyankpala Campus. The products were developed at the University for Development Studies Meat Processing Unit, with chemical and microbiological studies performed at the University for Development Studies' Nyankpala Campus and Kwame Nkrumah Science and Technology Kumasi Laboratories.

3.2 Planting, Management and Harvesting of Lemongrass (Cymbopogon citratus)

Land was prepared by ploughing, harrowing and filling the soil with groundnuts husk. Termite treatment was done using 5% benzene hexachloride (BHC) powder and 25 kg was applied per hectare. Termite treatment was done by mixing the BHC powder with the soil and ploughing it into the soil. Planting material was obtained from older plants by dividing the clumps from the older plants; the divided units are called ‘slips. Before digging out the clumps, all the leaves were removed 20-25 cm from the ground to minimize water loss via transpiration. Lengthy roots were trimmed and the dead leaves were removed from the slips to allow quick establishment of the slips in soil and to protect it from soil born insects and pests. Slips were planted on sunken beds due to the texture of the soil. The slips were planted in holes of about 5-8 cm deep and the soil surrounding the slips were used to cover the holes and gently pressed. Planting was done

at 30 × 30 cm intervals. Closer planting helps plants to compete against weeds. Watering was done twice daily and weeding was done as to when weeds appear. The lemongrass was grown for 3 to 4 months; thus, planting was done in the month of March, and first phase of harvest was done in June. Second phase of harvest was done in July respectively. After harvesting at 90 and 120 days, the outer leaves were separated as described by Lonkar *et al*. (2013a).

3.5 Drying of Lemongrass

The inner leaf, outer leaf and stem of the lemon grass samples harvested at the 90 days and 120 days were dried at 60℃ using a hot air oven for about one hour. The dried samples were then milled into powder using a dry sample kitchen blender.

3.6 Proximate Composition of Lemongrass Powder

3.6.1 Protein Content Determination

The protein content of the samples were measured using the A.O.A.C. micro-kjedahl technique (Hewavitharana *et al*., 2020). Dry samples were weighed onto filter sheets and folded into dry Kjedahl flasks in the amount of one gramme (1 g). In each Kjedahl flask, two Kjeltabs CQ 9 tablets were inserted, followed by 15 ml of concentrated sulphuric acid (H2SO4). The sample contents were then digested for four hours (4 h) and chilled for two hours (2 h). The contents were poured into the distillation equipment and distilled for 13 minutes using 50 millilitres (50 ml) of distilled water and sodium hydroxide (NaOH). The ammonia was collected in a 25 mL boric acid solution containing 2% boric acid. The trapped ammonia was titrated against a 0.1N HCl solution until it reached the desired concentration. solution until there was a change in colour to pale pink. The total

nitrogen and protein were calculated using the following formula as given by (Okalebo *et al*., 2002)

$$N\% = \frac{\text{Volume of HCl} \times N \times 14 \times 100}{\text{Weight of sample} \times 1000} \ldots\ldots\ldots\ldots (3.1)$$

$$P\% = N\% \times 6.25$$

Where:

N% = crude nitrogen.

P% = crude protein.

N = normality of HCl.

14 = equivalent weight of nitrogen

3.6.2 Fat Content

Total fat was calculated using the A.O.A.C. method(Thiex *et al*., 2012). For each case, 3.5 g was weighed into a thimble and stopped with cotton fleece prior to putting them in the thimble holder. Fifty milliliters (50 ml) of oil ether (40-60ºC) were added into a pre-gauged and dried fat can. The jars and the thimble holder with the thimbles were connected to the fat extractor (Soxhlet Extractor). The examples in the thimbles were then absorbed petrol ether in the fat jars and permitted to bubble for thirty minutes (30 min.), rising was then finished twenty minutes (20 min) trailed by dissipation for ten minutes (10 min). The jars with the separated fat were permitted to chill off in a desiccator prior to taking the complete weight (can + fat). The fat substance was determined using Equation 3.2 as given by (Okalebo *et al*., 2002).

$$\text{Fat\%} = \frac{(W2 - W1)}{\text{Weight of sample}} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.2)$$

Where:

W1 = weight of empty can

W2 = weight of can with fat/oil

3.6.3 Ash Content

Using a muffle furnace, the ash content of samples was determined using the A.O.A.C method (Thiex *et al*., 2012)For complete ashing, five grammes (5 g) of each sample were weighed into a porcelain crucible and heated in a temperature-controlled furnace at 550°C to 600°C. The crucible with ash was moved directly to a desiccator, cooled, and weighed after 2 hours of complete ashing. As a proportion of the initial weight of the sample, the ash content was determined using Equation 3.3 as given by (Okalebo *et al.*, 2002).

$$\text{Ash content (\%)} = \frac{(W2 - W1)}{\text{Weight of sample}} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots \quad (3.3)$$

Where:

W1 = weight of crucible and ash.

W2 = weight of empty crucible

3.6.4 Moisture Content Determination

The moisture content was calculated using the AOAC technique (2012). An electronic scale (Sartorius CP 124 S) was used to weigh eight grammes (8 g) of each sample into pre-weighed aluminium drying plates. The plates were then placed in an electric oven (J.P. Selecta s.a., incudigit) at 105°C for five hours (5 h) until a constant weight was

attained, then cooled in a desiccator, and the dried sample weight was taken. The moisture content was determined as follows as given by (Okalebo *et al.*, 2002)

$$\text{Moisture content (\%)} = \frac{(W1 - W2)}{W1} \times 100 \qquad \ldots\ldots\ldots\ldots\ldots\ldots (3.4)$$

Where:

W1 = sample's original weight.

W2 = weight of the sample after it has been dried.

