EFFECTS OF GROWING ENVIRONMENT AND STORAGE CONDITIONS ON PHYSICOCHEMICAL CHARACTERISTICS AND PROCESSING SUITABILITY OF TWO POTATO (*Solanum tuberosum* L.*)* VARIETIES HARVESTED AT DIFFERENT MATURITY STAGES

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Effects of Growing Environment and Storage Conditions on Physicochemical Characteristics and Processing Suitability of Two Potato (*Solanum tuberosum* L.) Varieties Harvested at Different Maturity Stages

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university

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DEDICATION

I dedicate this work to my Mum Rose Githieya and my Late Dad Godfrey Githieya Hinga for the great support they gave me throughout my study period

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ACRONYMS AND ABBREVIATIONS

a*	CIE red (+) Green (-) Color Attribute
AA	Acrylamide
AI	Aluminum
ANOVA	Analysis of variance
AOAC	Association of Official Analytical Chemists
b*	CIE Yellow (+) Blue (-) Color Attribute
B. P	Boiling Point
BS	Base Saturation
C*	Chroma
CEC	Cation Exchange Capacity
CH_3CN	Acetonitrile
CIE	International Commission on Illumination
$CuSO_4$	Copper Sulphate
DAE	Days After Emergence
Den DF	Denominator Degrees of Freedom
DF	Degrees of Freedom
FAO	Food and Agriculture Organization
G	Gram(s)

GA	Glycoalkaloids
GDP	Growth Domestic Product
H	Hue Angle
H_2SO_4	Sulphuric Acid
HCL	Hydrochloric Acid
HPLC	High-Performance Liquid Chromatography
K	Potassium
K_2SO_4	Potassium Sulphate
KALRO	Kenya Agricultural Livestock and Research Organization
KCSAP	Kenya Climate Smart Agriculture Project
KEPHIS	Kenya Plant Health Inspectorate Services
KNBS	Kenya National Bureau of Statistics
L^*	Lightness
MC	Moisture Content
Mg	Magnesium
mg	Milligrams
ML	Milliliters
Mm	Millimeters
MoALF &C	Ministry of Agriculture, Livestock, Fisheries and Co-operatives

N	Nitrogen
NaOH	Sodium Hydroxide
Num DF	Numerator Degrees of Freedom
P	Phosphorous
PG	Polygalacturonase
PME	Pectin Methylesterase
PPO	Polyphenol Oxidase
RH	Relative Humidity
RID	Refractive Index Detector
SD	Standard Deviation
SE	Standard Error
Sg	Specific Gravity
USD	United States Dollar
WHO	World Health Organization

ABSTRACT

Potato (*Solanum tuberosum* L*)* popularly referred to as a "hidden treasure" is the most consumed commodity among the non-grain foods globally and the second most important food crop after maize in Kenya. Two potato varieties namely Markies and Shangi have been certified by KEPHIS and released to potato farmers countrywide through registered seed merchants for production purposes. However, their suitability for industrial application is not sufficiently established. The objective of this study was therefore to determine the effect of growing environment on processing suitability of the two potato varieties harvested at different maturity stages, postharvest storage effects, and value addition through shelf-life extension of fresh-cut potato slices. The potatoes were obtained from Githioro and Kipipiri locations in Nyandarua county where they were all cultivated under similar conditions. Potato tuber physicochemical characteristics were evaluated at 3 stages of maturity, tuber storability was evaluated at ambient temperature of 18℃ at 85% RH in a dark room) and cold storage (5℃ at 95% RH). The effect of different treatments on the shelf life extension of the fresh potato slices was also determined. The results revealed significant ($P < 0.05$) effects on the physical characteristics due to the interaction between variety and maturity stages. A significant ($P=0.047$) difference was observed in the texture, ($P= 0.035$) in lightness (L*), and ($P=0.004$) in redness (a*) color parameters. Kipipiri location produced significantly larger tubers in size and weight ($P < 0.05$) at the 3rd maturity stage. There were significant ($P < 0.05$) differences in starch, ($P=0.004$) ascorbic acid, reducing sugars ($P=0.003$), glucose content ($P=0.006$), and sucrose contents ($P=0.035$) across the 3 maturity stages tubers harvested from Githioro location. There was a significant difference ($P < 0.05$) in starch, ($P < 0.05$) ascorbic acid, glucose content ($P=0.029$), and fructose content ($P=0.048$) in the two storage conditions. The shelf life of fresh-cut potato slices was extended for 6 weeks under cold storage at 5℃ at 95% RH in combination with vacuum sealing and ascorbic acid treatment at 2% ascorbic acid concentration. In conclusion, both varieties, Markies, and Shangi can be good sources of raw material for the potato processing industry. Variety, maturity stage, and growing environment influence the quality characteristics of the potatoes. The shelf life was extended for 6 months at 2% ascorbic acid concentration treatment being the optimum conditions for the most acceptable value-added products.

CHAPTER ONE

INTRODUCTION

1.1 Background

The year 2008 was declared the international year of the potato by the United Nations General Assembly. The potato (*Solanum tuberosum* L), "the humble- tuber", has been recorded as a vital part of the global food system, that will play a great role in strengthening world food security and alleviating poverty hence the emphasis of the slogan" *hidden treasure"* (Mackay, 2009). The crop is the world's number one non-grain food commodity with a production record reaching 360 million tons (FAO, 2022). It is placed 4th after all the staple foods namely wheat, rice, and maize (Laititi, 2014). It is cultivated in 75% of all the countries of the world becoming the 3rd most important food crop to combat food insecurity in the world (Devaux *et al*., 2021). Potato's adaptability, short growing period of 120-150 days, high yields, and nutritional contribution make it best positioned to alleviate food insecurity and improve household income (Devaux *et al.,* 2014).

Potato is a strategic food security crop in Kenya and is the second most important food crop after and a major staple food among growing communities (Kimathi *et al.*, 2021). Potatoes have high nutritional value and adapt to various production environments. It is an important commercialized food crop in Kenya (Kwambai et al., 2024). It has been prioritized as one of the major crops suitable to combat food insecurity. The average annual potato production in the country has been reported to be estimated at between 2 to 3 million metric tons (Chepkoech, 2022). This accounts for 23.5% of the country's economy through income generation of almost USD 500 million annually. The sector also employs about 3.3 million people along the potato value chain (World Bank, 2017). Potato equally provides significant income opportunities as well as food for smallholder farmers (Mburu *et al.,* 2020).

Potato contributes to poverty alleviation through income generation in both urban and rural households (Chepkoech, 2022). A survey on postharvest losses in the potato value chain in Kenya showed that 19% of produce is lost per season each year with only 9% of potato produce used for processing (Kaguongo, 2014). The potato has become one of Kenya's strategic food commodities, attracting great interest as one possible answer to the multiple challenges the country faces including; hunger, poverty, and climate change (Kaguongo *et al.*, 2013).

It is considered that by boosting food security, raising incomes, generating employment, and improving nutrition. Potato production will make an even greater contribution to achieving the objectives of Vision 2030, the National long-term development blueprint that aims at transforming Kenya into an industrializing, middle-income country (Kaguongo *et al*., 2013). Potato contributes to economic development and industrial growth through income of about 50 billion Kenya shillings annually towards the GDP (Chepkoech, 2022).

Food security is key in a growing population with increasing demand for food. Food security exists when all people, at all times have physical, social, and economic access to sufficient, safe, and nutritious food which meets their dietary needs and food preferences for active healthy life (Wijesinha-Bettoni, 2019). The importance of potatoes is attributed to their high nutritive value, high productivity and good processing qualities, and versatility in utilization (National Potato Council of Kenya, 2018).

There is a future projection of a significant increase in demand for processed products due to the expanding food processing industry driven by a growing urban population, changing population structure, and new eating habits (Maingi *et al.*, 2015). In a study by (Kaguongo et al., 2014) on the analysis of opportunities for growth in the production and marketing of potatoes for processing. The study findings indicated a growing local production ready cut fresh chips. The study also indicates a 10 percent growth rate with a projected quantity of 5,993MT in 2024 (Kaguongo et al., 2014).

Value addition of potatoes has the potential to enhance food security, household income, and nutrition. There are also unexploited opportunities in the value addition of potatoes with processing being limited to techniques such as grading, packaging, chips, and crisps. Crisp processing is the major processing technique among smallholder farmers because it is simple and marketable (Mlaviwa & Missanjo, 2019).

In recent years, consumers have become more health conscious in their food choices but they have less time to prepare healthy meals. As a result, minimally processed products have become an important sector of the food industry because of their fresh-like qualities, convenience, and speed of meal preparation (Rocha *et al*., 2003) The demand for fresh-cut, minimally processed, and ready-to-eat vegetables including potatoes is increasing especially particularly in urban areas due to the convenient nature of these products (Rocculi et al., 2009).

During processing the unit operations (peeling, cutting, and slicing) cause severe damage to living tissues which increases the respiration rate, enzymatic browning, microbial spoilage, and water loss resulting in quality losses and reduced shelf life (Rocculi et al., 2009). Enzymatic browning is one of the most prevalent causes of deterioration and loss of quality in processed potato products. It negatively affects the sensory quality and nutritional components of potatoes (Ali et al., 2021). It is triggered when phenolic compounds are leaked from damaged tissue and oxidized by polyphenol oxidase on the surface of fresh-cut potatoes. Inhibiting enzymatic browning is therefore key to extending the shelf life of peeled potatoes (Ali *et al*., 2021).

There are glaring opportunities in the potato industry due to population growth and increased demand for potato products. There are prospects of greater sales if products satisfy changing tastes and preferences (Devaux et al., 2014). A good example is the East African Community market, which has created opportunities for increased exports of Kenyan processed potato products to neighboring countries (Devaux et al., 2021). There is urbanization and a growing tourism industry increased the demand for potato products (Kaguongo *et al., 2*013). One of the seven National Potato Strategic objectives is to improve postharvest handling, value addition, and marketing to promote the growth and development of the potato industry (National Potato Council of Kenya, 2016).

Potato does well in cool sub-tropical and tropical highlands (Kwambai et al., 2024). However, most of the parts in Kenya are warming up in line with global trends resulting in reduced yields and poorer quality tubers for processing. To remain competitive, the potato industry needs to embrace innovative strategies for adapting to climate change (Kimathi et al., 2021). Such strategies include new varieties adapted to extreme weather conditions (heat and drought tolerant) and possessing other desirable traits such as early maturity, pest resistance, and tolerance to harsh environmental conditions generally referred to as climate-smart crops (Andati et al., 2023).

Climate change impacts agriculture and food security, therefore there is a need for the development of climate-smart robust plants. These plants are characterized by providing high micro-nutrients and high yield constancy. Climate-smart crops emphasize resilient ones which are prime to food under progressive climate alteration and unpredictability (Kimathi et al., 2021).

In a study by Radeny et al., (2022) examining the effects of climate-smart crop varieties on food security in Kenya, it was found that adopting stress-tolerant varieties of various crops enhanced household dietary quality by 40% and decreased food insufficiency by 75%. The crops were more important in improving food security (Radeny et al., 2022) hence the need to establish the processing suitability of the two potato varieties, Markies and Shangi, deemed as climate-smart crops.

1.2 Problem Statement

In Kenya, the Irish potato sector faces a critical challenge due to significant postharvest losses, which threaten food security, employment, and nutritional well-being. Despite the potato's potential as a key contributor to the county's food availability and economic growth, the short shelf life and high perishability of the crop result in postharvest losses ranging from 20% to 31% of total production (Kaguongo, 2014).

The processing sector further exacerbates this issue, with only 9% of potato produce being processed, while 3-5% of the supply is damaged, immature, or rotten.

Additionally, 1% of potatoes are undersized and discarded, and 4-7% are oversized and unsuitable for processing (Kaguongo, 2014). This translates to approximately 815000 tons of damaged produce annually when extrapolated to the national level, which represents a value of about KES 12.9 billion (Kaguongo,2014).

The long-term utilization of fresh potatoes in Kenya is significantly hindered by postharvest losses and inadequate storage systems. The absence of knowledge and efficient storage practices (Nyankanga et al., 2018) contributes to a substantial portion of potatoes—nearly a quarter becoming damaged or turning green in markets (Musita et al., 2019). This raises serious concerns about food losses and the safety of potato consumers due to the potential presence of glycoalkaloid compounds, which can be toxic to humans if consumed in large quantities. This research seeks to investigate these challenges and develop solutions to enhance potato storage, reduce food losses, and ensure consumer safety in Kenya (Musita et al., 2019).

Enzymatic browning is also a major industrial problem of fresh-cut vegetables and a widespread phenomenon that causes the loss of quality of fresh-cut potato slices. The potato subsector has also been hampered by many complex constraints like lack of value-added products and little research in new product development (Ali et al., 2021).

1.3 Justification

Given the challenges outlined, it is essential to identify and document the optimal maturity stage for harvesting different Irish potato varieties that exhibit desirable traits (Heltoft et al., 2017). Additionally, implementing proper storage solutions with adequate cooling and ventilation is crucial to extending the shelf life of ware potatoes (Gikundi, 2021). Furthermore, in response to the increasing demand for fresh and ready-to-eat foods driven by modern fast-paced lifestyles, it is important to consider the relationship between the appearance, texture, flavor, nutrition, and safety of fresh-cut produce(Mlaviwa & Missanjo, 2019) . Since appearance is a primary factor influencing consumer purchasing decisions, controlling undesirable physical changes in the product is imperative to maintain its quality and appeal (Ali et al., 2021).

The food processing industry demands potato varieties with excellent processing qualities. This research aims to assess the processing suitability of the varieties under study(Lal et al., 2023). The findings will provide valuable insights for potato processors, helping them select varieties that meet their specific quality requirements. Additionally, the research will offer important information to farmers regarding the significance of harvesting at the optimal maturity stage (National Potato Council of Kenya (, 2018).

This study will also benefit policymakers by informing the development of standards and guidelines within the potato value chain. Furthermore, insights into the storability of the two varieties under varying conditions will benefit processors and traders. Ultimately, this study will contribute to the knowledge and research on these potato varieties cultivated in Kenya.

1.4 Study Objectives

1.4.1 Overall Objective

To determine the effect of growing environment, harvesting stage, and storage conditions on physicochemical characteristics and processing suitability of two Irish potato varieties (Markies & Shangi).

1.4.2 Specific Objectives

i. To determine the effect of the growing environment and harvesting stage on the physicochemical characteristics of Shangi and Markies potato varieties.
ii. To determine the effect of cold and ambient storage conditions on the physicochemical characteristics of Shangi and Markies potato varieties.
iii. To determine the effects of different processing methods on the shelf life and consumer acceptability of French fries from Shangi and Markies varieties.

1.5 Hypotheses

i. The harvesting stage and growing environment do not affect the physicochemical characteristics of potato varieties.

ii. Storage conditions do not affect the physicochemical characteristics
iii. Different processing methods do not affect the shelf life and consumer acceptability of French fries from Markies and Shangi potato varieties.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Potatoes are consumed widely in the developing and developed world as a major source of carbohydrates (Bordoloi *et al.*, 2012). They are an important staple food known to have a more favorable nutrient ratio than other vegetables (Beals, 2019). Moreover, the potato is a year-round available crop, which makes it attractive for fresh market sales or processing (dehydration, freezing, and minimal processing) with many possibilities and various final products (Levaj et al., 2023). Potato is the third most important food crop after rice and wheat and is widely produced and consumed all over the world (Subramanian, 2012).

The crop is said to have its origin in Peru (South America) from where it is believed to have been introduced to the rest of the world by war, expedition, shipment, and transportation around 350 million years ago (Spooner *et al.,* 2014). Potato evolved slowly into its present form in the South American Andean highlands between Peru and Bolivia, domestication of wild potato started around 8 millennia BC (Bista & Bhandari, 2019). Potatoes were first grown in Kenya in the 1880s (National Potato Council of Kenya, 2018). The year 2008 was celebrated as the International Year of the Potato recognizing it as one of humanity's most important and universally loved staple foods, and a vital part of the global food system that is projected to play a greater role in strengthening world food security and alleviating poverty (Mackay, 2009).

The potato is an ideal candidate for crop diversification programs in Kenya, which many households depend on as a primary or secondary source of food. Potatoes are rich in proteins, calcium, potassium, and vitamin C and have good amino acid balance (Kaguongo *et al.,* 2013). Moreover, potato is a highly productive crop, compared with wheat, maize, and rice, it produces more food per unit area and time. It has a short and highly flexible vegetative cycle harvestable within 100 days of planting. Another attribute of the crop is its great adaptability to almost any altitude and a wide variety of climates, including arid and semi-arid lands (Devaux et al., 2021). It is already cultivated as both a primary and an off-season crop in different parts of Kenya. The crop generates considerable employment in production, marketing, and processing.

Only a fraction of total global potato production enters foreign trade, compared to major cereal commodities which shield potatoes from international price shocks because the potato prices are determined by local demand and supply (Devaux *et al*., 2021). The potato is a highly recommended nutrient-rich crop that can protect low-income countries from the risk of rising international food prices while providing a valuable source of income for subsistence farm households (Kaguongo *et al*., 2013).

2.2 Potato Plant Description

The potato crop is an herbaceous dicotyledonous plant with underground stems that give rise to several tubers. It is a starchy tuberous crop from the perennial genus Solanum of the Solanaceae family also known as the nightshade family (Kumar &Chandra, 2018). The potato plant production is through vegetative propagation. The new growth arises from axial buds (eyes), as opposed to a fully formed embryo as occurs with seeded crops; it grows up to 100 cm and produces a tuber. They are grown for their tuber, which is part of the plants that grow below the ground and are enlarged to store nutrients (Amsel *et al*., 2008).

During growth, potato plants form compound leaves that manufacture starch, which is transferred to the end of their underground stems (stolons). This causes the stem to thicken to form many tubers, which vary in shape and size. The tuber is the economically significant part of the plant which is both the organ of commercial production, the site for storage of carbohydrates, and the primary propagule (Mackay, 2009).

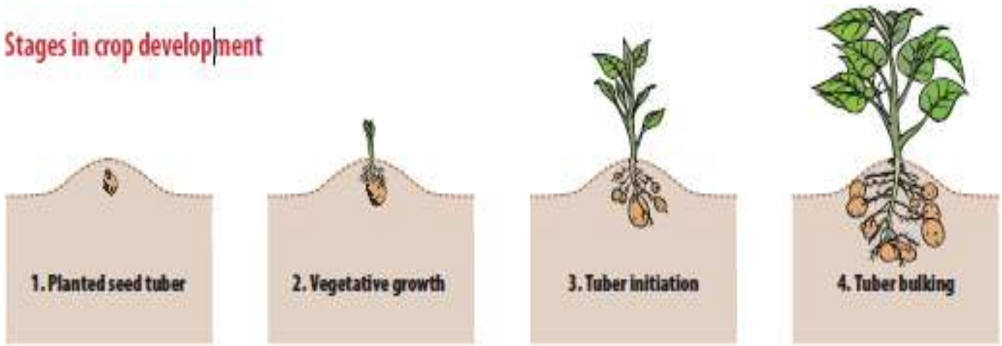

Figure 2.1: Illustration of a Potato Plant Development Stages

Source: (Irshad, 2013)

2.3 Potato crop Development

The potato crop is small (30-100 cm), vegetative propagated with the bud (eyes) sprouting to grow into a mature plant. Tuber formation starts at the flowering stage and ceases at the fruiting stage while the size of the tuber depends on the cultivar and age of the plants. The growth stages shown in Figure 2.1 above include; sprout development, plant establishment, tuber initiation, tuber bulking, and maturation. The timing of growth stages varies depending upon factors such as temperature, moisture, variety, and geographical location.

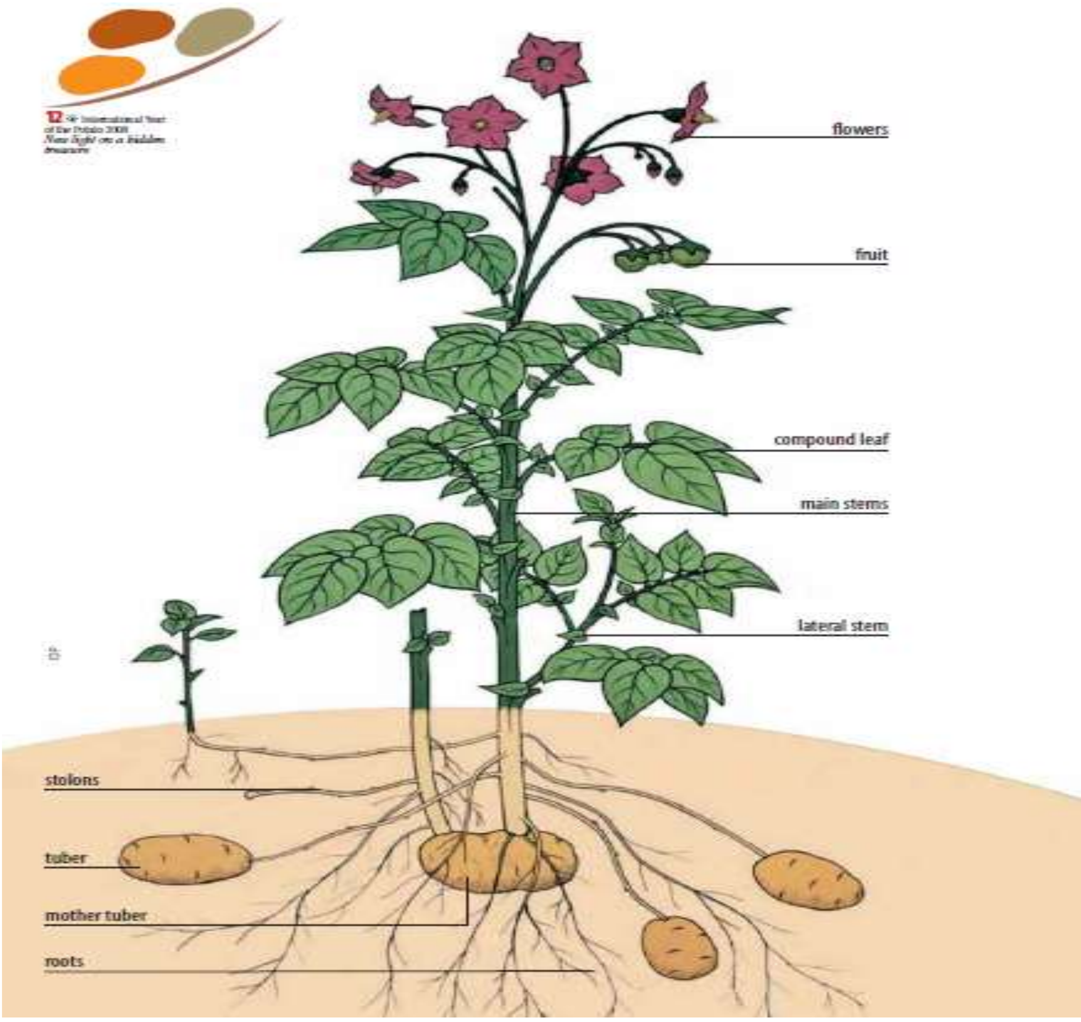

Figure 2.2: Description of the Potato Plant

Source: (Mackay, 2009).

2.4 Potato production

The global production of potatoes stands at 388 million metric tons with a yield per hectare of 20,110.8 tons/ha (Chepkoech, 2022). Potato demand is also rising at a greater rate because of its high industrial value as well as the population blast (Chepkoech, 2022).In Africa 26.5 million metric tons with a yield of 13,215.4 tons/ha, with Kenya having a share of 2-3 million metric tons (Ogola & Ouko, 2021). Approximately half of the world's potato production is in Asia followed by

Europe producing about a third. Africa produces 7% of global potato output, growing mainly in Egypt and South Africa.

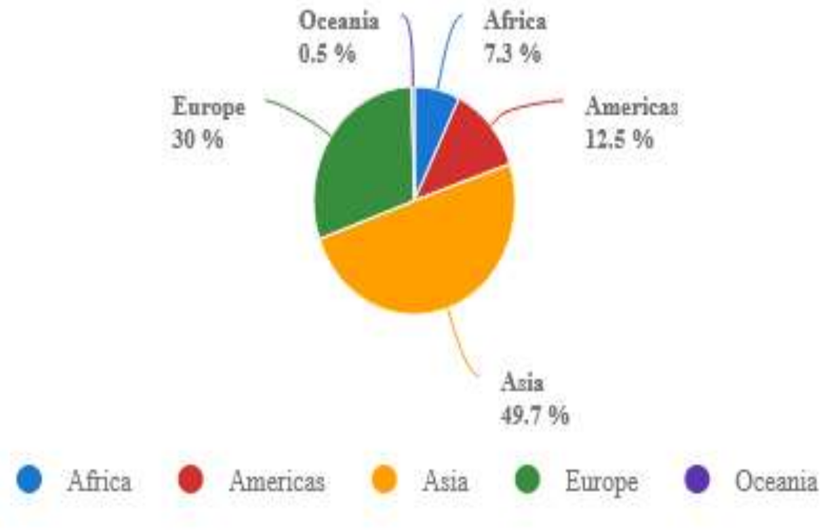

Figure 2.3: Worldwide Potato Production

Source: (FAOSTAT, 2020)

In Kenya, potato is the second most important staple crop from maize and a valuable nutritious crop that drives food security and contributes to the country's GDP valued at 500 million USD. Kenyans directly benefit from potato production while across the whole value chain, 2.5 million people receive income from potatoes (Mburu *et al.*, 2020). It is produced by over 1 million farmers and cultivated in an acreage of about 161,000 ha producing about 2-3 million metric tons annually (National Potato Council of Kenya, 2018). The potential average yield per hectare per season is estimated to be 40 tons under recommended good agronomic practices (National Potato Council of Kenya, 2018).

Potato production is dependent on weather, rainfall, and temperatures. The ecological requirements include highlands and midlands with attitudes ranging from 1,500 to 3000 meters above sea level due to cool weather and adequate rainfall (Mugambi et al., 2021). It requires a cool temperature of 15 to 18^{o} C, soil pH of 5.5 to 6, and at least 1000 mm of rainfall per annum. The five major potato-growing regions are in the highland areas of Kenya at altitudes of 1500 to 3000 m above sea level. This include the following counties; Embu, Meru, Kirinyaga, Kiambu, Murang'a, Nyandarua, Bomet, Narok, Nakuru, (Uasin Gishu, Elgeyo Marakwet, Trans-Nzoia, Bungoma Taita Taveta counties (Musita *et al.*, 2019 and Mugambi *et al.*, 2021). They can also be grown in a wide range of soil types but well-drained loamy to sandy loam soils are the most recommended because they are loose and allow enlargement of the tubers (Otieino *et al*., 2015)

Figure 2.4: Map of the Major Potato-Producing Counties in Kenya

Source: (Ministry of Agriculture, 2016)

2.5 Agronomical Factors Affecting Potato Production and Yield

2.5.1 Nutrient Fertilization

Potatoes grow in different agro-climatic conditions and require adequate management of the crop throughout the growth period to maximize yield. The yield of potatoes is determined by their specific genetics. However, biotic and abiotic factors affect yield and production. The biotic constraints include pathogenic diseases such as late blight, early blight, bacterial wilt, viral infections, and nematode parasites. Examples of abiotic factors are temperature extremes, nutrient-deficit soils, drought, salinity, and lack of availability of quality potato seed (Irshad, 2013: Majeed & Muhammad, 2018, Naumann *et al.*, 2020).

Potato is a high-nutrient mining crop, thus requiring a sufficient amount of mineral fertilization for its proper growth and development (Bista & Bhandari, 2019). The potato has an extraordinarily high yield potential and high nutritional value, therefore nutrient management is key to supplying sufficient mineral nutrients that can protect the potato plant against adverse growth conditions.

The most important macronutrients in potato production are nitrogen, phosphorous, potassium, magnesium, calcium, and Sulphur supplied to the crop through soil fertilization management(Naumann et al., 2020). Proper nutrient management is essential for the successful growth and production of quality potatoes, and for achieving a high yield of potatoes with desired quality traits. The crop's nutritional status and optimum management of water during the growing season have a huge effect on the crop, disease development, and storage (Naumann et al., 2020).

Bista and Bhandari (2019) in their study reported that potassium (K) plays several roles in the growth, development, yield, and quality of potato tubers. This includes alleviation of drought stresses, slowing senescence, and reduction of physiological disorders in storage thus enhancing shelf life and high levels of vitamin C with the application of optimal levels of K. Another major function of K in plants is controlling enzymatic activity in potatoes. K helps in stimulating the starch synthase for starch synthesis, thus assumed to have a central relevance in the potato crop for establishing desired tuber and starch yield.

Nitrogen also plays a key role in stimulating the tuber growth and size, when applied late in the seasons it delays maturity, reduces specific gravity, and increases the sugar content. When applied in excess N may stimulate the overlay of large plant canopies, lower the dry matter content, delay the maturity of the potato crop, and result in poor skin set. Therefore, it should be applied just enough to meet the crop's needs (Naumann *et al*., 2020).

Phosphorous in potato production is required in relatively large amounts; P has a significant impact on the setting of the potato tuber in the early growth stages and later growth stage for enhancing maturity. A study by Leonel *et al.* (2017) revealed that increased availability of phosphorous (P) in soil resulted in the production of tubers with higher dry matter content, lower total sugar content, and a higher percentage of starch. Thus, increased availability of P in the soil can promote significant changes in the nutritional and industrial quality of potatoes and hence broaden the potential use of tubers. Magnesium (Mg) is commonly described as the "forgotten "nutrient in fertilizer programs. It plays a key role in alleviating the adverse effects of abiotic stress conditions such as drought on crop plants (Orlovius & McHoul, 2015).

Nutrient concentration in the soil, therefore, affects the production and yields of Irish potatoes. This happens through the movement of nutrients in the soil towards the roots. Factors such as soil texture, play a very important role in plant nutrition due to its effect on the ability to retain both water and nutrients. Another factor is cations and anion exchange capacity, where generally soils have a 'net' negative or bottom-line negative charge. The total negative charge on soil is referred to as the cation exchange capacity (CEC) and it is a good measure of the ability of a soil to retain and supply nutrients to a crop.

Organic matter like clay has a high surface area and a high CEC, making it an excellent supplier of nutrients to plants. In addition, as organic matter decomposes, it releases nutrients that are bound to the organic matter's structure, essentially imitating a slow release of fertilizers. The pH of the soil which is a measure of the soil's acidity is another factor whereby different crops have different pH needs, with acidic soils limiting the uptake of nutrients by the plants (Jones Jr., 2012).

2.5.2 Climate Change

Climate change is the long-term or permanent shift either upward or downward of average climate conditions characterized by changes in weather, rainfall, and temperature (Kharin *et al.,* 2007). This is a major threat to the agricultural sector globally. A review of climate change impacts on agriculture and food security by Kogo *et al.,* (2021) revealed that Kenya is already experiencing episodes of climate change. This is manifested by; seasonal changes in precipitation, increasing temperatures of varying severity and duration with more frequent climate shocks such as droughts and flash floods (Kogo et al., 2021). .The climate changes are negatively impacting the potato value chain resulting in; crop damages, crop failures, reduced yields, poor tuber quality, increased land degradation, and postharvest losses (National Potato Council of Kenya, 2018).

CSA strategies are essential for enhancing the production of Irish potatoes (Andati et al., 2023). These strategies focus on increasing productivity, enhancing resilience, and reducing greenhouse gas emissions. The strategies that can be employed include; Utilizing climate-resilient varieties, which can significantly improve yields under changing climate conditions (Okaka et al., 2020). Water management through efficient use of rainwater harvesting and drip irrigation can help optimize water availability, especially during dry spells. Capacity building through increasing farmer's awareness of CSA practices and their benefits. Adoption of CSA practices among Irish potato farmers is influenced by their awareness and preferences (Ogola & Ouko, 2021 &Waaswa et al., 2022).

2.5.3 Potato Varieties

Today more than 5000 varieties are present in different parts of the world, with the majority being confined to South America (Zaheer & Akhtar, 2016). More than 4000 potato varieties are consumed in about 150 countries (Nema, 2013). Due to varying physicochemical characteristics, potato cultivars can be bred specifically for some functional and nutritional. Various features including tuber shape, number and depth of the eyes, skin texture and color, maturity type, and disease resistance characterize varieties. They are also characterized by cooking quality, composition, and usage (Furrer *et al.*, 2018).