3.6.5 Carbohydrate Content

According to A.O.A.C. (2012), the total carbohydrate (CHO) was determined using the formula:

$$\text{Complete CHO} = 100 - (\%\, dampness + \%\, fat + \%\, protein + \%\, ash \quad \ldots\ldots (3.5)$$

3.7 Mineral Analysis of Lemongrass Powder

All of the chemicals used in the experiment were of analytical grade. Surechem Products provided concentrated HCl (37 percent w/w) (England). The diluted acid was made with deionized water (Siemens Water Technologies – Ultra Clear RO EDI 10) from Siemens Water Technologies. Merck provided commercially prepared Pb, Cd, Cu, Zn, K, Fe, Ni, Mg, and Mn standard solutions (1000 mg/L) (Darmstadt, Germany). The stock solution was serially diluted with 0.1 percent HCl to create calibration solutions of various concentrations for the instrument calibration (Table 3.1). During the instrument calibration, a blank of analyte-free solution (0.1 percent HCl) was utilised.

Table 3.1: Standards used in the preparation of analytes

Element (analyte)	Standard working solutions (mg/L)
Pb	2, 4, 6, 8 and 10
Cd	0.2, 0.4,0.6, 0.8 and 1.0
Cu	2, 4, 6, 8 and 10
Zn	0.2, 0.4,0.6, 0.8 and 1.0
K	0.2, 0.4,0.6, 0.8 and 1.0
Fe	1, 2, 3, 4 and 5
Ni	2, 4, 6, 8 and 10
Cr	2, 4, 6, 8 and 10
Mn	1, 2, 3, 4 and 5

3.7.1 Instrumentation

The single-beam optical mode was used to perform flame atomic absorption spectroscopy (FAAS) observations using an Analytikjena model novAA400P atomic absorption spectrophotometer. For the analysis, a hollow cathode lamp (HCL) was employed as the light source for the various elements. The oxidant and fuel gas for the flame were air (compressed air) and acetylene (N26 grade, Air Liquide, Ghana), respectively. The instrumental conditions for measuring all of the elements are summarised in Table 3.2.

Table 3.2: Instrumental conditions for measurement of the element

Element (analyte)	Wavelength (nm)	Slit width (nm)	Power supply (mA)	Flame, flow setting (L/h)
Pb	283.3	1.2	2	65
Cd	228.8	1.2	2	50
Cu	324.8	1.2	2	50
Zn	213.9	0.5	2	50
K	766.5	0.8	4	80
Fe	248.3	0.2	4	65
Ni	232	0.2	3	55
Mg	285.2	1.2	1.5	70
Mn	279.5	0.2	5	60

For all of the measurements, the integration time was (3mA). Background correction was done with a deuterium lamp (D2 – Lamp), except for the potassium measurement, which had no background correction.

3.7.2 Digestion Procedure of Sample

Glassware Cleaning

Clean digestion tubes were soaked in a ratio of 2:3 for NHO_3 to H_2O and boiled for an hour. The tubes were rinsed under tap water and further rinsed in deionized water and dried in the oven.

3.7.3 Dry Digestion

About 5g of sample was ashed at 600°C and the resulting ash dissolved in 10% (v/v) HCl, filtered and made up to 100ml in volumetric flasks using deionized water. Flame photometry was used to determine Na and K, whereas atomic absorption spectrophotometry was used to identify Ca, Mg, Zn, Fe, and Mn. The limit of detection for Fe was 0.0819 mg/L while that for Mn was 0.1616 mg/L.

3.7.4 Wet Digestion

About 0.25g of the sample was weighed into the digestion tube and 2.5ml of conc. H2SO4, 2.5ml conc. HNO3 and 1ml perchloric acid were then added. The samples were then digested at 400°C until the solution turned colorless. The digested samples in the tubes were cooled and diluted with distilled water to 50ml.

3.7.5 The Measurement Procedure

A small amount of the sample was inhaled into a flame using a pneumatic nebulizer, where the ions were reduced to elements and evaporated. The elements in the sample

then absorb light (produced by the HCL) at specified wavelengths in the visible and ultraviolet spectrum (Table 3.2). This is determined by the analytes maximum absorption wavelength. After passing through a monochromator, the transmitted light is detected with a detector.

3.7.6 Calibration Curve

Before beginning the analysis, the instrument was calibrated using prepared standard solutions of at least five (5) distinct concentrations (Table 3.1). A linear calibration curve was created using the measured absorbance of these standard solutions. The calibration curve was utilised to figure out an element's unknown concentration in the samples. Prior to analysis, samples with high concentrations of elements outside the instrument's linear range were diluted. To quantify the elements concentrations, the light absorbed by the flame containing the sample is compared to the absorption from recognised standards.

3.8 Bioactive Compound Analysis of Lemongrass Powder

3.8.1 Antioxidant Activity

Weighing 0.5 g of dried lemongrass outer leaf powder into a 15 ml centrifuge tube yielded total antioxidant activity of flour extracts. It was then extracted using 10 mL distilled water and centrifuged for 15 minutes at 10,000 rpm. After that, hand shaking was used to fully mix a 6.4 ml reaction mixture in tubes containing 0.2 ml sample, 0.2 ml distilled water, and 6 ml of 0.004 percent DPPH (1,1-diphenyl-2-picrylhydrazyl). It was maintained at room temperature in the dark for 30 minutes. At 517 nm, the absorbance of the reaction mixture and the blank were measured. The reaction mixture with the least amount of sample creates the most vibrant colour. The colour fades as the amount of

extract applied increases. The following formula as given by (Siddhuraju *et al*., 2003; Sun *et al*., 2009)was used to calculate the ability to scavenge the DDPH:

DPPH radical scavenging activity (% of Inhibition) = $[1 - (As/A0)] \times 100$ …… (3.6)

AS= Absorbance of sample,

Ao= Absorbance of DPPH solution diluted to same volume of distilled water.Distilled water was used as blank.

3.8.2 β-carotene Content

The estimation of carotenoids contents was done according to the method of Mackinney (1941) and Maclachan and Zalick (1963). 50ml of acetone was added to 100 mg of the fresh sample in a funnel. It was slightly swirled and 10 ml petroleum ether added. The lower layer was discarded and the upper layer was transferred into a glass test tube. The optical densities (O.D) was read with the help of a UV spectrophotometer. The carotenoids contents were expressed in mg/g fresh sample and calculated according to the formulae given by (Sun *et al*., 2020)

Beta carotene =$\underline{0.216(OD.663nm) - 0.304(OD.505nm) + 0.452(OD.453)x\ V \ldots\ldots (3.7)}$

Total carotenoids =7.6(OD.480nm)-1.49(OD.510nm) x Vd x1000 x W

Where:

V = final volume of the extract.

D = length of light path

W = fresh weight of sample

O.D = optical density of a given wavelength

3.8.3 Total Flavonoid Content

The colorimetric method was used to determine the total flavonoid content(Yaoguang *et al*., 2015). In 2 mL of distilled water containing 0.15 mL sodium nitrite (50 g/L), around 0.5 mL of the extract was added. After five minutes, 0.15 mL of 10 % $AlCl_3$ solution was added, and the mixture was maintained at room temperature (25°C) for another five minutes before being added 1 mL of 1 M NaOH. The reaction solution was completely mixed and incubated at room temperature for 15 minutes before being measured using a spectrophotometer at 415 nm. The calibration curve in this work employed Catechin as the standard (R^2 = 0.996), and total flavonoid content was represented as mg Catechin equivalence (mg CE/100 gDM).

3.9 Water Activity of Lemongrass Powder

The water activity values were determined using 2.5 g of each sample by Novasina AG (CH-8853 Lachen, Switzerland). Triplicate measurements were taken.

3.10 Sausage Preparation

The outer part of the lemongrass was used for the sausage production. Drying of the outer leaf took a shorter time during drying. The longer the drying, the more the bioactive compounds and the minerals denatured and per analysis done on the lemon grass powder, the nutrient found in reduce due to long hours of drying. But the outer part of the lemon grass took a short time in terms of drying and it retained it bioactive compounds, flavors and its mineral. UDS Meat Units provided the meat for the sausage making. The meat was thawed overnight at 1°C, chopped into smaller pieces, then minced using a table top mincer with a 5 mm sieve (Taller Ramon, Spain).The formula for sausage preparation is presented in Table 3.3. Lemongrass powder were included at 0 g (T1), 4 g (T2), 8g (T3)

and 12 g (T4) per kg to a variety of sausage recipes. Meat samples were minced in a mincer. During mincing spices, water and oil were added to form a batter. Afterwards, they were stuff into casing and manually linked into 10cm length. Lemongrass beef sausages were then smoked at 105^{o}C for 30 minutes, scalded at 60^{o}C for 45 minutes and kept in a freezer for sensory, chemical and microbial analyses.

Table 3.2: Recipe for the production of sausages

Ingredient	Treatments			
	T1	T2	T3	T4
Beef	4000	4000	4000	4000
Vegetable oil	440	440	440	440
Curing salt	60	60	60	60
Phosphate	20	20	20	20
Red chili	20	20	20	20
Black pepper	4	4	4	4
White pepper	4	4	4	4
Adobo	8	8	8	8
Lemongrass powder	0	4	8	12
Ice	800	800	800	800

T1=Control, T2=4g of LG, T3=8g of LG, T4=12g of LG

3.11 Sensory Assessment of Beef Sausages

A total of 25 panellists were chosen from UDS Nyankpala Campus students and staff and trained according to the British Standard Institution criteria for panel selection and training (BSI, 1993) to constitute the sensory panel for product evaluation. The lemongrass beef sausages were cooked in an electric oven (Turbonfan, Blue Seal, UK) to a core temperature of 70°C, then sliced into 2 cm thickness and wrapped with coded aluminium foil. The sausages were rated on a 9-point hedonic scale (1 = Extremely detest to 9 = Extremely like) for colour, scent, flavour like, juiciness, texture, taste, and overall acceptability. Sensory evaluations were performed on the first, seventh, and fourteenth days of storage.

3.12 Proximate Composition of Lemongrass Beef Sausages

Composition in close proximity of sausage was determined as described in drying of lemongrass using 1 g lemongrass sausage of each treatment.

3.13 Mineral Analysis of Lemongrass Beef Sausage

The mineral content of the sausages was determined as described in proximate composition of lemongrass. A Flame Atomic Absorption Spectrophotometer (AAS Model Nov AA 400p) was used to determine the amounts of calcium (Ca), potassium (K), magnesium (Mg), sodium (Na), manganese (Mn), iron (Fe), and zinc (Zn) in the samples AOAC (2005).

3.14 Bioactive Compounds of Lemongrass Beef Sausages

Bioactive compounds of the sausages were determined as described in **Section 3.7**.

3.15 Water Activity of Lemongrass Beef Sausages

Water activity of the sausages was determined as described in mineral analysis of lemongrass powder.

3.16 Colour of Lemongrass Beef Sausages

After calibrating the device with a D65 white plate (Y = 80.1, X = 0.3219, y = 0.3394), colour components such as L* a* b* were measured with a chroma metre (Konica Minolta, CR-400, Japan). In accordance with Izli *et al*. (2018), colour saturation (Chroma, C*), hue (h*), and colour change (E*) were calculated mathematically using Equations 3.8, 3.9 and 3.10.

$$C^* = \sqrt{a^{*2} + b^{*2}} \quad \text{..... (3.8)}$$

$$h^* = tan^{-1}\left(\frac{b^*}{a^*}\right) \quad \text{..... (3.9)}$$

$$\Delta E^* = \sqrt{(L^*_1 - L^*_0)^2 + (a^*_1 - a^*_0)^2 + (b^*_1 - b^*_0)^2} \quad \text{..... (3.10)}$$

Where: L_0* a_0*, and b_0* are the L*, a* and b* values of the control samples while L_1* a_1*, and b_1* are the final L*, a* and b*.