Differences in texture result from the characteristic starch type which in the end contributes to performance in certain products and potential nutritional impact (Camire *et al.,* 2009). Potato tuber quality has been reported to differ between and within varieties, making variety the most critical factor for matching the tuber quality with the intended use (Gikundi et al., 2021). The development of potato varieties with improved postharvest quality and wide adaptability is important in all segments of the potato industry. Processors and other users of potatoes would benefit from a uniform product if varieties produce the same specific gravity when grown in differing regions (Soboka *et al*., 2018).

Recently, Kenya has seen a significant increase in the number of previously released potato varieties (Kwambai et al., 2024) However, the performance of these varieties remains unclear, and their adoption across different growing environments is relatively low (Kwambai et al., 2024). In his study on seed quality and variety preferences among potato farmers, Kwambai et al.,(2024) found that tuber processing quality was ranked 10th in importance. Farmers prioritize varieties based on key agronomic traits such as tuber yield, disease resistance, and early maturity.

Although the Shangi variety is the most preferred, its popularity is not linked to processing suitability. Other introduced varieties, including Markies, Destiny, and Manitou, have not been widely adopted by farmers. Factors influencing variety selection include seed availability, access and quality, agronomic resilience, productivity, and market demand. Below is a brief description of the two potato varieties discussed in this study.

2.5.3.1 Markies Variety

Figure 2.5: Markies Potato Variety

Markies variety originated from the Netherlands, in the year 1997; Agrico Potato Company introduced it. It is a chipping and crisping variety with yellow skin and light-yellow flesh color. Tubers are big and oval with shallow eyes of uniform size and deliver high yields. Markies fry well and is known to absorb less oil, it has low sugar content and potentially very low acrylamide levels after processing (PotatoPro, 2022). Markies variety is suitable for growth in all potato-growing areas. The cultivar occupies a prominent place in the crops because it presents greater resistance to reburn and double culinary aptitude (Petrucci et al., 2021).

The variety is characterized by late maturity of >4 months, an erect tall variety with white flowers. It has good heat tolerance, good resistance to diseases such as early and late blight, Viruses A, Virus X, and Ro1 of the potato cyst nematodes, and is fairly susceptible to common scabs (National Potato Council of Kenya, 2019a). The tuber has the potential for a high yield of up to 40 tons per hectare or 16.19 tons per acre. It has good resistance to internal bruising with a dormancy of >3 months and with a dry matter content of 23% (National Potato Council of Kenya, 2019a).

2.5.3.2 Shangi Variety

Figure 2.6: Shangi Potato Variety

Shangi is one of the most popular varieties commonly marketed and traded in Kenya (Abong *et al.,* 2015). It is early maturing and has higher productivity compared to other varieties thus most preferred by many farmers. It has a short cooking time saves energy and has good cooking qualities hence preferred for the processing of French fries (Musita *et al*., 2019). The plant is a semi-erect tall variety slightly below one meter with moderately strong stems and light green leaves which flower profusely with pink flowers (National Potato Council of Kenya, 2019a).

Shangi variety is moderately susceptible to late blight and grows well in areas with >1500 metres above sea level, for example, Nyandarua, Kiambu, Nyeri, Bomet, Nandi, Kisii, etc. It has an early maturity of <3 months with a dormancy of one month and a dry matter content of 21.4 % (National Potato Council of Kenya, 2019a). It has a high yield potential of up to 30-40 tons per hectare or 12.14-16.19 tons per acre. The tuber is oval-shaped with cream-shaped skin and medium to deep eyes with white flesh. It finds application as a table and processing variety for chips (National Potato Council of Kenya, 2019a). The variety controls more than 80% of the potato market share in the country. However, it has a short shelf life of less than 1 month (Irungu et al., 2022).

2.6 Chemical Composition of Potatoes

Potatoes are a significant horticultural and vegetable crop (Beliyu & ederose, 2014). Irish potatoes are crucial in developing countries, serving as a vital source of food, employment, and income. Their high energy content and ease of cultivation contribute to their role in agriculture and food security (Christopher & Gershom, 2024). They are also valued by consumers as a key component of a healthy, balanced diet (Ogolla *et al.*, 2015).

Compared to staple crops such as rice, wheat, and maize, potatoes offer substantial energy and nutritional benefits and contain beneficial phytochemicals, including phenolics and carotenoids (Furrer *et al*., 2018). Enhanced production and processing of potatoes are therefore critical in addressing hunger, malnutrition, and poverty (Zaheer & Akhtar, 2016). Their adaptability to various growth conditions, rapid growth rate, and resilience with minimal inputs underscore their agricultural significance.

The nutrient composition of potatoes is influenced by various factors including soil conditions, climate, agricultural practices, as well as preparation, cooking methods, and the specific variety or cultivar used (Wijesinha-bettoni, 2019). Potatoes are a fundamental component of the human diet, providing essential macronutrients such as carbohydrates and proteins, as well as a range of micronutrients including vitamin C, potassium, magnesium, thiamine, riboflavin, folate, niacin, phosphorus, iron, and zinc. Additionally, they contain potentially beneficial phytochemicals such as carotenoids and phenolics (Furrer et al., 2018). The potato tuber comprises approximately 80% water, with the remaining portion consisting of dry matter (Furrer *et al.*, 2018; Bista & Bhandari, 2019).

2.7 Anti-nutrients in Irish Potatoes

In addition to health-promoting constituents, potatoes can also contain anti-nutritive substances, namely glycoalkaloids (GA): **α**-chaconine and α-solanine which can be toxic and can cause poisoning: Potatoes can also contain food processing-induced acrylamides (AA) which can be carcinogenic (Levaj et al., 2023;Wijesinha-bettoni, 2019).

2.7.1 Food Processing-Induced Acrylamides

Acrylamide (AA) is an odorless white, crystalline organic solid. Naturally formed when several carbohydrate-rich foods are fried, baked, or roasted at elevated temperatures. The formation of acrylamide begins at 120^{o}C, with optimal development occurring between 160^{o}C and 180^{o}C. The primary reaction of AA formation in foods is the reaction of naturally occurring compounds in plants such as reducing sugars with free asparagine. An amino acid that occurs in a wide variety of foods and causes the browning reaction (Arvanitoyanni & Dionisopoulou, 2014; Kafouris *et al*., 2018).

Potato products are strongly susceptible to acrylamide formation due to the presence of asparagine and reducing sugars that react at high temperatures greater than 120^{o}C. Normally used for frying and roasting that favor Maillard reactions linked to AA formation (Meulenaer *et al*., 2016). In their study, Borda and Alexe (2011), reported that there was a link between dietary intake of AA and endocrine tumors in women (endometrial, ovarian, and breast) concluding that a link between AA in food and the induction of cancer was apparent. This was after observing a positive association between AA and breast cancer incidence from the examination of blood samples. Acrylamide has been classified as a Group 2A carcinogen by the International Agency for Research on Cancer (Ogolla *et al.,* 2015).

2.7.2 Glycoalkaloids

Glycoalkaloids (GA) are a family of steroidal toxic secondary metabolites present in plants of the Solanaceae family namely; potato, eggplant, tomato, and pepper. The predominant GA in potatoes being α-solanine and **α**-chaconine with α-chaconine rated the most toxic of the two (Friedman, 2006)**.** They occur as natural toxins in all parts of the potato. Synthesized as a form of defense against parasites and diseases due to their anti-microbial, insecticidal, and fungicidal properties However, they have pharmacological and toxicological effects in humans. They impart a bitter taste and can cause fatal illness at concentrations >280 mg/kg (Nema, 2013).

The reported effects of GA on human health suggest that they can be toxic and lethal depending on the doses consumed, with symptoms occurring within 8-12 hours after ingestion. The symptoms include gastrointestinal disturbances and neurological disorders. Mild clinical symptoms of GA poisoning include headaches, dizziness, abdominal pain, nausea, vomiting, and diarrhea (Omayio *et al.*, 2016). At lower concentrations, they contribute to the flavor characteristics of processed potato, but at levels above 15 mg/100 g fresh weight, they result in a bitter taste. Consumption of large amounts of GA by humans could produce toxication symptoms ranging in severity from nausea to extreme cases of death (Consolata, 2018).

The majority of the GA in the potato tuber is located within the first 1mm from the outside surface and decreases towards the centre of the tuber (Nema, 2013). The post-harvest factors reported to influence the formation of GA during storage are physical damage, sprouting, temperature, and exposure to light. Some mechanisms that can be used to delay the formation of GA in potatoes include storage in a dark place with low intensity of light, heat, and exposure to phytopathogens (Omayio *et al*., 2016).

2.8 Potato Quality Traits for Processing

The term quality can be defined as "the suitability of the tubers for the intended end use". Potatoes are primarily a foodstuff in this case those meant for direct consumption, nutritional quality is of prime importance. Tuber quality is influenced by the fact that the potato is maintained in a fresh state throughout its existence. The tuber is constantly respiring and exposed to physiological and environmental influences during the growth stage and storage (National Potato Council of Kenya, 2018) Dry matter content and specific gravity, are considered major quality attributes in potatoes meant for processing (National Potato Council of Kenya, 2018).

Werij (2011), also defined tuber potato quality as the sum of favorable characteristics of the tuber which is a subjective and dynamic concept that depends on consumers' traditional lifestyle, food habits, and the industrial processes used. A complex set of external and internal quality traits is required for fresh and processed products. External quality traits include tuber shape, eye depth, skin and flesh color, sprouting, and greening. Internal qualities include starch content, reducing sugar content, glycoalkaloid content, enzymatic discoloration, and nutritional quality. The physical characteristics of agricultural products are the most important parameters in the design of grading, handling processing, and packaging system (Abedi *et al.*, 2019).

Besides the shape and size of the tubers, eye depth, average weight, and specific gravity of potatoes are very important factors in determining their suitability for processing. Medium to large-sized tubers with shallow eyes are preferred for most processed products because they result in lower peeling losses. Color is also an important quality attribute where golden yellow color is considered to be the best for high-quality potato products (Noe *et al.,* 2019).

2.8.1 Tuber Shape, Size, Eye Number, and Tuber Texture

The quality of potato tuber affects its aptness for processing and appreciation of its products by consumers as described in a study by (Noe *et al.,* 2019). Tuber shape is a trait of many characters, that consider the length/width ratio for describing the overall shape (Werij, 2011). In their study, Kabira and Lemaga (2003) described tuber shape as a varietal characteristic, with irregular shapes associated with secondary growth and higher losses during peeling.

According to Zehra Ekin, (2011), long oval tubers larger than 50 mm are ideal for preparing French fries while round oval tubers between 40 and 60 mm are ideal for preparing crisps, therefore shape remains a significant factor to the processor. The number of eyes and depth affect the appearance of the tubers and add to the cost of peeling in processing factories. Eye depth is a varietal characteristic and varieties with shallow eyes are most preferred for processing since they minimize waste during peeling (Werij, 2011).

Food texture has several definitions such as “all the rheological and structural (geometrical and surface) attributes of a food product perceptible using mechanical, tactile and where appropriate visual and auditory receptors (Rocculi *et al.*, 2009). The texture is related to the potato tubers' resistance to an applied force, a function of the potato structure, when a force is applied to the potato tuber the cells separate through rupture of the middle lamella, or the cells burst depending on the strength of the cell lamella. Raw potatoes undergo cell rupture, while cooked ones undergo cell separation because of the thermal destabilization of pectic materials in the middle lamella.

The microstructure of fresh potato properties of cell wall polymers, an abundance of starch in the potato cells, shape and size of starch granules are important attributes of the texture of the potato (Singh *et al.,* 2016). Further, the microstructural characteristic of raw potatoes such as the parenchyma cell, cell size, and cell wall has a considerable effect on the final texture of the potato (Bordoloi *et al.,* 2012).

2.8.2 Tuber Flesh Color

Color is one of the most important quality attributes influencing consumer choices and purchase behavior. Color measurement analysis is therefore important in postharvest handling bioprocessing to optimize the quality and value of food. Color is considered the most important visual attribute in the perception of potato chip quality and is an extremely important criterion for the potato processing industry which is strictly related to consumer perception (Pathare & Opara, 2013). The most commonly used in the color measurement of foods is the L* a* b* color space because of the uniform distribution of colors and it is also very close to the human perception of color (Pedreschi *et al.*, 2011).

Color perception interacts with other sensory attributes such as sweetness, creaminess, flavor, and overall acceptance, which makes sensory analysis an important tool in food characterization. 'The Hunter Lab L^*, a^*, b^* and the modified CIE system called CIELAB color scales are the types of systems commonly used in the food industry. The CIELAB coordinates are read directly. L^* is the psychometric index of lightness which is an approximate measurement of luminosity.

The parameter a^* takes positive (+) values for reddish colors and negative (-) values for greenish ones. Whereas b^* takes positive (+) values for yellowish colors and negative (-) values for the bluish ones. L^* is the approximate measurement of luminosity, which is the property according to which each color can be considered as equivalent to a member of the grey scale, between black and white, taking values within the range 0-100.

Chroma value is considered the quantitative attribute of colorfulness whereas Hue angle is considered the qualitative attribute of color and is both calculated from a* and b* values (Pathare & Opara, 2013). Processors and consumers often associate the quality of a product with tuber color. Potatoes develop chlorophyll that detracts from the normal appearance of ware potatoes when exposed to light. This takes place if tubers are not well covered with soil during ridging. Green potatoes are unfit for human consumption due to high glycoalkaloid levels build up beneath the surface of the skin (Kabira & Lemaga, 2003).

2.8.3 Tuber Dormancy and Sprouting

Dormancy is the physiological state after harvest during which tubers do not sprout even when stored under favorable conditions (Pinhero & Yada, 2016)**.** At harvest, tubers are in a dormant state, but after harvest, dormancy is released progressively. This results in sprouting, a physiological process, which is accompanied by biochemical changes such as carbohydrate hydrolysis, water loss, and, an increase in respiration. These changes are detrimental to the nutritional and processing quality of potatoes (Benkeblia *et al.*,2008)**.**

Sprouting affects the quality of the tubers during storage by re-mobilizing mainly starch and causing shrinking of tubers owing to loss of water through increased respiration. This reduces the value of the crop because of increased levels of toxic GA, accelerated starch breakdown with concomitant accumulation of undesirable reducing sugars, and a decrease in vitamin content. It also increases physiological aging and affects the appearance of the tubers (Pinhero & Yada, 2016).

2.8.4 Specific Gravity

Specific gravity is a quick indicator of potato quality, it varies from one variety to another; it is related to the yield of processed potato products. An increase of 0.005 in specific gravity is related to an increase of 1% in yield chips (Ndungutse *et al.*, 2019). Specific gravity and dry matter content are positively correlated and are measures of potato tuber quality. They are of prime importance to processors because the recovery of the finished product is directly linked to them. The higher the specific gravity the higher will be the quantity of dry matter and vice versa. Potatoes with high specific gravity are preferred for the preparation of chips and French fries while those with low specific gravity are used for canning (Zehra Ekin, 2011). The specific gravity of the tuber is affected by factors such as potato variety, growing location, and the type of fertilizer used (Bista & Bhandari, 2019). Therefore, the specific gravity of potatoes should be taken into consideration when choosing potatoes for specific uses, to get good quality fried products (Ndungutse *et al.*, 2019).

2.8.5 Starch Content

Starch is the major component of dry matter accounting for 70% of the potato tuber (Bordoloi *et al.*, 2012). There are variations in starch content between different varieties which are attributed to genetics (Lemos, 2004). Starch is an insoluble carbohydrate present in different plant organs, occurring as transitory starch in green leaves or storage starch in roots, tubers, and seeds. In potatoes, starch is mainly accumulated in starch granules of tubers and consists of two polysaccharides, amylose, and amylopectin in a ratio of one to four respectively which influences different starch characteristics (Werij, 2011).