3.17 Microbial Analysis of Lemongrass Beef Sausage

Total bacteria plate count, yeast and mould counts were used to assess the microbial quality of the lemongrass beef sausage samples (AOAC, 1995). PCA (Merck, Germany) and PDA (Merck, Germany) are two types of agar (Merck, Germany) plus Chloramphenicol selective supplement were used as media for total bacteria and fungi (yeast and molds) counts, respectively. The media were prepared by following procedures described by the manufacturer. Prior to the microbial analysis, all petri dishes (rapped in aluminum foil) were sterilized at about 150°C for 90 min using a hot-air oven to sterilized them. Spreaders, prepared peptone water and media were all autoclaved at 121°C for 15 minutes. A gram of dry sample was dissolved in 9 mL peptone water in a test tube to give a stock solution. One milliliter of the stock solution was pipetted into a 9 mL peptone water and thoroughly mixed to give 10^{-1}. One milliliter of 10^{-1} solution was taken to form 10^{-2} and one milliliter of 10^{-2} also taken to form 10^{-3}. After which, 0.1 mL of the each of the10^{-1}, 10^{-2}, and10^{-3} were plated on duplicate petri dishes of PCA and PDA. The PCA was incubated at 37°C for at least 24 h. All colonies formed after the given incubation period were counted with the aid of a colony counter, with findings given in colony forming units per gram of material (cfu/g).

3.18 Peroxide Value of Lemongrass Beef Sausages

In a 100 ml Erlenmeyer flask, ten grammes (10 g) of each sample were measured and 30 ml of hexane were added. On a shaker, the contents were shaken for 60 minutes at 250 rpm. They were placed into 50 ml falcon tubes after shaking and centrifuged for 5 minutes at 3000 rpm using Rotofix 32 A. (Hettich, VID, CE, Germany).The supernatant was evaporated with an evaporator, and the evaporated residues were extracted first with acetic acid-chloroform solution (5 ml), then 10 ml of additional acetic acid-chloroform was added twice to the evaporated residues, and the extracted samples were transferred to a 100 ml Erlenmeyer flask. The mixture was then titrated against a 0.01N sodium thiosulfate solution using one millilitre (1 ml) of potassium iodide saturated solution, followed by 5 ml of 1 percent starch soluble solution ($Na_2S_2O_3$). The transition from a cyan or orange colour to a transparent or white colour denoted the termination point. For calibration, a blank test was employed. The peroxide value was estimated using the following formula given by (Nurul Syahida *et al*., 2021)

Peroxide value (mEq/kg) = $\frac{((V1 - V0) \times N)}{S \times 1000}$

Where:

V1 = titre value of sample.

V0 = titre value of blank.

S = weight of sample.

N = stands for sodium thiosulfate normality.

3.19 pH Value of Lemongrass Beef Sausages

A digital pH metre was used to determine the pH of the samples (Crison, Basic 20, Spain). The metre was calibrated with two buffers of pH 4.01 and 7.00 prior to the test. Each sample was measured into cans and homogenised with ten millilitres (10 ml) of distilled water by shaking for sixty seconds (60 s) and let to rest for ten minutes (10 min), after which the pH values were determined.

3.20 Cost of Formulating Lemongrass Beef Sausage

We calculated the cost of a kilogramme of beef and lemongrass, as well as the cost of manufacturing each kilogramme of lemongrass beef sausage. The cost of each gramme inclusion level (0 g, 4 g, 8 g, and 12 g) was calculated as a percentage of the total cost of each kilogramme. For each treatment, the cost of spices, curing salt, and ice cubes for processing a kilogramme of beef sausage was added evenly. All treatments were charged the same amount for transportation.

3.21 Statistical Analysis

All of the tests were done in duplicates. GENSTAT version 2016 was used to do a one-way analysis of variance (ANOVA) on all of the data. At a 95 % confidence level, Fischer LSD was used to evaluate significant differences between means. The data were presented in tables and figures as means and standard deviations.

CHAPTER FOUR

RESULTS

4.1 Water Activity (a_w) of Lemongrass Outer Leaf Samples

Figure 4.3 shows that there is a highly significant difference (p 0.001) between the fresh and dried samples harvested at 90 and 120 days. Fresh outer leaf samples revealed high water activity at 90 and 120 days, compared dried outer leaf samples harvested at 90 and 120 days.

4.2 Mineral Constituent of Fresh and Dry Lemongrass Outer Leaf Samples Harvested at 90 and 120 days

The mineral content of fresh and dry lemongrass samples harvested at 90 and 120 days is shown in Table 4.1. Except for Zn, all mineral elements in dried samples showed significant variations (p 0.05) (90 days after planting). Also, Mn was within undetectable range (below 0.16) for all samples except for dried samples obtained at 120 days after planting. For results obtained for samples obtained after 90 days of planting, there was a drastic decline in Mg and Zn contents for dried samples compared to the fresh samples. Except Zn, dried outer leaf samples harvested at 90 days and 120 days samples recorded appreciable values from moderate to high for all mineral elements.

Table 4.1: Mineral constituent of fresh and dry lemongrass outer leaf samples harvested at 90 and120 days

Sample	K	Mg	Ca	Zn	Fe	Mn
Fresh Sample						
Outer leaf at 90 days	2520.11±40.34[a]	1579.37±1.35[a]	655.46±1.10[a]	13.65±0.05[a]	BDL	UR
Outer leaf at 120 days	1476.60[a]	2326.10±21.6[a]	772.66±10.70[a]	BDL	BDL	UR
Dried Sample						
Outer leaf at 90 days	7171.55±10.77[a]	5845.03±62.75[a]	3647.61±10.10[a]	20.86±0.49[a]	11.50±0.14[a]	UR
Outer leaf at 120 days	3842.20[a]	6595.51±18.01[a]	3251.19±2.57[a]	8.55±0.39[a]	0.00±0.00[a]	BDL
F. pr	<.001	<.001	<.001	<.001	<.001	

Means and standard deviation (P 0.05) are used to calculate the values. The difference between values in the same column with different superscripts is substantial.

4.3 Active Compounds of Lemongrass Outer Leaf Samples Harvested at 90 and 120 Days

All of the lemongrass samples had significant variations in active chemicals (p 0.05). Generally, dried outer samples obtained after 120 days of planting recorded the highest values for all the active compounds. From the results, the quantities of active compounds recorded for dried outer leaf (120 days) samples were more than double that of fresh outer leaf at 90 days, fresh outer leaf at 120 days, and dried outer leaf at 90 days. This was followed by fresh outer leaf (120 days) and then fresh outer leaf at 90 days.

Table 4.2: Active compounds of lemongrass outer leaf samples harvested at harvested at 90 and 120 days

Sample	Vitamin C (mg/100g)	Antioxidant (%)	Total Phenol (mg/g)	Flavonoid (mg/g)	Beta Carotene (mg/g)	Total Carotene (mg/g)
Fresh Sample						
Outer leaf at 90 days	29.12[a]	56.00[a]	11.51[a]	0.1514[a]	0.04302[a]	3.415[a]
Outer leaf at 120 days	59.19[a]	28.78[a]	18.47[a]	1.74[a]	0.06[a]	3.22[a]
Dried sample						
Outer leaf at 90 days	15.71[a]	67.7[a]	75.79[a]	1.714[a]	0.14417[a]	2.64[a]
Outer leaf at 120 days	493.3[a]	82.72[a]	163.84[a]	2.12[a]	0.23[a]	3.34[a]
F. pr	0.003	0.003	0.001	0.008	<.001	<.001

4.4 Peroxide content of Sausage Samples

There was critical contrast ($p < 0.05$) among peroxide values (Table 4.4) of the beef sausage. Within a peroxide value range of 0.49 - 2.82 meq/kg, T1 recorded twice as much as those values recorded for T3 and T4.

Table 4.3: Peroxide content of sausage samples

Treatment	Peroxide value (meq/kg)
T1	2.82±0.00[a]
T2	1.89±0.04[b]
T3	0.49±0.03[c]
T4	0.77±0.01[d]
P – value	<.001

Values are means± standard deviation (P< 0.05). Values in the same column with different superscripts are significantly different.

4.5 pH and water activity of sausage samples

Sausage samples stored from day 1 to day 14 showed significant differences ($p < 0.05$) for pH and water activity at Day 1 and Day 14 for both parameters (Table 4.4). However, at day 7, there were no significant differences ($p > 0.05$) among treatments for both parameters (pH, water activity).

Table 4.4: pH and water activity of sausage samples at Days 1, 7 and 14

	pH			Water activity		
	Day 1	Day 7	Day 14	Day 1	Day 7	Day 14
1	5.67±0.01^{Ab}	5.90±0.41^{Aa}	5.70±0.01^{Aa}	0.84±0.00^{a}	0.84±0.00^{a}	0.83±0.00^{a}
2	5.65±0.06^{Ab}	6.11±0.08^{Aa}	5.75±0.01^{Ab}	0.82±0.00^{b}	0.82±0.00^{a}	0.82±0.00^{a}
3	5.75±0.00^{Aa}	5.99±0.02^{Aa}	5.75±0.00^{Ab}	0.82±0.00^{bc}	0.52±0.43^{a}	0.82±0.00^{a}
4	5.76±0.01^{Aa}	5.98±0.01^{Aa}	5.76±1.10^{Ac}	0.83±0.00^{bc}	0.82±0.00^{a}	0.82±0.00^{a}
– value	0.003	0.676	<.001	0.010	0.472	0.072

alues are means± standard deviation. Values in the same column with different lower case letters superscripts are gnificantly different (p< 0.05). Values within the same rows with different upper-case superscripts are significantly different < 0.05).

4.8 Colour of Sausage Samples

On the various colour parameters analysed (Table 4.6) for day 1, 7 and 14 of storage, treatments mostly did not show significant differences ($p > 0.05$) except for lightness (L*) at day 14, redness (a*) at day 1 and day 7, and yellowness (b*) at day 14. At these instances, there were high significant differences for redness (a*) at day 1 and day 7, and yellowness (b*) at day 14.

Table 4.5: Instrumental colour measurements of sausage samples

Parameter	Treatment	Storage time (day)		
		Day 1	Day 7	Day 14
Lightness (L*)	T1	59.70 ± 3.69^{Aa}	61.63 ± 3.26^{Aa}	58.19 ± 3.26^{Ab}
	T2	62.12 ± 2.29^{Aa}	61.38 ± 0.64^{Aa}	61.97 ± 0.96^{Aa}
	T3	62.73 ± 4.17^{Aa}	63.11 ± 1.29^{Aa}	59.72 ± 0.85^{Aab}
	T4	62.22 ± 2.69^{Aa}	62.35 ± 1.24^{Aa}	60.92 ± 0.27^{Aab}
Redness (a*)	T1	10.61 ± 0.93^{Aa}	10.46 ± 1.37^{Aa}	6.96 ± 0.51^{Ba}
	T2	8.43 ± 0.48^{Ab}	7.74 ± 1.91^{Bb}	6.17 ± 0.40^{Cab}
	T3	7.06 ± 0.75^{Ac}	5.61 ± 0.87^{Bc}	5.69 ± 0.84^{Bc}
	T4	7.56 ± 0.71^{Abc}	6.44 ± 0.62^{Bbc}	7.25 ± 0.39^{Bab}
Yellowness (b*)	T1	15.16 ± 1.08^{Aa}	14.81 ± 0.69^{Aa}	15.83 ± 0.25^{Ab}
	T2	15.36 ± 1.58^{Aa}	15.11 ± 0.23^{Aa}	15.79 ± 0.36^{Ab}
	T3	14.71 ± 1.54^{Ba}	14.69 ± 0.61^{Ba}	17.03 ± 0.99^{Aa}
	T4	14.20 ± 0.54^{Ba}	14.82 ± 0.53^{ABa}	15.36 ± 0.21^{Ab}

Values are means± standard deviation. Values in the same column with different lower case letters superscripts are significantly different ($p< 0.05$). Values within the same rows with different upper-case superscripts are significantly different ($p< 0.05$).