Starch composition determines gelling properties and influences the frying quality. In storage, it is important to regulate the conditions because cold storage induces the sweetening of potato tubers which affects processing (Werij, 2011). When sugars are elevated during cold storage, starch is broken down into glucose and fructose making the tubers unsuitable for processing. Starch content in tubers is highest after harvest but reduces gradually during storage because of the degradation of simple sugars (Mareček *et al.*, 2016). Along with sugar content, starch determines the quality and suitability of potatoes for industrial processing. The starch content is one of the parameters influencing the nutritional value of potatoes and it is susceptible to high variation (Dramićanin *et al.*, 2018)**.**

The total content of starch is influenced by their genotype as well as environmental and growth husbandry. Starch is of major importance for the taste and properties such as viscosity and consistency of the tubers (Zehra Ekin, 2011). The length of the growing period of tubers also affects the starch concentration of harvested tubers. Since starch comprises the largest part of dry matter, it has a direct influence on technological quality concerning the texture of the processed product (Lemos, 2004)**.**

2.8.6 Ascorbic Acid (Vitamin C)

Ascorbic acid better known as vitamin C is an essential nutrient in the human diet. It performs many physiological functions in its primary role as an electron donor and antioxidant (Love & Pavek, 2008). Vitamin C is directly linked to collagen formation, iron absorption, immunomodulation, and maintenance of normal nerve function (Love & Pavek, 2008). Vitamin C is important for collagen formation and hence causes scurvy if deficient in the human diet. It is also critical when it comes to protection against oxidative stress as an antioxidant (Bandana *et al.*, 2015).

Humans have lost the ability to synthesize ascorbic acid and hence depend on the diet to acquire the necessary amounts required to maintain good health (Valcarcel *et al.*, 2015). Ascorbic acid is abundant in fruits and vegetables compared to potatoes with moderate to low concentrations. Potatoes provide 25 mg per serving compared to 95 mg for red-ball pepper, 60 mg for orange, 60 mg for broccoli, and 50 mg for strawberries (Love & Pavek, 2008). However, it is a labile vitamin affected by potato variety, changes in temperature, and other environmental conditions (Abong *et al.*, 2015).

2.8.7 Reducing Sugars

The concentration of sugars varies from one potato variety to another and also environmental conditions play an important role in sugar accumulation (Ndungutse *et al.,* 2019)**.** The main sugars present are such as glucose (0.15-1.5%), fructose (0.15-1.5%), and sucrose (0.4-0.6%) a non-reducing disaccharide. The amount of reducing sugars is related to factors like genotype, environmental conditions, cultural practices, postharvest factors, and storage conditions (Ndungutse *et al.,* 2019).

The level of sugars in potato tubers is a critical factor affecting the quality of potatoes because at high temperatures reducing sugars glucose and fructose interact with free amino acids in the Maillard reaction, affecting the color, and flavor of the product has been linked to acrylamide formation in fried potato products (Kumar *et al.*, 2004). The higher the content of the reducing sugars the darker the fried potatoes' color which is an important quality criterion for French fries and potato crisps (Kabira & Lemaga, 2003). It is recommended that potatoes for French fries and crisps contain reducing sugars at 0.3-0.5% and 0.2-0.3% respectively (Meulenaer *et al.,* 2016).

2.9 Potato Processing and Value Addition

Potato is an important crop for food and income generation, recognized as a strategic commodity with the potential to make a significant contribution to increasing incomes, and improving food and nutrition security. However, this potential has not been fully utilized (Kajunju *et al.,* 2021). Potatoes are highly perishable and cannot be stored for extended periods in their fresh form without experiencing undesirable biochemical changes in quality (Lal et al., 2023). The production of value-added processed products is a valuable solution, to ensure all year-round availability of potatoes and reduce the challenge of postharvest losses.

Value addition is the process of changing or transforming a product from its original state to a more valuable state. Diversified value-added products of potatoes have the potential to increase the production of the crop and also play an important role in nutritional security and improved incomes (Mlaviwa & Missanjo, 2019). This not only extends shelf life but also provides consumers with safe, nutritious, convenient food operations. This approach also benefits farmers by increasing the profitability of their potato produce. Potatoes can be produced into a wide range of products including cooked potatoes, par-fried potato strips, French fries , potato chips, potato starch, and dehydrated diced potatoes (Lal et al., 2023)

The range of value-added potato products has however remained limited in Kenya and the need to upgrade the potato value chain cannot be over-emphasized. The most important products in the Kenyan potato processing industry are potato chips (French fries), followed by crisps and frozen French fries (Abong *et al.,* 2009). Value addition provides a means to carry over surplus production from one season to another, increases the shelf life, and facilitates easy handling and transportation of the produce. It also bridges the gap between agriculture and industry and creates employment (Abong *et al.,* 2010).

The demand for processed potato products is increasing continuously in present days due to improved living standards, urbanization, consumer preference particularly among the young generation, and expanding tourist trade (Kaguongo *et al.,* 2013). Only about 28% of the total potato produced throughout the world is processed (National Potato Council of Kenya, (2018). In his study, Abong *et al*., (2010) reported that information on the processing characteristics of potato varieties was required to support the rapidly expanding potato industry.

The processing of potatoes has the potential to change its status to an industrial crop similar to that of maize and wheat. This will help to create more employment, improve nutrition, and enhance income from potatoes. The suitability of potato tubers for processing depends on the tuber quality which includes both internal and external parameters (Noe *et al.,* 2019). Processing industries require potatoes with specific characteristics, which allow them to produce products of high quality with high consumer preferences.

There are over 200 companies that process potatoes in Kenya which are categorized into either large or cottage industries based on their processing capacity. There is also rapid growth of small processing companies that have gone into crisps and peeled, ready-to-cook potatoes that are supplied to hotels and restaurants (National Potato Council of Kenya,(2018). However, potato processing causes many physiological and biochemical changes that compromise product quality. Amongst these are those that are caused by enzymatic and non-enzymatic browning reactions which negatively affect the color, texture, and nutritional quality of potatoes (Nascimento *et al.*, 2020).

There exist research gaps in value addition and utilization of value-added products. A study by Christopher & Gershom, (2024) identified several factors affecting value addition and utilization of value-added products which include; lack of knowledge on value addition technologies, and lack of storage facilities. While existing studies provide valuable insights there are still significant research gaps in understanding the constraints ,opportunities and impacts of value addition and innovation in the Irish potato sector. Addressing these gaps can inform the design of effective interventions to enhance the competitiveness and sustainability of the Irish potato value chain.

2.10 Factors that Affect the Quality of Potato Tubers for Processing

The most appropriate definition of quality is the suitability of potatoes for their intended use (Noel et al., 2019). Both growers and processors must maintain quality based on end-use

2.10.1 Postharvest Handling of Potatoes

In Kenya, one of the major constraints facing the potato value chain is poor postharvest handling, especially during marketing and distribution which has caused significant losses of potatoes (Musita *et al.*, 2019). Long-term use of fresh potatoes is constrained due to poor storage systems. Loss of potato quality during storage is mostly due to weight loss, excessive sprouting ,decaying ,greening and changes in sugar content which is a major concern for processors (Gikundi, 2021). Due to a lack of knowledge and efficient storage systems ,most farmers in Kenya sell their potato produce immediately after harvest or harvest their produce only upon identifying a buyers (Gikundi, 2021).Therefore, proper handling is an important factor in the reduction of postharvest losses as well as maintenance of the safety and nutritional quality of potatoes.

Exposure of the potato to unfavorable conditions such as light, extreme temperatures, and bruising can lead to the accumulation of toxic substances such as GA which are toxic to humans (Omayio *et al.,* 2016). The levels of these toxins are significantly affected by postharvest handling practices with exposure to light, high storage temperatures, and injuries/bruising being important stress factors (Musita *et al.,* 2019). Therefore, addressing the aspect of postharvest handling will help prevent food losses while at the same time promoting food safety and hence protecting the health of the consumers.

Postharvest handling immediately after harvesting is crucial, potatoes should be handled gently to avoid bruising and damage. The use of appropriate containers for example crates and bags that minimize movement and protect tubers during transport is recommended (Kaguongo, 2014). Other best practices include transportation, which greatly influences the quality of potatoes. It is important to minimize exposure to sunlight and extreme temperatures during transport. Vehicles should be fitted with enclosed backs, to protect potatoes from environmental stresses (Musita et al., 2019). Effective harvesting practices and robust postharvest management are vital for reducing losses and maintaining the quality of potatoes. By adopting proper harvesting techniques, ensuring appropriate storage conditions, and implementing effective transportation methods can enhance the sustainability and profitability of potato production(Lal et al., 2023).

The potato tuber is a living entity and it continues to respire in storage. An effective storage management protocol is required to slow down the breakdown of starch into simple sugars. (National Potato Council of Kenya (, 2018). Good storage conditions should be cool dry, dark, and well-ventilated to keep tubers alive. Long storage of tubers requires a temperature of between 4^{o}C-8^{o}C with humidity maintained at 95% (National Potato Council of Kenya (, 2018).

2.10.2 Maturity of Tubers

Maturity is defined as the physiological and morphological status of the crop which is affected by factors such as variety, weather conditions, and biological and environmental stressors (Heltoft *et al.,* 2017). The maturity of the potato is also defined by chronological and physiological age. Chronological age refers to the true age in terms of months, whereas physiological age is the physical state of the tubers (Pinhero & Yada, 2016). Another definition is by using three approaches, physical, physiological and chemical maturity. Physical maturity is characterized by the development of mature and fully set periderm. Physiological maturity is achieved when the dry matter reaches its maximum levels. Chemical maturity on the other hand is related to minimum sucrose content in the tuber (Bethke *et al.,* 2009).

Tuber physiological maturity can also achieved when the soluble sugar content is at a minimum and the starch content reaches maximum upon full development of thickened periderm layer.

The maturity of the crop has been reported to influence respiration, dormancy, and sweetening behavior during storage (Pinhero & Yada, 2016). Throughout tuber maturation, nutrients are transported from the leaves to the tubers, and during vine senescence before harvesting a drop in sugar levels in the tuber is normally observed (Pinhero & Yada, 2016). This drop in sugar levels is normally an indicator of chemical maturity and at this point, potatoes can be harvested with the likelihood of quality being maintained in storage (Torres & Parreño, 2009).

Potatoes should be harvested after reaching maturity to preserve quality and attain maximum storability. Proper handling should be employed to resist mechanical damage during harvesting. The relative maturity of the crop can be estimated by monitoring the fructose, glucose, and sucrose levels. Mature potatoes store better than immature potatoes since they are less susceptible to skinning injury. Have lower weight rates, loss and are less susceptible to diseases (Heltoft *et al.*, 2015).

2.10.3 Enzymatic Discoloration

The demand for fresh minimal processed and ready-to-eat fruits and vegetables, including potatoes is on the increase. Particularly in urban areas due to the convenient nature of these products. During processing the unit operations (peeling, cutting, and slicing) cause severe damage to living tissues, which increases respiration rate, enzymatic browning, water loss, and microbial spoilage resulting in quality losses and reduced shelf life (Ali et al., 2021).

Enzymatic browning is a widespread phenomenon of major economic importance that causes loss of quality caused by the enzyme polyphenol oxidase (PPO). This is an important enzyme in the food industry and its activity in general causes a decrease in nutritional value and consumer appeal leading to economic losses (Queiroz et al., 2008). PPOs are a group of copper-proteins, widely distributed phylogenetically from bacteria to mammals (Queiroz et al., 2008). The PPO enzyme causes discoloration in potato tubers when phenolic compounds are oxidized to quinones after which the quinones are transformed into dark pigments (melanin) which results in major economic losses in the food processing and retail industries (Werij, 2011).

2.10.3.1 Control of Browning

There are several techniques and mechanisms developed to control PPO activity. They are designed to act on one or more components necessary for the browning reaction. They include oxygen, enzyme, copper, or substrate (Queiroz et al., 2008). Different methods have been investigated with heat treatment being considered the most effective method for controlling enzymatic browning, but best suited for canned but not practical for fresh foods. Retardation of browning is through the elimination of oxygen from the surface of the potato strip. This is possible by immersion in deoxygenated water, syrup, brine, or coating food with surfactants, which can be a relatively expensive process (Queiroz et al., 2008).

A common approach is considerations such as toxicity; effects on taste, flavor, and color limit the use of anti-browning agents. The most widespread method applied is the addition of sulfating agents. However, due to their adverse health effects, the World Health Organization (WHO) has recommended minimal use of sulfites in the treatment of foodstuffs (Queiroz et al., 2008). Reducing agents such as ascorbic acid are most preferred; they are able to reduce the enzymatic browning chemically.

2.11 Potato Utilization

The global consumption of potatoes as food is shifting from fresh potatoes to value-added products (Zehra Ekin, 2011). About 50% of potatoes grown worldwide are consumed fresh and the rest are processed into potato food products and ingredients, feed for livestock, processed as starch for industrial use, or re-used as seed tubers for growing the next season's potato crop (Noe et al., 2019). The utilization of potatoes is as discussed below.

2.11.1 Domestic Use

Potato is a versatile, carbohydrate-rich food prepared and served in a variety of ways (Lutaladio & Castaldi, 2009). They are mixed with beans and maize in most poor rural households. They are also included in the basic diet of maize and beans as a vegetable to add flavor (Muthoni *et al*., 2010). Fresh potatoes are baked, boiled, or fried and used in a range of recipes including mashed potatoes, baked potatoes, and soups, among others (Prokop & Albert, 2008).

2.11.2 Processed Food Products

The main categories are; frozen potatoes peeled and packaged for the fast-food market, and French fries 'chips' produced by slicing, parboiling, air drying, and frying. (Prokop & Albert, 2008). Potato crisps is another product that is an outstanding snack" king of snack foods" simply prepared by deep frying thin potato slices and then they are flavored with varied flavors. Dehydrated potato flakes are made by drying a mash of cooked potatoes, to a moisture level of 5-8 %, and this finds application as an ingredient in snacks (Mackay, 2009).

Another product is Potato flour ground from whole cooked or uncooked potatoes. The product has a distinct potato taste, is gluten-free, and is rich in starch. There are other snack foods such as "chevda" (a mixture of potato crisps, corn, legumes, and pepper), frozen potato chips, and dried potato cubes (National Potato Council of Kenya, 2018).

2.11.3 Industrial Uses of Potatoes

Potato also finds application large number of industrial and food processing applications because of its high starch content (Zehra Ekin, 2011). Starch comprises 65-80% of the dry weight of tubers, though variations can occur due to differences in genotypes (Lemos, 2004) Potato starch is characterized by a fine mouthfeel, and bland taste, it also has a wide range of properties including encapsulation properties, gelling, thickening, coating, and adhesion properties which make it preferable in a broad range of food applications. Furthermore, potato starch has a higher viscosity than cereal-based starches and has a better advantage when used in instant soups and sauces. These properties are attributed to its unique structure which is composed of linear amylose (20-30%) and highly branched amylopectin (comprising the remaining fraction), and their organization within the polymer (Fajardo *et al*., 2013).

Starch is increasingly used as a functional group in many industrial applications due to its ability to work as a thickener. Starch also finds application in yogurt manufacturing as a thickener to improve viscosity and sensory properties. Starch is also used to decrease whey separation during storage, pie filling sauces, and soups (Altemimi, 2018). Potato starch with freeze-thaw stability and resistance to retrogradation is applied in frozen foods (Phogat *et al.*, 2020).

Potato starch is also widely used by the pharmaceutical, textile, wood, and paper industries as an adhesive, binder, texture agent, and filler and by the oil drilling firms to wash boreholes Potato starch is a 100% bio-degradable substitute for polystyrene and other plastics (Werij, 2011). It is used in the production of disposable plates, dishes, and knives, while the peel and other “zero value” wastes from potato processing are rich in starch that can be liquefied and fermented to produce bioethanol (Ugonna *et al.*, 2013).

2.11.4 Utilization Opportunities of Shangi and Markies Potato Varieties

Kenya has recently experienced a significant rise in the number of formally released potato varieties (Kwambai et al., 2024). However, the performance of these new varieties remains unclear, and their adoption across various growing environments is limited (Kwambai et al., 2024). Currently, Shangi and Dutch Robjyn are the predominant varieties utilized in crisps processing. In contrast, other newly released varieties, such as Markies, Jelly, Derby, Caruso, and Rudolph, have been introduced for use in the processing of ready-cut chips (Kaguongo et al., 2014).

The Shangi potato variety is a widely recognized cultivar in Kenya, valued for its rapid maturation and versatility. It can be harvested as early as 75 days after planting, with a typical growth period of approximately 90 days, enabling farmers to optimize production by planting multiple cycles within a year (Kwambai et al., 2024). Due to its versatility in both table use and industrial processing, Shangi dominates over 80% of the potato market share in the country (Irungu et al., 2022). The Markies cultivar is also notable, offering strong resistance to reburn and dual-purpose culinary suitability, making it a promising variety for the processed potato market (Petrucci et al., 2021).