4.9 Proximate Compositions of Sausage Samples

Results from Table 4.7 show significant differences ($p < 0.05$) between treatments for fat, protein, and carbohydrates. Among these parameters, there are high significant differences among treatment for protein where T1 recorded the highest. However, moisture (%)and ash (%) for treatments showed no significant differences.

Table 4.6:Proximate compositions of sausage samples

Treatments	Parameters (on wet basis)				
	Moisture (%)	Ash (%)	Fat (%)	Protein (%)	Carbohydrate (%)
T1	67.57±0.80[a]	2.07±0.02[a]	12.92±0.15[a]	18.32±0.21[a]	1.19±0.30[a]
T2	66.95±1.51[a]	2.17±0.11[a]	13.38±0.33[a]	15.89±0.10[a]	0.14±0.01[a]
T3	67.71±0.25[a]	1.88±0.11[a]	12.43±0.21[a]	14.78±0.23[a]	1.58±0.33[a]
T4	67.80±1.40[a]	1.93±6.25E-05[a]	13.05±0.03[a]	14.32±0.02[a]	2.44±0.20[a]
P – value	0.865	0.069	0.045	<.001	0.003

Values are means± standard deviation (P< 0.05). Values in the same column with different superscripts are significantly different.

4.10 Cost of Formulating Lemongrass Beef Sausages

The formulation cost of lemongrass beef sausages is shown in Table. The formulation cost in Ghana cedis (Gh¢) for the control (T1), (T2), (T3) and (T4) treatment levels are 35.30, 35.20, 35.20 and 35.40, respectively.

Table 4.7: Formulation Cost of lemongrass powder Flour Beef Sausages

Ingredient	Treatments											
	T1			T2			T3			T4		
	Unit price/g	Qty	Am't	Unit price/ g	Qty	Am't	Unit price/ g	Qty	Am't	Unit price/ g	Qty	Am't
Beef	26.00	4000	104.0	26.00	4000	104.00	26.00	4000	104.00	26.00	4000	104.00
Vegetable Oil	64.00	440	5.63	64	440	5.63	64	440	4.63	64	440	2.63
Curing salt	1.50	60	0.18	1.50	60	0.18	1.50	60	0.18	1.50	60	1.0
Red Chili	5.00	20	1.00	5.00	20	0.50	5.00	20	1.00	5.00	20	1.00
Black Chili	20.00	4	0.71	20.00	4	0.50	20	4	0.71	20.00	4	0.71
White Pepper	98.00	4	1.74	98	4	1.74	98.00	4	1.74	98	4	1.74
Casing	75.00	900	18.75	75.00	900	16.	75	900	15.5	75.00	900	14.75
Adobo	18.00	8	0.4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lemongrass	0.00	0	0.00	110.0	200	2.20	110.0	200	4.40	110.0	200	4.6
Ice Cubes	1.20	800	0.30	1.20	800	0.30	1.20	800	0.30	1.20	800	0.30
Transportation	0.00	0	2.20	0.00	0	2.50	1.50	0	1.50	0	0	1.50
Total Cost (Gh¢)			**135.0**			**133**			**133**			**119**

Qty = Quantity, Am't = Amount

4.11 Bioactive Compound Compositions of Sausage Samples

Results from Table 4.8 showed significant differences among treatments. Among these, flavonoids (mg/g), beta carotene (mg/g), anti-oxidant (%) and ascorbic acid (mg/g) showed significant differences ($p < 0.05$) among treatments, where T2 recorded highest values except for ascorbic acid content which was replaced by T3.

Table 4.8:Bioactive compound compositions of sausage samples

'eatments	Parameters					
	Flavonoids (mg/g)	Beta Carotene (mg/g)	Total Carotene (mg/g)	Total Phenol (mg/g)	Anti-oxidant %	Ascorbic Acid (mg/g)
l	0.001±4.4E-05^{d}	3.857E-04±4.7E-06^{d}	0.213±0.007^{a}	4.083±0.018^{a}	39.740±0.738^{c}	20.760±0.952^{c}
2	0.009±0.000^{b}	6.599E-04±1.7E-05^{a}	0.203±0.003^{a}	2.840±0.215^{b}	54.250±0.567^{a}	40.250±0.375^{b}
3	0.006±9.3E-05^{c}	4.316E-04±4.4E-06^{c}	0.166±0.013^{b}	3.705±0.070^{a}	43.480±0.485^{b}	51.920±0.968^{a}
4	0.029±0.001^{a}	5.116E-04± 1.3E-05^{b}	0.142±0.007^{b}	4.000±0.069^{a}	43.570±0.477^{b}	42.010±0.203^{b}
– value	<.001	<.001	0.003	0.001	<.001	<.001
S. D.	0.001	0.000	0.023	0.3285	1.600	1.975

ılues are means± standard deviation (P< 0.05). Values in the same column with different superscripts are significantly fferent.

4.12 Sensory Properties of Sausage Samples

Sensory properties for sausage (Table 4.9) stored for 1 day and 14 days were not significantly different ($p > 0.05$) except for colour in day 1. This difference showed no significance on overall liking of sausage. However, for samples stored for 7 days, significant differences were recorded among treatments for texture, which significantly shows differences among treatments for overall liking. Among the treatments stored for 7 days, T2 is highly preferred.

Table 4.9: Sensory properties of fresh and stored lemon grass powder-based sausages

Sensory parameters	Treatment	Storage duration		
		Day 1	Day 7	Day 14
Appearance	T1	7.00 ± 0.80^{Aa}	6.76 ± 2.10^{Aa}	6.20 ± 1.80^{Aa}
	T2	6.68 ± 1.80^{Aa}	6.52 ± 1.20^{Aa}	6.28 ± 1.60^{Aa}
	T3	6.56 ± 1.50^{Aa}	6.84 ± 1.60^{Aa}	6.84 ± 1.50^{Aa}
	T4	6.72 ± 1.43^{ABa}	6.20 ± 1.73^{Ba}	7.28 ± 1.60^{Aa}
Colour	T1	6.96 ± 1.15^{Aab}	6.36 ± 1.60^{Aa}	6.56 ± 1.80^{Aa}
	T2	6.56 ± 1.30^{Aab}	6.52 ± 0.92^{Aa}	7.08 ± 1.40^{Aa}
	T3	6.16 ± 1.60^{Ab}	6.28 ± 1.20^{Aa}	6.40 ± 1.70^{Aa}
	T4	7.08 ± 0.95^{Aa}	6.48 ± 1.01^{Aa}	6.80 ± 1.30^{Aa}
Texture	T1	7.16 ± 1.12^{Aa}	7.16 ± 0.70^{Aa}	7.08 ± 2.30^{Aa}
	T2	7.00 ± 1.80^{Aa}	7.120 ± 1.01^{Aa}	7.20 ± 1.40^{Aa}
	T3	6.64 ± 1.44^{Aa}	6.360 ± 0.90^{Aa}	6.92 ± 1.40^{Aa}
	T4	6.68 ± 1.11^{Ba}	6.360 ± 1.04^{Bb}	7.52 ± 1.20^{Aa}
Taste	T1	6.44 ± 1.70^{Ba}	7.60 ± 0.74^{Aa}	6.92 ± 1.11^{Aba}
	T2	6.80 ± 1.63^{Aa}	7.36 ± 1.10^{Aa}	7.32 ± 1.41^{Aa}
	T3	6.12 ± 1.30^{Ba}	7.08 ± 1.00^{Aa}	7.24 ± 1.51^{Aa}
	T4	6.64 ± 1.40^{Aa}	6.92 ± 1.26^{Aa}	7.40 ± 1.12^{Aa}
Mouthfeel	T1	6.40 ± 1.24^{Ba}	7.60 ± 0.92^{Aa}	7.40 ± 1.40^{Aa}
	T2	6.44 ± 1.39^{Ba}	7.48 ± 1.30^{Aa}	7.28 ± 1.20^{ABa}
	T3	6.48 ± 1.36^{Ba}	6.84 ± 1.34^{ABa}	7.40 ± 1.40^{Aa}
	T4	6.48 ± 1.50^{Ba}	6.96 ± 1.14^{ABa}	7.64 ± 1.22^{Aa}
Overall liking	T1	7.12 ± 1.52^{Ba}	8.24 ± 0.70^{Aa}	7.80 ± 1.00^{ABa}
	T2	7.44 ± 1.30^{Ba}	8.44 ± 0.83^{Aa}	7.64 ± 1.11^{Ba}
	T3	6.88 ± 1.10^{Ba}	7.44 ± 1.30^{ABa}	7.96 ± 1.10^{Aa}
	T4	7.04 ± 1.30^{Ba}	6.96 ± 1.14^{Bb}	8.00 ± 1.12^{Aa}

Values are means± standard deviation ($P< 0.05$). Values in the same column with different superscripts are significantly different.

4.13 Microbial Assessment of Sausage Samples

Results from Table 4.10 show significant differences ($p < 0.05$) among treatments for days 1 and 7 of storage. However, treatments showed no significant differences ($p > 0.05$) when stored for 14 days. Trend shows that microbial load in T1 decreased with storage time, whereas it increased in T2. However, T3 and T4, recorded fluctuations; decreasing at day 7 and increasing at day 14.

Table 4.10: Microbial assessmentof sausage samples

Treatments (%)	logcfu/cm-Day 1	logcfu/cm-Day 7	logcfu/cm-Day 14
T1	2.924 ± 0.13^{ab}	2.650 ± 0.14^{a}	2.230 ± 0.60^{a}
T2	2.520 ± 0.10^{b}	2.816 ± 0.04^{a}	2.820 ± 0.21^{a}
T3	2.907 ± 0.34^{ab}	1.894 ± 0.14^{b}	2.800 ± 0.20^{a}
T4	3.153 ± 0.22^{a}	2.542 ± 0.40^{a}	2.800 ± 0.32^{a}
P – Value	0.042	0.004	0.195

Values are means± standard deviation (P< 0.05). Values in the same column with different superscripts are significantly different.

CHAPTER FIVE

DISCUSSION

Water activity results (Table 4.1) showed that fresh samples of fresh outer leaf at 90 days and 120 days had high water activity compared to their corresponding dried outer leaf samples harvested at 90 days and 120 days. Drying, which is the physical removal of water affects the water activity in samples. Thus, the amount of water removed will directly affect the water activity in the samples which is also dependent on the temperature air drying. As reported by Barbosa *et al*. (2008), Leaves dried at 40°C had average equilibrium moisture levels that were approximately 35 % higher than leaves dried at 50°C and 80 % higher than leaves dried at 60°C (Therdthai and Zhou, 2009).

Mineral composition of fresh and dry lemongrass samples harvested at 90 and 120 days (Table 4.2) showed minimum and even undetectable ranges of trace mineral elements. Most especially, Mn was within undetectable range (below 0.1616) for all samples except for dried samples obtained at 120 days after planting. This may be owing to the age at which lemongrass was harvested. For results between fresh and dried samples, the observation that mineral element composition decline as samples undergo drying may be as result of mineral losses through evaporation of moisture. However, increases in these elements may be associated with the increase in dry matter retaining mineral elements as moisture is lost. Dried samples at 90 days proved to retain more mineral elements expect for Mg, whereas dried samples at 120 days showed adequate presence of all minerals tested. This may be due to the amount of mineral components and accompanying moisture content in samples associated with the age of harvest (Kashani *et al*., 2020; Uraku *et al*., 2015)

Results illustrated in Table 4.3 on active compounds of lemongrass showed a better performance of dried samples at 120 days for all compounds tested for. This may be due to the age or the vegetative state of the plant at harvest, as Gulcan *et al.* (2010) reported that extracts and essential oils yields, chemical compositions, free radical scavenging activities, and reducing/antioxidant capabilities were influenced by the vegetative periods of growing season. Overall, the drying temperature can have a significant impact on the quality of the plant material produced. The most important changes in the post-harvest of medicinal plants are chemical alterations, which can be affected by drying. Thus, it is reported that changes such as the product appearance (color) and smell, can be promoted by drying (Aboltins and Kic, 2016).