In summary, several critical research gaps exist in the Kenyan potato industry, particularly regarding postharvest losses and storage challenges. Despite potatoes being a highly commercialized crop, postharvest losses can reach up to 19% of total production, primarily due to inadequate storage systems. This leads to a decline in potato quality, manifesting as weight loss, excessive sprouting, decay, greening, and alterations in sugar content, which are major concerns for processors.

Furthermore, the local crisps processing industry operates below its installed capacity. The limited number of potato varieties suitable for crisps production is plagued by susceptibility to diseases and poor yields. Key desirable traits for processing, such as size, shape, flesh color, reducing sugar levels, and dry matter content, are not consistently met. Additionally, the lack of knowledge and efficient storage systems forces most farmers to sell their produce immediately after harvest or delay harvesting until a buyer is found.

While crisps processing has been ongoing in Kenya for over four decades, there is a notable lack of data on the installed processing capacity. Another significant gap is the issue of enzymatic browning, a process driven by the enzyme polyphenol oxidase (PPO), which leads to a decrease in nutritional value and consumer appeal, resulting in substantial economic losses in the food processing and retail industries. Addressing these gaps is essential for improving the efficiency and profitability of the potato value chain in Kenya.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Site

This study conducted a comparative evaluation of the potato varieties Markies and Shangi. The samples were cultivated by members of common interest groups under the Kenya Climate Smart Agriculture Project (KCSAP), who were subcontracted to provide the samples. The seeds for the Markies variety were sourced from Agrico Potato Services, while the Shangi seeds were obtained from KARLO Tigoni. The potatoes were planted at two sites, Githioro and Kipipiri, within Nyandarua County, using uniform agronomic practices.

The soil types at the two sites are planosols. Githioro features moderately acidic clay soils, with a pH of 5.8, and non-saline with a base saturation (BS) of 20%. In contrast, Kipipiri has clay loam soils with a pH of 5.5 and non-saline with a BS of 24%(Vågen et al., 2013). Both locations receive an average annual rainfall of approximately 1,600 mm. The biophysical characteristics of the two sites include an elevation range from 2,079 to 3,348 meters above sea level, with potatoes generally thriving in elevations below 3,200 meters above sea level (as illustrated in Figures 3.1 and 3.2).

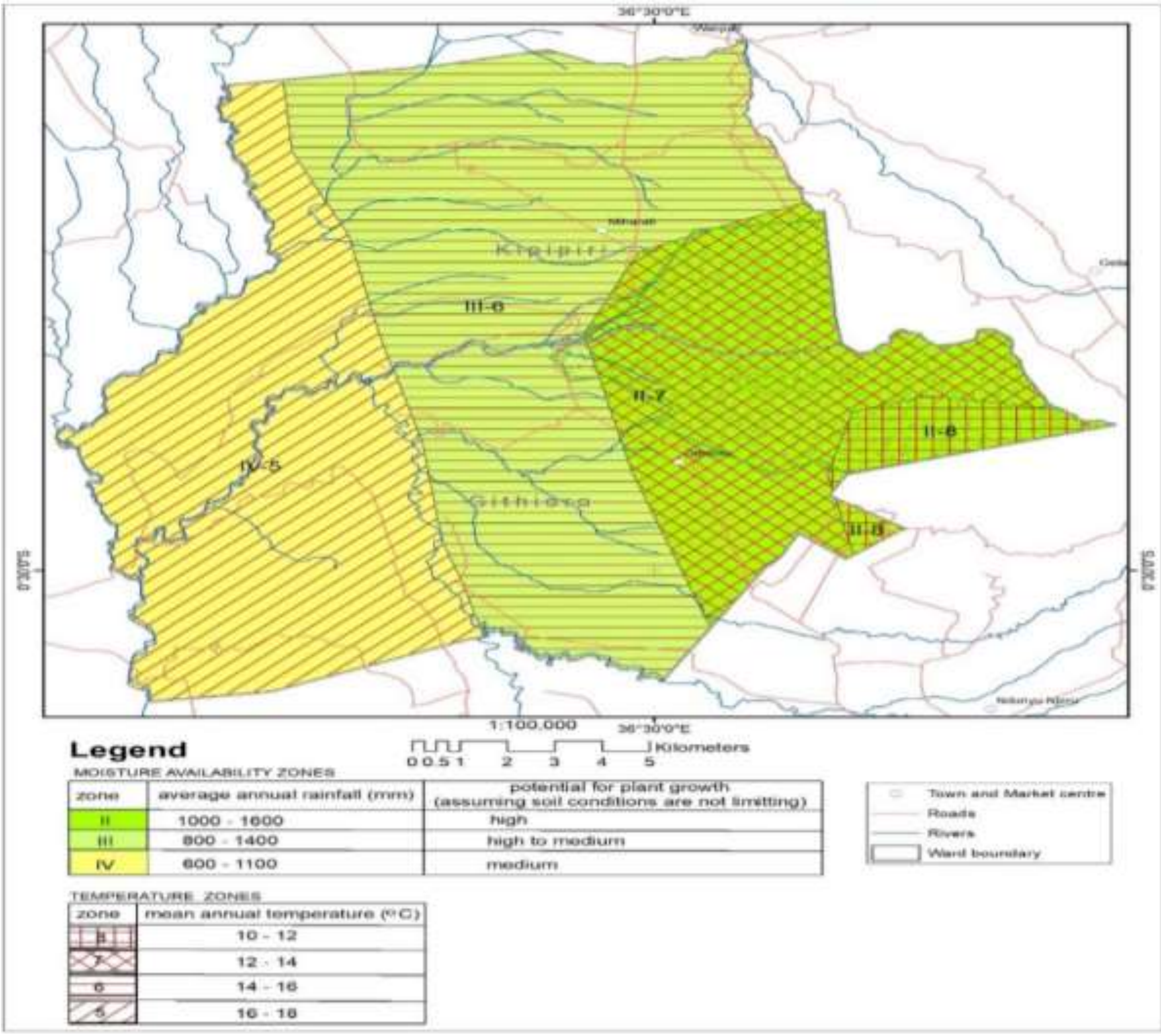

Figure 3.1: A map showing the agro ecological characteristics for Githioro and Kipipiri Locations in Nyandarua County.

Source: (Sombroek et al., 1982)

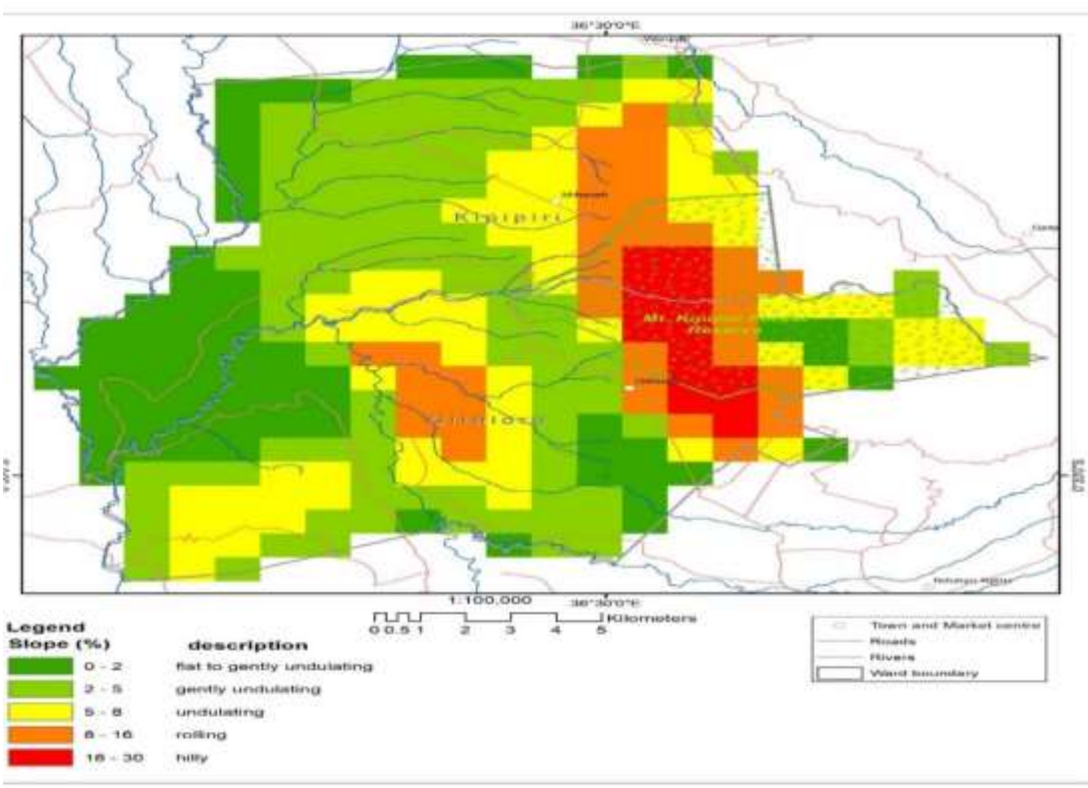

Figure 3.2: Elevation Map for Githioro and Kipipiri Locations in Nyandarua County

Source: (Farr & Kobrick, 2000).

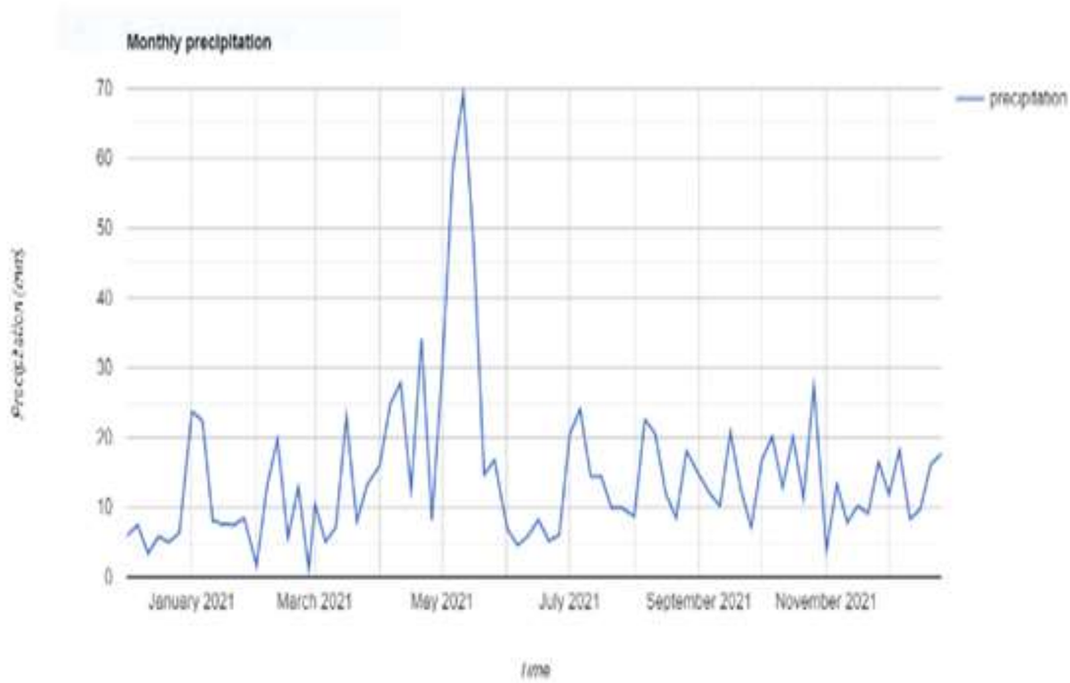

Figure 3.3: Rainfall Data for the Potato Growing Season of 2021 is Segmented into Two Distinct Periods: The Long Rains from March/April to July/August, and the Short rains from September/October to November/December.

Source: (Funk et al., 2015)

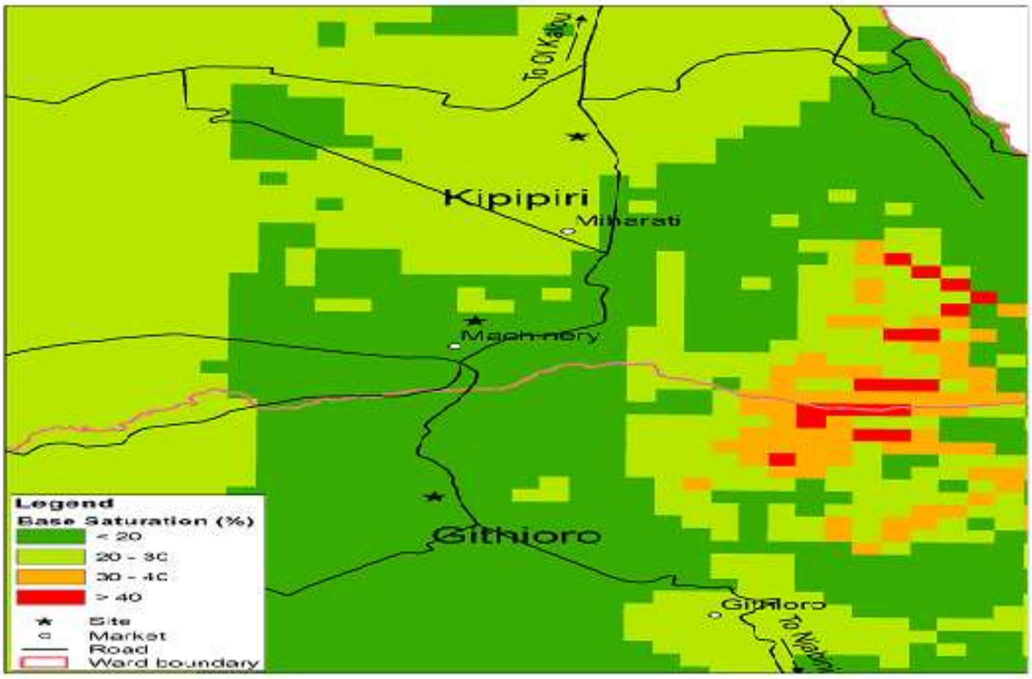

Figure 3.4: Base Saturation for Kipipiri and Githioro Locations in Nyandarua County

Source: https://dataverse.harvard.edu/dataset.xhtml?persistentId=hdl:1902.1/19793

3.2 Study Design

The study was conducted in Nyandarua County, a key region for potato production in Kenya, particularly in the Kipipiri and Githioro sub-counties, which show high potential for adopting potato farming practices. A randomized complete block design (RCBD) was utilized, with Kipipiri and Githioro locations serving as the main blocks. Farmers were randomly selected, and blocking was performed across different farmer plots. Composite samples were collected from various sites within these plots. The experimental treatment included three replicates.

The study primarily focused on three factors: variety, growing location, and harvesting stage. Due to the distinct growth phenology of the two potato varieties, sampling was conducted at different intervals. For the Shangi variety, sampling occurred at three stages: the first maturity stage, marked by flowering between 55-60 days after planting; the second maturity stage (dehaulming) at 70-75 days; and the final maturity/harvesting stage at 75-85 days. For the Markies variety, sampling was conducted during flowering at 75-90 days after planting, dehaulming at 90-104 days, and the final maturity/harvesting stage at 105-120 days.

The primary components assessed in the study were quality traits, which are crucial for both fresh and processed potatoes and directly influence their processing quality. These traits were divided into two categories: chemical characteristics, which included ascorbic acid content, starch content, and reducing sugars content; and physical characteristics, such as tuber flesh color, size, shape index, weight, texture, number of eyes, and specific gravity. Additionally, a proximate analysis was conducted as a baseline study for the two varieties across different maturity stages.

For evaluating postharvest changes, 25 kilograms of each variety were stored under two different conditions: ambient ware storage and cold storage. The study examined chemical changes, including reducing sugars, starch content, and ascorbic acid content, as well as physical characteristics like specific gravity, texture, and tuber flesh color. Moreover, a product was developed with the goal of extending the shelf life of fresh-cut potato slices by controlling enzymatic browning, a phenomenon of significant economic importance.

3.3 Sample Preparation

The tubers were harvested at different maturity stages as described in section 3.2. Tubers for storage were harvested at the physiological harvesting stage. The two varieties (Markies and Shangi) were sampled from Githioro and Kipipiri wards in Nyandarua County. One consignment was transported to Jomo Kenyatta University of Agriculture and Technology, Food Science laboratory for analysis and the other portions (25 kgs of each variety) were taken to KARLO, Tigoni for storage studies before analysis

The tubers were first sorted to obtain uniform size and separate the bruised, rotten, and infested ones. They were then washed with distilled water to remove any adhering dirt and soil and then dried using kitchen paper towels. Twenty tubers of uniform size and shape of each variety were picked from the lot collected from three plots in each location for evaluation of physical properties based on uniformity in shape and size as described by (Abedi et al., 2019). For chemical composition tubers from each location were peeled, blended, and analyzed Fifty kilograms (50kg) of each potato variety were obtained for the determination of changes during storage. They were apportioned to twenty-five kilograms each for the respective storage chambers.

3.4 Proximate Analysis

3.4.1 Determination of Moisture Content

Moisture content was determined according to AOAC Method 930.04 (1995). Moisture dishes were dried to a constant weight. Triplicate samples of about 5 g were accurately weighed into the dishes and oven-dried at 105°C for 3 hours. The samples were cooled in a desiccator, and the final weight was recorded. The process of heating, cooling, and weighing was repeated until a constant weight was attained. The proportion of moisture content was then calculated as shown below:

$$\%\ \text{Moisture content} = \frac{\text{Weight of sample before drying} - \text{Weight of sample after drying}}{\text{Weight of sample before drying}} \times 100$$

3.4.2 Determination of Ash Content

Ash content was determined using the AOAC method 920.117 (AOAC, 1995). Crucibles were dried in the oven, cooled in a desiccator, and weighed. Five (5) g of each sample was weighed into the pre-dried crucibles and then charred using flame until all smoke was removed. The samples were then transferred into a muffle furnace and incinerated at 550°C for about 5 hours until white ash was obtained. The remains were cooled in a desiccator and weighed. Ash content was expressed as a percentage of the original sample weight on a dry weight basis as follows:

$$\%\ \text{crude ash} = \frac{\text{weight of ash}}{\text{weight of sample}} \times 100$$

3.4.3 Crude Protein Determination

Crude protein was determined using the semi-micro Kjeldahl method 976.05 AOAC, (1995). This included digestion of 1.5 g sample that was weighed into a digestion flask followed by the addition of a catalyst mixture composed of 5 g of potassium sulphate (K_2SO_4), 0.5 g copper sulphate ($CuSO_4$) and 15 ml of concentrated sulphuric acid (H_2SO_4). The mixture was digested using a semi-micro Kjeldahl digester until the color changed to blue, indicating completion of digestion.

The contents were cooled and transferred into a 100 ml volumetric flask which was topped up to the mark using distilled water. A blank digestion composed of catalyst and acid was performed simultaneously.

Approximately 10 ml of the topped-up digest was added into a distilling flask and washed with 2 ml of distilled water, followed by the addition of 15 ml of 40% sodium hydroxide (NaOH) and washed down with 2 ml of distilled water. Distillation was performed to obtain a distillate of about 60 ml in volume mixed indicator was added to the distillate followed by titration with 0.02N HCl until the color changed to orange. All determinations were performed in triplicate. The titres were recorded and protein content was determined following the process below:

$$\%\ \text{Nitrogen} = (\text{Titre for sample} - \text{titre for blank}) \times N \times f \times 0.014 \times \frac{100}{S} \times \frac{100}{V}$$

N = Normality of standard hydrochloric acid (HCl) solution (0.02)

f = factor of standard HCl solution

V = Volume of diluted digest taken for distillation (ml)

S = weight of sample taken (g)

% Protein = Nitrogen × protein factor (6.25)

3.4.4 Determination of Crude Fat

Crude fat was determined using the Soxhlet Method 920.39C AOAC (1995). Extraction flasks were dried in the oven for 1 hour at 105°C then cooled in a desiccator to room temperature and weighed. Five grams of pre-dried samples were weighed into extraction thimbles and covered with defatted cotton wool. The thimbles were placed in thimble support holders and fixed into the extraction unit. Fat extraction was done using petroleum ether (b.p. 40-60°C) and extraction proceeded for 8 hours. The extraction solvent was removed using rotary vacuum evaporation then the extracted fat was put to dry in an air oven at 105°C for 30 min. The extraction flasks were cooled in a desiccator and the final weight of the flasks with the extracted fat was taken. Fat content in percentage was calculated as follows:

$$\% \text{ fat} = \frac{\text{weight of extracted fat (g)}}{\text{weight of sample (g)}} \times 100$$

3.4.5 Determination of Total Carbohydrates

Carbohydrate content was determined by difference method (E. N. Gikundi et al., 2021)

% Total carbohydrates = 100 - (% moisture content + % ash content + % fat content + % protein**)**

3.5 Determination of Physical Characteristics

A sample of 20 tubers of similar size was selected from the two varieties, Shangi and Markie'*s* from Kipipiri and Githioro wards in Nyandarua County a.

3.5.1 Specific Gravity

Specific gravity was determined using the method described by Abedi, Abdollahpour, and Bakhtiari (2019). From a sample of 20 tubers, the mass of tubers in air and mass of water displaced by the tuber was determined and computed using the following formula:

$$Sg = \frac{m}{mw}$$

Where *Sg* = specific gravity, *m* = mass of the tuber and *mw* = mass of water displaced.

3.5.2 Tuber Flesh Color

Color was determined using the method adopted by Wang (2015) using a hand-held Minolta color meter (Model CR-200, Osaka Japan). From a sample of 20, each tuber was cut into 2 pieces and the L* (lightness), a* (redness), and b* (yellowness) values were determined directly from the color meter. Calculations for the hue angle and Chroma were done using the L* a* and b* values as follows;

$$Hue\ Angle = tan^{-1}\left(\frac{b*}{a*}\right)$$

$$Chroma\ value^{*} = (a^{*2}+b^{*2})^{0.5}$$

3.5.3 Mean Tuber Weight

Tuber weight was determined from a sample of 20 tubers obtained from each plot using the method described by Zheng *et al.* (2016) using an electronic scale (Model Shimadzu Libror AEG-220) and the average for each variety obtained.

3.5.4 Mean Size of Tubers

The size of tubers was determined by measuring dimensions from a sample of 20 potato tubers using a Vernier caliper (Mituyoyo-Japan) with an accuracy of 0.01 mm (Bubeníčková *et al.,* 2011). Size in terms of linear dimensions was determined by measuring the length (largest diameter of the maximum projected area), width (minimum diameter of the maximum projected area), and thickness (diameter of the minimum projected area).

3.5.5 Tuber Shape

Tuber shape was determined by calculating the shape index (I) of the measured tubers as described by Gamea et al., (2009) using the following formula

$$I = \frac{L}{\sqrt{DT}}$$

Where *I* = shape index, *D* = tuber width, *L* = Tuber length, *T* = tuber thickness. The potato was considered spherical if *I* was ≤1.5 and classified as oval shape if *I* ≥1.5.

3.5.6 Eye Number

The mean number of eyes was determined from a sample of 20 tubers by counting – R2the total number of eyes and averaging them in each tuber from the test varieties as described by (Abong et al., 2010).

3.5.7 Tuber Texture

Tuber texture was evaluated by measuring the firmness using a penetrometer (Compac-100, model CR-100, Sun Scientific Co. Ltd Japan), with a maximum loading of 10 kg at the 3 stages of maturity. The penetrometer was fitted with a 5 mm piercing probe, which was allowed to penetrate the tuber to a depth of 15 mm, and 7mm for the fresh-cut potato slices respectively at different points. The tuber texture was expressed in Newton's (N) force as described by Jiang (1999).

3.6 Determination of Chemical Characteristics

3.6.1 Simple Sugars

Simple sugars analyses was done using the method described by Abong and Kabira, (2011). Approximately 5 g of fresh blended potato was weighed into 50 ml conical flasks (QF) and approximately 20 ml ethanol (C_2H_5OH) was added and swirled to mix. The mixture was heated under reflux for 1 hour and the resulting slurry was filtered into a 50 ml conical flask to obtain the filtrate. The solvent was evaporated to dryness at 80°C using a rotary evaporator. The dried sample was reconstituted with 2 ml of distilled water (dH_2O) and acetonitrile (CH_3CN) in a ratio of 1:1. The sample was then filtered with 0.45 µm filters and 20 µl injected into the Liquid Chromatograph (Shimadzu LC 20A series fitted with RID 10A detector) and separated at 30°C using Sepax amino HP-Amino-5 µm 120A 4.6x250 mm column at 1 ml/min flow rate of Acetonitrile: water (75:25). Sugars present were identified and their concentration calculated by comparing samples with standards of fructose, glucose, and sucrose and expressed as mg/100 g fresh weight.

3.6.2 Starch Content

Starch content was analyzed by the Anthrone Direct Acid hydrolysis method (AOAC 1980: method 13.056). Carbohydrates were first hydrolyzed into simple sugars using dilute hydrochloric acid (HCl) to dehydrate glucose to hydroxymethylfurfural, a compound that reacts with anthrone to form a green-colored product with an absorption maximum at 630 nm. Approximately 5 ml of 2.5 M HCl was added into a tube containing approximately 100mg of sample and boiled in a water bath for 3 hours then cooled to room temperature. This was neutralized with sodium carbonate (Na_2CO_3) until the effervescence ceased. The solution was made up to 100 ml and centrifuged. Then 0.5 ml and 1 ml aliquots were taken from this analysis solution. Standards were prepared by taking 0, 0.2, 0.4, 0.6, 0.8, and 1 ml of the working standards of glucose. The volume was made up to 1 ml in all the tubes including the sample tubes by adding H_2O. Four (4) ml of the anthrone reagent was then added and the solution was heated for 8 minutes in a boiling water bath and cooled rapidly. Readings of the green to dark green color were read at 630 nm using a UV-VIS Shimadzu 1800 spectrophotometer. A standard curve was plotted and the graph was used to calculate the amount of carbohydrates present in the sample and results were multiplied by a factor of 0.9 to give the % starch content in the sample as shown below:

Amount of carbohydrate present in 100 mg of the sample

$$= \left(\frac{g}{v} \times 100\right) \times 0.9$$

Where *g* =amount of glucose, *v*= volume of test sample

3.6.3 Ascorbic Acid Content

Ascorbic acid content in the samples was determined by the HPLC method as described by Vikram (2005). Approximately 2 g of the blended sample was weighed and extracted with 0.8% metaphosphoric acid. This was made up to 20 ml and centrifuged at 10,000 rpm at 4^{o}C. The supernatant was filtered and diluted with 10 ml of 0.8% metaphosphoric acid (H_3PO_4). It was then passed through a 0.45 µm syringe filter and 20 µL was injected into the HPLC fitted with Shimadzu SPD 20AD detector set at 266 nm and Phenomenex Luna C18 (2) HPLC 5 µm 250x4.6 mm column. Various concentrations of ascorbic acid standards were also made to make a calibration curve. The mobile phase was 0.8% metaphosphoric acid, at a flow rate of 1.2 ml/min and at a wavelength of 266 nm.

3.7 Determination of Postharvest Changes during Storage

3.7.1 Determination of Physicochemical Changes

Post-harvest changes during storage were determined as per the method described by (Abong *et al.*, 2015). Approximately 25 kg of Markies and Shangi were stored each under two different storage conditions (ware and cold storage). The store condition for ware storage was a dark room at 18^{o}C and 85% RH and cold storage was maintained at 5^{o}C and 95% relative humidity (RH). Determination of the physicochemical changes (Starch content, reducing sugars, ascorbic acid, specific gravity, texture, and color changes) during storage was done as per the methods described earlier. Sampling was done at monthly intervals for four months, Visual evaluation for sprouting was done every week at an interval of 7 days for four months.

3.7.2 Sprouting

The rate of sprouting was determined as per the method described by Evelyne *et al.*, (2021). Tubers were considered sprouted if they had at least one visible sprout of at least 3 mm in length. To determine the number of sprouts per tuber all sprouted tuber s from each lot were selected,sprouts in each tuber were counted,and the number of sprouts was averaged per the number of tubers sprouted.per sample batch. This was monitored every week.

3.8 Product Development

Product development refers to the systematic process of improving existing products based on research. Outlined below is a systematic schedule aimed at improving and extending the shelf life of fresh-cut potato slices.

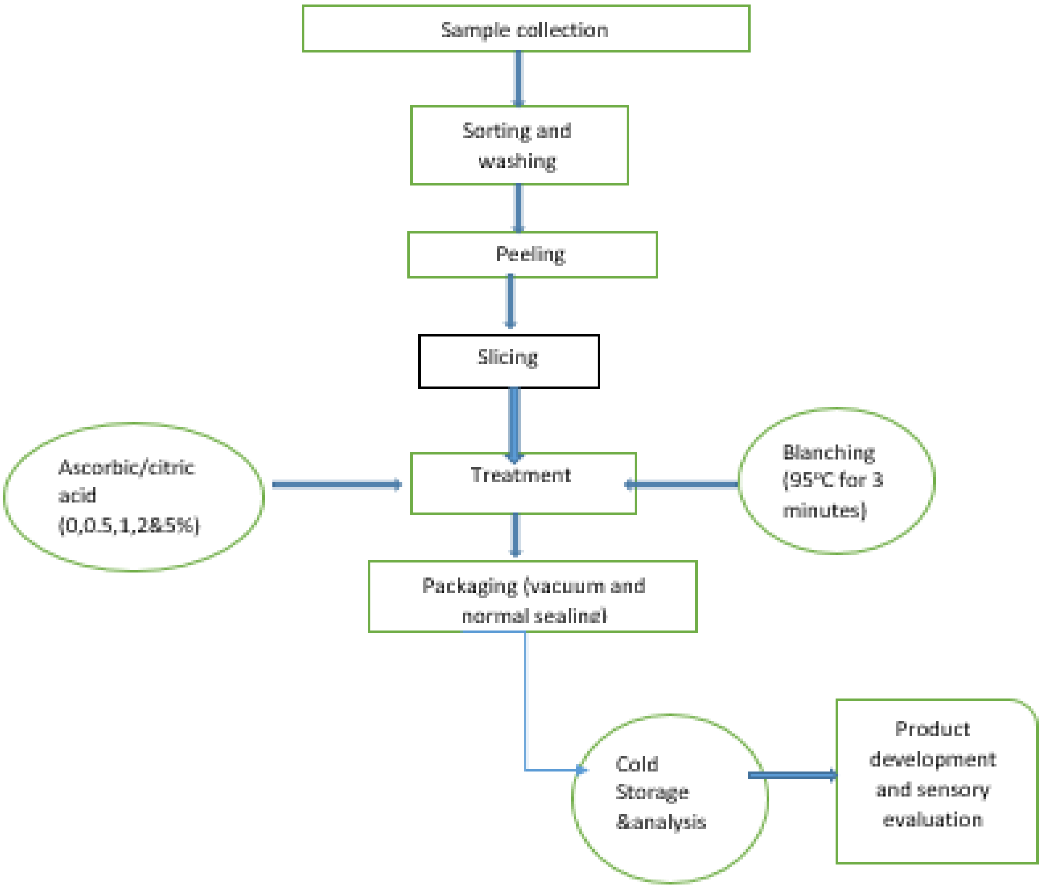

Figure 3.5: Fresh–Cut Potato Slices Production Flow Diagram

3.8.1 Preparation of Fresh-Cut Potato Slices

The two potato varieties, Markies and Shangi, were harvested at maturity stage 3 and transported to the food processing workshop at JKUAT. Preparation of fresh-cut potato slices was done as per the method described by Ali *et al.* (2021). Uniform sizes of potatoes free from mechanical damage were selected, washed, peeled, and cut lengthwise using a hand-operated chip cutter producing (8.84 x 10.15 mm) and (10.57 x 9.62 mm) slices in cross-section of Markies and Shangi respectively. The fresh-cut slices were washed to remove surface starch and subdivided randomly into 3 groups per variety. They were treated at concentrations of 0%, 2%, and 5% of ascorbic and citric acid respectively, and blanched at 95^{o}C for 3 minutes. Further, the samples were subdivided into 100 g, some were vacuum packed using a vacuum sealer (DZ-260 model made in China) while others were sealed normally using an impulse sealer. They were stored at 7.0±1.0^{0}C in a cold storage room. During storage the period measurement of color and textural changes was done on weekly basis for 6 weeks

3.8.2 French Fries' Preparation

The stored fresh slices as described above were processed into French fries using the method described by Abong *et al.* (2009). The slices were fried using a deep fryer, equipped with a thermostatically controlled electric heating coil. The slices were pre-fried at 170^{0}C for 5-8 minutes. The oil was drained off and chips were placed on plates for sensory evaluation.