On sausage samples, dried outer leaves (120 days) employed in beef sausage processing at different inclusion levels (0, 4, 8 and 12 g/kg) showed peroxide values (Table 4.5) within a range of 0.49 - 2.82 meq/kg. Although the range recorded does not depict notable rancidity or primary oxidation compared to the generally recognized range, fresh oils have a peroxide value of greater than 10 meq/Kg (Alajtal *et al.*, 2018). T1 which is without lemongrass powder recorded the highest peroxide value followed by the other lemongrass inclusions. This shows lemongrass inclusions had positive influence on sausage reducing rancidity of fat. However, T4 peroxide value exceeded that of T3. This may be due to the point that optimum inclusion level may have been exceeded and thus the extra grams of lemongrass powder did not have positive effects, which is similar to the research conducted by Olorunsanya *et al*. (2014).

Water activity (a_w) for sausage samples shown in Table 4.5 and indicates preservation and stabilization of food. Sausage sample (T2) water activity values seemed to be more

stable from day 1 to day 14 (0.82±0.02). This may be owing to the inclusion of optimum amount of lemongrass powder, such that the solute content of the sausage will be appropriate to deal with water. This is typical in T4 (sample with highest inclusion) as water activity reduces drastically, relative to other samples.

Reduction of water activity in sausage samples prevents the growth of microbes (Table 4.10). Low water activity makes water unavailable to microbes (Syamaladevi *et al*., 2016). However, the fluctuations recorded in T3 and T4 in colony forming units may be as a result of inadequate hygienic conditions during sausage preparation. This may have caused contamination by microbes. pH (Table 4.6) for sausage samples may also have accounted for microbial loads recorded in Table 4.10. T2 after 7 days of storage recorded a pH near neutral and this may have influenced on the microbial load (Table 4.10). However, the microbial load stabilized after 14 days of storage after pH decreases to more acidic conditions. Color (Table 4.6) and the ability of the water activity of sausage may be affected by pH variations (Table 4.5). Meat products with a low pH have a lower water-holding capacity (lower water activity) and a lighter colour, whereas meat products with a higher pH have a darker colour and less drip loss(increased water activity) (Fiorentini *et al*., 2020; Mancini and Hunt, 2005).Thus, a pH range of 5.65-5.76 across the 14 days of storage may have accounted for the many statistically non-significant differences among sausage samples. However, the few that were significantly different, especially redness at days 1 and 7 may be associated with the pH 6.11 which seems to be an outlier from the rest. Such that as pH nears neutral, the water activity increases with corresponding increase in colouration and even increased microbial load due to water availability. Proximate compositions of sausage samples from Table 4.7 showed

significant differences among treatments for fat (%), protein (%) and carbohydrate (%). Among these T2, recorded the least value for carbohydrate. These results may be due to the amount of lemongrass powder included in the formulation. It was observed that T3 and T4 which had higher inclusion levels recorded higher levels of carbohydrate. Sausage sample T1 had highest protein value compared to the other sample. However, T2 which is second after T1 had an appreciable protein value (De Oliveira *et al.*, 2011). This may be due to the reason that lemongrass powder offers some colligative effects on meat protein thus reducing the available protein in sausage (Cofelice, 2019). This is further evident in protein values as more portions of lemongrass powder produce lesser protein values in T3 and T4 (Table 4.7).

Results from Table 4.8 (bioactive compound compositions of sausage samples), particularly on ascorbic acid values depicted that, the higher the inclusion level of lemongrass powder, the higher the ascorbic acid value; although the value of T4 was lower than that of T3. This may be due to the reason that the optimum level of inclusion may have been reached at T3. High values of beta-carotene (mg/g) and anti-oxidant (%) were recorded for sausage sample T2. These results show an improved anti-oxidant activity, which may have curbed lipid oxidation in the sausage sample even as T2 recorded highest fat content (Table 4.7). This may have alleviated rancidity and promoted better sensory characteristics as seen in Table 4.9. Sensory properties (Table 4.9) for sausage stored for day 1 (except for colour) and day 14 were not significantly different. This did not have influence on the overall liking of sausage. However, for samples stored for 7 days, significant differences were recorded among sausage samples for texture, which had a significant influence on the overall liking. Among the sausage samples

stored for 7 days, T2 was highly preferred. This may be as a result of the better sensory characteristics arising from the improved anti-oxidant activity, which could reduce rancidity and improve taste, accompanied by the pH and inclusion level of lemongrass powder which may have contributed to the colour and texture respectively of the T2 sausage sample.

CHAPTER SIX

CONCLUSION AND RECOMENDATIONS

6.1 CONCLUSION

Concluding on this study, dried outer leaves of lemongrass harvested after 120 days of planting offered more significant results for the various parameters investigated as compared to the other lemongrass treatments. At the sausage formulation stage, T2, lemongrass powder at 4 g/kg inclusion level showed best results for the parameters tested for and most importantly sensory characteristics. In addition, the study revealed that lemongrass powder inclusion level above 8 g/kg (T4) did not have positive influence on sausage product.

6.2 RECOMMENDATION

Recommendation for further studies;

At 90 and 120 days following planting, natural oil can be gathered from various segments of the lemongrass plant, examined, and utilized in sausage definition rather than different oils.

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APPENDIX

Laboratory and field photos