3.9 Sensory Evaluation

For the sensory evaluation part of this study, the assessment was carried out using the method described by Noe *et al.*, (2019). French fry samples were prepared from the fresh-cut potato slices preserved for 6 weeks as described in section 3.8.1. The products for evaluation were processed as described in section 3.8.2 followed by sensory evaluation using a 9-point hedonic scale with categories from like extremely good (9) to dislike extremely (1) as shown in Table 3.1 below. The color, texture, flavor, and overall acceptability of the potato fries was evaluated by a panel of forty persons. The panelists are regular potato consumers and made up of students and workers of both males and females at JKUAT. The coded samples were separately served to panelists with potable water for rinsing of mouth between samples.

Table 3.1: Sensory Evaluation Scale for French Fries Prepared from Shangi and Markies Potato Varieties under Different Treatments

Acceptability	Quality description	Score
Unacceptable	Extremely poor	1
	Very poor	2
Barely acceptable	poor	*3*
	Below fair/above poor	4
	fair	5
Acceptable	Below good/above fair	6
	Good	7
	Very good	8
Highly acceptable	Extremely good	9

3.10 Data Analysis

The methodology used to compare the means was two-way ANOVA using R software version 4.2.0 and tests were conducted at alpha 0.05 level of significance.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Proximate Composition

The results of this study, presented in Table 4.2, reveal a significant difference ($P<0.05$) in moisture content between the two potato varieties across the three maturity stages. Both the variety and maturity stage significantly impacted the moisture content. Specifically, Markies at the flowering stage exhibited the highest moisture content at 82.48±0.72%, whereas Shangi at the leaf-yellowing stage showed the lowest moisture content at 69.46±3.68%. Leonel *et al.,* (2017) reported moisture contents ranging from 78.17% to 88.11% for five potato cultivars, which aligns with the findings of this study. Additionally, the study by Leonel *et al.*, (2017) noted that soil phosphorus availability and cultivar type significantly influenced tuber moisture content.

Lower moisture content in potatoes is associated with reduced frying time, decreased oil absorption, a lower risk of soggy products, and minimized discoloration during cooking (Zehra, 2011, Abong *et al.*, 2009). In deep-frying, the amount of oil absorbed impacts the caloric content of the food. Health-conscious consumers often prefer French fries with lower oil content while maintaining desirable sensory attributes (Abong et al., 2009). The observed differences in moisture content between the varieties may be attributed to genetic traits that affect moisture retention. Additionally, variations in water requirements among potato varieties can influence tuber moisture content (Jama-Rodzeńska et al., 2020).

Table 4.1: Proximate Composition of Markies and Shangi Evaluated at Three Maturity Stages

Variety	Maturity Stage	%MC	%Ash	%Fat	%Proteins	Total Carbohydrates
Markies	Flowering	83.24 ± 0.72^{c}	0.76 ± 0.18^{a}	0.05 ± 0.02^{a}	0.04 ± 0.01^{a}	15.91 ± 2.55^{a}
	Shedding of flowers	81.28 ± 2.56^{bc}	1.09 ± 0.03^{b}	0.0 ± 0.01^{b}	1.83 ± 0.12^{b}	16.82 ± 0.79^{a}
	Yellowing of leaves	79.88 ± 2.30^{b}	1.57 ± 0.21^{c}	0.09 ± 0.01^{c}	2.44 ± 0.08^{c}	16.11 ± 2.56^{a}
Shangi	Flowering	82.48 ± 0.72^{bc}	0.26 ± 0.02^{a}	0.01 ± 0.00^{a}	1.80 ± 0.08^{a}	15.45 ± 1.35^{a}
	Shedding of flowers	79.46 ± 2.31^{b}	1.40 ± 0.07^{b}	0.03 ± 0.02^{b}	2.25 ± 0.18^{b}	16.86 ± 3.68^{a}
	Yellowing of leaves	69.46 ± 3.68^{a}	1.80 ± 0.19^{c}	0.06 ± 0.01^{c}	2.97 ± 0.00^{c}	25.51 ± 2.43^{b}
P value						
Variety		0.023	0.067	0.026	0.003	0.004
Maturity stage		0.014	0.034	0.014	0.019	0.001
Variety * maturity stage		0.037	0.042	0.029	0.021	0.005

Values are means ± standard deviation. Means with different subscript letters in the same column for each variety are significantly different at $P<0.05$

No significant difference (P>0.05) in protein content was observed between the two potato varieties. However, a significant difference (P<0.05) was found in protein content with respect to variety and maturity stage. The Shangi variety exhibited a slightly higher protein content (2.97%) compared to the Markies variety (2.44%) at maturity stage 3. Leonel *et al.* (2017) reported similar protein content levels among five Brazilian potato varieties, ranging from 1.45% to 2.35%, which is consistent with the findings of this study. The relatively high protein content in both Shangi and Markies varieties makes them suitable for processing into products such as noodles, which require a minimum protein content of approximately 1.61 g/100 g or higher (Zhang et al., 2017).

A significant difference (P<0.05) in carbohydrate content was observed between the two potato varieties. The Shangi variety had a higher carbohydrate content of 25.51% compared to the Markies variety, which had 16.11% carbohydrate at maturity stage 3. Both variety and maturity stage had a significant effect (P=0.005) on carbohydrate content, with the highest levels recorded at maturity stage 3. These differences may be attributed to genotypic variations among the varieties. The findings are consistent with those of Gikundi et al., (2021) who reported carbohydrate content ranging from 15.16% to 20.40% in the proximate composition of three Kenyan potato varieties, including Dutch Robijn, Unica, and Shangi, with Dutch Robijn exhibiting the highest carbohydrate content of 20.43%.

The results are consistent with findings from other researchers. For example, Jin *et al.*, (2016) reported a carbohydrate content range of 15.14% to 16.07% in four Korean potato varieties. Carbohydrates, predominantly in the form of starch, are the principal macronutrient in potatoes. Potatoes with high carbohydrate content are particularly suitable for processing. The observed differences in carbohydrate content between the varieties are likely due to genotypic differences (Gikundi, 2021) .

A significant difference (P=0.029) in fat content was observed between the Shangi and Markies varieties across the maturity stages, with the highest fat content recorded at maturity stage 3. Specifically, Shangi had a fat content of 0.06%, while Markies had a fat content of 0.09%. However, there was no significant effect (P>0.05) of variety or maturity stage on fat content. Although the low fat content in potatoes may not have a significant nutritional impact, it can enhance the sensory attributes of cooked tubers and improve cellular integrity, thereby increasing resistance to bruising (Kalita & Jayanty, 2017).

The study revealed no significant difference (P>0.05) in ash content between the Shangi and Markies potato varieties. However, a significant interaction (P<0.05) was observed between the variety and maturity stages, with the third maturity stage exhibiting the highest ash content. Specifically, the Shangi variety had the highest ash content at 1.80%, compared to 1.57% in the Markies variety. These differences are likely due to genotypic variation. The results are consistent with those of Leonel *et al.*,(2017), who reported ash content ranging from 0.81 to 1.38 g/100 g in Brazilian potato varieties. Similar findings were reported by Jin *et al.*, (2016) in four Korean potato varieties, with ash content ranging from 0.87 to 1.04 g/100 g. These findings suggest that potatoes, in terms of ash content, can serve as substitutes for staple cereals such as maize and rice, whose ash content ranges from approximately 0.79 to 1.49 g/100 g and 0.50 to 2.00 g/100 g, respectively (Gikundi et al., 2021).

Proteins and macrominerals are vital components of potatoes due to their physiological and nutritional importance in human diets (Zehra Ekin, 2011). Determining the ash content in food is crucial for evaluating nutritional value, quality, and stability. Ash content represents the residual minerals and inorganics after a food sample is heated to high temperatures, removing moisture, volatiles, and organics. This analysis aids in assessing the overall nutritional profile and is essential for quality control in the food industry, ensuring that food products meet specific standards and do not contain harmful levels of inorganic materials.

4.2 Physical Properties

The results of this study are as tabulated in Table 4.2 below

Table 4.2: Physical Properties of Potato Varieties (Markies and Shangi) Grown in Two Locations (Githioro and Kipipiri) and Evaluated at 3 Maturity Stages

PV	MS	L	Texture (N)	Weight (g)	Specific gravity	Length (mm)	Width (mm)	Thickness (mm)	Shape index	No of eyes	lightness	Redness	Yellowness
Markies	Stage 1	Githioro	3.74±0.05[a]	76.55±2.62[c]	1.06±0.02[a]	67.37±3.2[c]	40.74±.03[ab]	45.13±2.45[a]	1.5±0.06[a]	6.4±0.47[a]	67.84±0.75[d]	-7.12±0.17[e]	21.13±0.72[a]
		Kipipiri	3.92±0.04[a]	78.9±4.86[c]	1.14±0.05[a]	71.33±2.14[d]	44.21±0.98[c]	48.43±1.09[b]	1.6±0.03[a]	7.49±0.33[a]	50.28±1.08[a]	-6.89±0.09[e]	20.41±0.42[a]
	Stage 2	Githioro	3.74±0.05[a]	83.58±5.06[d]	1.06±.02[a]	69.45±.01[cd]	41.52±2.33[b]	46.67±1.93[ab]	1.61±0.03[a]	7.11±0.31[a]	60.64±0.98[c]	-5.91±0.13[c]	19.62±0.67[a]
		Kipipiri	4.13±0.05[b]	112.73±.60[g]	1.16±0.07[a]	78.07±1.35[e]	46.77±0.67[cd]	52.48±0.62[cd]	1.6±0.03[a]	7.39±0.21[a]	54.14±0.82[b]	-5.59±0.15[bc]	19.07±0.33[a]
	Stage 3	Githioro	3.92±0.08[a]	90.3±2.8[e]	1.07±.02[a]	69.67±0.22[cd]	47.83±1.19[d]	52.21±0.92[cd]	1.6±0.07[a]	7.2±0.29[a]	54.07±2.53[b]	-5.14±0.34[ab]	19.95±3.93[a]
		Kipipiri	4.13±0.04[b]	147.7±5.07[g]	1.25±0.08[a]	91.4±1.85[g]	49.19±0.72[e]	56.26±0.84[d]	1.7±0.03[a]	9.27±0.19[b]	70.16±0.60[e]	-5.06±0.36[ab]	19.86±0.30[a]
Shangi	Stage 1	Githioro	3.67±0.06[a]	44.65±3.21[a]	1.04±0.02[a]	56.7±2.5[a]	38.76±1.73[a]	44.9±2.00[a]	1.29±0.04[a]	9.3±0.36[b]	60.16±1.47[c]	-5.48±0.18[bc]	21.86±0.97[a]
		Kipipiri	3.51±0.04[a]	61.3±2.69[b]	1.08±0.01[a]	58.12±1.55[a]	40.95±0.82[ab]	44.13±0.82[a]	1.4±0.03[a]	9.78±0.24[b]	67.96±0.62[d]	-6.15±0.26[d]	20.2±0.44[a]
	Stage 2	Githioro	3.76±0.06[a]	80.36±3.20[d]	1.09±0.01[a]	61.9±1.66[b]	46.29±1.45[cd]	51.44±1.54[c]	1.33±0.05[a]	8.5±0.33[b]	52.46±1.92[ab]	-5.33±0.21[b]	19.84±0.58[a]
		Kipipiri	4.16±0.05[b]	103.4±2.80[f]	1.10±0.02[a]	75.83±1.33[e]	45.98±0.81[c]	51.24±0.62[c]	1.6±0.04[a]	9.9±0.26[b]	62.74±1.49[c]	-4.98±0.16[a]	19.86±0.47[a]
	Stage 3	Githioro	4.08±0.08[b]	86.5±2.58[d]	1.10±0.02[a]	65.23±1.23[c]	46.75±1.45[cd]	53.31±1.17[d]	1.37±0.06[a]	9.3±0.45[b]	50.9±1.02[a]	-4.87±0.21[a]	19.07±0.06[a]
		Kipipiri	4.35±0.06[b]	150.95±.0.67[h]	1.27±0.04[a]	89.32±2.87[f]	53.14±1.04[f]	60.28±1.1[2e]	1.6±0.06[a]	11.22±0.34[c]	50.28±1.0[a]	-4.60±0.13[a]	20.18±0.71[a]
P values													
Variety			0.291	<0.001	0.342	0.002	0.029	0.873	0.432	0.046	0.047	0.092	0.065
Maturity stage			0.045	<0.001	0.164	<0.001	0.012	0.012	0.871	0.042	0.032	0.049	0.125
Location			0.039	<0.001	0.562	<0.001	0.018	0.002	0.190	0.039	0.057	0.031	0.073
Variety* maturity stage* location			0.047	0.001	0.697	0.001	0.033	0.025	0.265	0.048	0.035	0.047	0.085

Values are means ± SD. Means with different superscript letters along the columns are significantly different at p<0.05.

4.2.1 Texture

There was a significant interaction effect between variety, maturity stage, and location on the texture of the potatoes. Specifically, Markies and Shangi potatoes harvested at maturity stages 2 and 3 in Kipipiri, as well as Shangi potatoes harvested at stage 3 in Githioro, exhibited the highest texture values. In contrast, all other varieties, regardless of maturity stage or location, had the lowest texture values. Texture, which serves as an indicator of potato hardness, was found to be highest in Markies and Shangi potatoes grown in Kipipiri at stage 3 of maturity. The hardness values were 4.13±0.04N for Markies and 4.35±0.06N for Shangi.

Potato hardness is a key quality attribute that consumers use to determine acceptability. It reflects the potato tuber's resistance to applied force and is closely linked to the tuber's structural characteristics (Singh et al., 2009). Singh *et al*. (2016) demonstrated that hardness profiles can vary significantly between different potato cultivars. Similarly, Bordoloi et al., (2012) found that differences in potato hardness are related to their microstructural features. Specifically, raw potato parenchyma with smaller cell sizes and a well-defined cellular structure yields a harder and more cohesive texture. The texture of potatoes is a complex attribute that greatly affects their suitability for processing, playing a crucial role in determining the final texture and quality of potato-based products (García-Segovia et al., 2008).

4.2.2 Tuber Weight

There was a significant interaction effect ($P<0.05$) on the weight of potato samples across variety, maturity stage, and location. Potato weight increased with maturity, with the highest weights observed at maturity stage 3. At this stage, the Markies variety recorded a weight of 147.7±5.07 g, while the Shangi variety reached 150.95±0.67 g. These results align with those of Rahman (2017, who studied 40 potato varieties in Bangladesh and reported a weight range of 72.84 g to 138.10 g. Eaton *et al*., (2017) suggested that the observed variations in potato weight could be due to factors such as genetics, management practices, seed quality, or ecological conditions.

Rahman (2014) also noted that higher tuber weight may be linked to sufficient vegetative growth during tuberization. Tuber weight is a key determinant of yield, with significant implications for potato production. For instance, in Kenya, the Crops (Irish Potato) Regulation 2019 mandates that potatoes be sold based on weight, with a standard of 50 kg bags (National Potato Council of Kenya, 2019b) Additionally, tuber weight is critical for determining the quality of processed potato products. Factors such as dry matter content, reducing sugars, specific gravity, and storage conditions interact with tuber weight to influence product yield, texture, and flavor. Therefore, achieving heavier tubers with optimal characteristics is essential for producing high-quality processed potato products (Das et al., 2021).

4.2.3 Specific Gravity

There was no significant effect ($P>0.05$) on specific gravity among the potato samples across the variety, maturity stage, and location. At maturity stage 3, the Markies variety had a specific gravity of 1.25 ± 0.08, while the Shangi variety recorded a specific gravity of 1.27 ± 0.04. The high specific gravity observed at this stage is likely due to increased starch content, which is positively correlated with both specific gravity and dry matter content. These findings are consistent with those reported by Gikundi et al., (2021) and Wayumba *et al*. (2019). Similarly, Soboka *et al* (2018) confirmed significant variations in specific gravity across different environments, and Mohammed (2016) also noted a significant influence of variety and location on specific gravity in an earlier study.

Specific gravity is a crucial parameter for assessing tuber quality, particularly in major potato-growing regions, and processors can utilize specific gravity conversion charts for this purpose (Mohammed, 2016). It serves as an important indicator in the potato processing industry, providing a quick estimation of dry matter content. Specific gravity varies between varieties and is directly related to the yield of processed products

(Ndungutse *et al*., 2019). Kabira and Lemaga (2003) reported that potatoes with a specific gravity greater than 1.08 are considered to be of good quality. The potatoes from both locations in this study exhibited good specific gravity, indicating their suitability for processing into tuber-based products.

4.2.4 Geometric Properties (length, width, and thickness)

There was no significant difference (P=0.873) in thickness between the Markies and Shangi potato varieties. However, there was a significant interaction effect (P<0.05) of variety, maturity stage, and location on the geometric properties, specifically length and width. At maturity stage 3, the Markies and Shangi varieties grown in Kipipiri had the highest tuber lengths, with Markies reaching 91.4±1.85 mm and Shangi 89.32±2.87 mm. In terms of width, the Markies variety from Kipipiri recorded 49.19±0.72 mm, while Shangi measured 53.14±1.04 mm at the same maturity stage. These tuber sizes align well with those reported by Noel *et al*., (2019), who observed a tuber length range of 46.74–91.45 mm. Additionally, Abong *et al.*, (2010) noted that acceptable tuber sizes for processing in Kenya are those with a diameter greater than 50 mm and a length greater than 30 mm, as recommended for French fries. The ideal tuber size varies depending on the intended product: tubers larger than 50 mm are optimal for French fries, while those between 40 and 50 mm are preferred for crisps (Kabira & Lemaga, 2003; Abong *et al*., 2010).

4.2.5 Shape Index

There was no significant interaction effect (P>0.05) on shape index between variety, maturity stage, and location. The tuber shape for both the Markies and Shangi varieties was oval (I ≥1.5). Tuber shape, determined by the ratio of length to width, is important for processing; long tubers are preferred for French fries, while round ones are ideal for crisps, as noted by Werij (2011).. Additionally, tuber shape plays a crucial role in the design of processing machinery (Wayumba, Choi, and Seok, 2019)Unlike tuber size, which is influenced by cultural practices, tuber shape is primarily a varietal characteristic (Noel *et al*., 2019). Although genetic factors predominantly control tuber shape, environmental conditions can also have some impact (Afroj & Bashar, 2014). Consequently, both the Markies and Shangi varieties are well-suited for French fry production.

4.2.6 Number of Eyes

There was a significant interaction effect ($P<0.05$) on the number of eyes among variety, maturity stage, and location. The Shangi variety had more eyes compared to Markies, which had fewer eyes. Additionally, Shangi's eyes were shallower than those of Markies. Eye depth and number are inherent varietal characteristics, with eye depth being controlled by a specific gene (Werij, 2011). Varieties with shallow eyes are preferred for processing, as they result in lower losses during peeling and trimming, as noted by Noel *et al*. (2019) and Rahman *et al*. (2017). Shallow or medium eye depth is optimal to minimize processing losses (Abong *et al.*, 2010). Given that the Markies variety has fewer and shallower eyes, it is likely to incur lower losses during peeling. The number of eyes on Irish potatoes is crucial for processing suitability, as it affects both the efficiency of processing operations and the quality of the final product. Varieties with fewer eyes are generally more desirable for processing.

4.2.7 Tuber Flesh Color

There was a significant effect ($P<0.05$) on lightness (L^*) and redness (a^*) between the potato variety and the maturity stage, with lightness decreasing as maturity progressed. However, no significant effect ($P>0.05$) was observed on yellowness (b^*). Gilsenan *et al*. (2010) suggested that location may influence potato flesh color, while Bordoloi *et al*. (2012) reported that high L^* values are associated with whiteness, b^* with yellowness, and $-a^*$ with darkness. Tuber flesh color is a key quality attribute evaluated by both processors and consumers, influencing their choices and preferences. Tubers with cream or yellow flesh are ideal for processing French fries and crisps, as they yield a light golden product that is highly preferred by consumers (Kajunju *et al*., 2021). Food color is determined by various chemical, biochemical, microbial, and physical changes that occur during growth, maturation, postharvest handling, and processing (Pathare & Opara, 2013). Color is a critical quality attribute that shapes consumer perception, with higher lightness often associated with better quality, as noted by Rahman *et al*., (2017).

4.3 Chemical Characteristics of the Potato Varieties

The chemical properties refer to those compounds within potato tubers, which are crucial in processing the internal quality traits that may impact processing as outlined in Table 4.3 below:

4.3.1 Starch Content

The starch content of potatoes was significantly influenced by the variety, maturity stage, and location ($P<0.05$). The Shangi variety at maturity stage 3, harvested in Kipipiri, exhibited the highest starch levels, while the Markies and Shangi varieties at stage 1, harvested in Githioro, showed the lowest starch content. Specifically, at maturity stage 3, the Markies variety from Kipipiri had a starch content of 44.38±6.60 mg/100 g, compared to 30.00±3.11 mg/100 g in samples from Githioro at the same stage. Similarly, the Shangi variety at maturity stage 3 from Kipipiri had a starch content of 49.21±1.16 mg/100 g, whereas samples from Githioro at the same maturity stage had a starch content of 20.25±4.23 mg/100 g. The starch content range observed in this study, 19 - 49 mg/100 g, aligns with findings reported by Ndungutse *et al.*, (2019), Soboka *et al.*, (2018), and Mohammed, (2016). Starch constitutes the largest portion of potato dry matter, with high starch content being desirable due to its association with high dry matter content. Potatoes with elevated starch levels are favored for their yield and texture, as high starch content promotes significant gelatinization during processing. Thus, the starch content in potatoes is considered a critical factor in determining their suitability for various applications.

Table 4.3: Chemical Properties of Potato Varieties Markies and Shangi Evaluated at 3 Maturity Stages

Potato variety	Maturity stage	Location	Starch (mg/100 g)	Ascorbic acid (mg/100 g)	Glucose (mg/100 g)	Fructose (mg/100 g)	Sucrose (mg/100 g)
Markies	Stage 1	Githioro	12.10 ± 1.57^{a}	11.43 ± 0.12^{a}	44.59 ± 6.79^{e}	115.64 ± 8.47^{h}	149.3 ± 2.43^{f}
		Kipipiri	21.14 ± 1.23^{d}	15.59 ± 0.32^{b}	39.4 ± 1.98^{b}	23.34 ± 1.70^{d}	93.8 ± 1.74^{g}
	Stage 2	Githioro	24.50 ± 2.40^{e}	15.71 ± 0.97^{b}	31.0 ± 6.60^{f}	96.88 ± 8.47^{h}	137.04 ± 5.52^{e}
		Kipipiri	21.86 ± 4.49^{d}	15.66 ± 0.55^{b}	21.25 ± 0.88^{d}	14.68 ± 0.18^{bc}	60.48 ± 3.58^{d}
	Stage 3	Githioro	30.00 ± 3.11^{f}	15.81 ± 1.15^{b}	29.34 ± 9.79^{h}	65.64 ± 2.31^{i}	89.4 ± 0.72^{c}
		Kipipiri	44.38 ± 6.60^{g}	18.06 ± 0.50^{cd}	11.76 ± 1.56^{g}	13.51 ± 1.60^{d}	43.55 ± 0.69^{b}
Shangi	Stage 1	Githioro	13.53 ± 0.80^{a}	11.15 ± 2.71^{a}	63.56 ± 0.46^{g}	79.71 ± 2.34^{g}	130.27 ± 4.32^{g}
		Kipipiri	$14.83+3.19^{b}$	12.85 ± 0.57^{a}	22.89 ± 3.65^{d}	39.62 ± 2.55^{f}	89.86 ± 7.26^{c}
	Stage 2	Githioro	19.96 ± 1.61^{c}	18.21 ± 0.36^{cd}	46.45 ± 3.54^{h}	32.7 ± 719^{e}	91.63 ± 1.66^{f}
		Kipipiri	31.63 ± 2.05^{f}	16.63 ± 0.58^{bc}	17.35 ± 1.81^{c}	23.61 ± 3.06^{d}	45.15 ± 0.80^{b}
	Stage 3	Githioro	20.25 ± 4.23^{cd}	19.08 ± 0.09^{d}	40.58 ± 9.87^{i}	13.98 ± 0.81^{g}	58.2 ± 1.05^{d}
		Kipipiri	49.21 ± 1.16^{h}	17.28 ± 0.71^{c}	16.95 ± 1.4^{d}	16.89 ± 1.35^{f}	30.42 ± 2.62^{a}
P values							
Variety			0.051	0.612	0.002	<0.001	<0.001
Maturity stage			<0.001	0.012	<0.001	<0.001	<0.001
Location			<0.001	0.034	<0.001	<0.001	<0.001
Variety*Maturity stage*location			<0.001	0.039	0.003	<0.001	<0.001

Values are means ± SD. Means with different superscript letters along the columns are significantly different at $p<0.05$

In his study, Zehra (2011) emphasized the critical role of starch content in determining the quality of potato products. He classified starch content into three categories: 19 mg/100 g as optimal for mashing, 16-19 mg/100 g as suitable for roasting, and 13-15.9 mg/100 g as intermediate and appropriate for either cooking or roasting. Varieties with a starch content of less than 12 mg/100 g are considered ideal for boiling (Zehra, 2011). According to (Kaguongo et al., 2014) the preferred starch content for processing crisps and chips comes from potato varieties that are high in starch and low in sugars, ensuring both quality and taste in the final product.

The starch content results were consistent with those reported by Soboka *et al*. (2018), who found significant variations in starch content among different potato varieties across various environments. This suggests that the quality traits of potatoes are influenced by both the variety and the growing conditions. Consequently, the observed differences in starch content can be attributed to the interaction between genotype and environmental factors (Dramićanin *et al.*, 2018).

The starch content of potato varieties is largely influenced by their genetic composition. Additionally, environmental factors such as soil type, climate, and cultivation practices significantly impact starch accumulation in potatoes. Variations in dry matter content and starch yield across different growing regions suggest that both genetic factors and environmental conditions play a critical role in determining the final starch content of potato varieties (Gikundi et al., 2021).

4.3.2 Ascorbic Acid Content

There was a significant effect ($P<0.05$) of maturity stage and location on the ascorbic acid content of the potatoes. Ascorbic acid levels increased in both varieties across the maturity stages in both the Kipipiri and Githioro locations, as shown in Table 4.3. The Markies variety from Githioro had an ascorbic acid content of 11.43±0.12 mg/100 g at maturity stage 1, which increased to 15.81±1.15 mg/100 g by maturity stage 3. In Kipipiri, the ascorbic acid content in the Markies variety was 15.59±0.32 mg/100 g at maturity stage 1, rising to 18.06±0.50 mg/100 g at maturity stage 3. For the Shangi variety, the ascorbic acid content from Githioro was 11.15±2.71 mg/100 g at maturity stage 1, increasing to 19.08±0.09 mg/100 g at maturity stage 3. In Kipipiri, the Shangi variety had an ascorbic acid content of 12.85±0.57 mg/100 g at maturity stage 1, which rose to 17.28±0.71 mg/100 g at maturity stage 3.

The results of this study fall within the range reported by Burgos *et al.*, (2009), who observed ascorbic acid levels of 6.5-36.9 mg/100 g. However, our findings differ from those of Abong *et al*. (2011), who reported higher ascorbic acid levels of 65.18-73.31 mg/100 g in four Kenyan potato cultivars (Dutch Robyn, Tigoni, 393385.39, and 391691.96), likely due to varietal differences. Discrepancies in reports on changes in ascorbic acid content during tuber growth may be attributed to differences in cultivar and genetic characteristics.

Variety has been identified as a major factor influencing variation in ascorbic acid concentration in potatoes (Abong *et al*., 2011). Additionally, as Burgos *et* al., (2009) noted, variation in ascorbic acid levels may be due to cultural practices, genetic makeup, and location. In another study, Bandana et al., (2015) reported that potato tubers can contain up to 46 mg/100 g of ascorbic acid, with its availability depending on variety, tuber maturity, and environmental conditions.

The ascorbic acid content in potatoes can fluctuate throughout their growth stages, influenced by factors such as irrigation and growth cycle. Both cultivar and growing conditions also play a role in this variation. Despite the moderate ascorbic acid content in potatoes, a single serving of 148 g of baked potato can provide about 45% of the recommended daily intake, highlighting potatoes as a significant source of ascorbic acid (Love & Pavek, 2008).

4.3.3 Sugars in Potatoes

Potato variety, maturity stage, and location had a significant effect ($P<0.05$) on the glucose, fructose, and sucrose content in both Markies and Shangi varieties. Both glucose and fructose levels decreased with maturity at both the Githioro and Kipipiri locations. The highest reducing sugar content was observed at maturity stage 1, with the lowest levels occurring at maturity stage 3. In the Markies variety from Kipipiri, glucose content was 39.4±1.98 mg/100 g at maturity stage 1, decreasing to 11.76±1.56 mg/100 g at maturity stage 3. For samples from Githioro, glucose content in the Markies variety was 44.59±6.79 mg/100 g at maturity stage 1, dropping to 29.34±9.79 mg/100 g at maturity stage 3. The Shangi variety from Kipipiri had a glucose content of 22.89±3.65 mg/100 g at maturity stage 1, which decreased to 16.95±1.40 mg/100 g at maturity stage 3. Meanwhile, Shangi samples from Githioro had a glucose content of 63.56±0.46 mg/100 g at maturity stage 1, which reduced to 40.58±9.87 mg/100 g at maturity stage 3.

The fructose content in the Markies variety from the Githioro location was 115.64±8.47 mg/100 g at maturity stage 1, decreasing to 65.64±2.31 mg/100 g at maturity stage 3. In comparison, Markies samples from the Kipipiri location had a fructose content of 23.34±1.70 mg/100 g at maturity stage 1, which reduced to 16.89±1.35 mg/100 g at maturity stage 3. Overall, Githioro exhibited higher levels of glucose and fructose compared to Kipipiri. The variation in sugar content between the two locations may be attributed to ecological factors such as temperature, soil mineral nutrition, irrigation practices, and genetic variability. Naumann *et al*., (2020) also reported significant locational effects on sugar content in potato tubers, likely due to differences in the nutritional management of the potato plants during growth. The observed decrease in reducing sugars like glucose and fructose as potato tubers mature is primarily due to their conversion into starch, a process that is influenced by genetic factors and environmental conditions (Morales-Fernández et al., 2018). However, this aspect was not investigated in the present study.

Sucrose concentration in the potato tubers was initially high during the early growth stages, but decreased rapidly, reaching its lowest level at maturity stage 3, as shown in Table 4.3. Sucrose, along with the monosaccharides D-glucose and D-fructose, are crucial factors when selecting tubers for processing (Pinhero *et al*., 2009). D During high-temperature processing, reducing sugars react with free amino acids, particularly asparagine, in a non-enzymatic Maillard reaction, leading to the formation of undesirable pigments that impart a bitter taste to crisps. For tubers intended for processing, a sugar content of up to 200 mg/100 g is considered ideal (Mareček *et al*., 2016).

The sugar content in potatoes is undesirable during processing because it leads to the formation of acrylamide, a by-product of the Maillard reaction, which is considered potentially carcinogenic and harmful to human health (Ogolla, 2013). Morales-Fernández et al.,(2018) studied the growth and sugar content of potato tubers across four maturity stages and found that soluble sugar content varied with maturity, with the highest concentration occurring at maturity stage 1. This variation was also influenced by genetic factors, and the differences in sucrose, glucose, and fructose levels were independent of tuber maturity.

Reducing sugar levels is a critical quality parameter in tubers intended for processing, as it determines the color and flavor of fried potato products. Excessive reducing sugars can cause darkening, leading to burnt flavors in French fries, crisps, and other fried products, raising safety concerns due to elevated acrylamide levels (Abong *et al*., 2015).

4.3.4 Effect of Location on the Physicochemical Properties of Tubers

The study results demonstrated that location significantly affected ($P < 0.05$) the physicochemical properties of the two potato varieties. These findings are consistent with Soboka *et al*., (2018), who concluded that potato quality characteristics are influenced by both the variety and environmental conditions. Other research has similarly reported that potato quality traits are genetically determined but also impacted by growing locations and seasonal factors (Mohammed, 2016). The study indicated that the physicochemical attributes of the tubers varied between the two locations. This variation could be attributed to base saturation (BS), which influences soil fertility. Base saturation is defined as the percentage of the Cation Exchange Capacity (CEC) occupied by basic cations such as Ca^{2+}, Mg^{2+}, and K^{+}. The percentage of base saturation is closely related to soil fertility, as it reflects the availability of essential minerals and cations for plant uptake (Vågen et al., 2013).

Driskill et al., (2007) found that tuber maturity, cultivar, and seasonal variability significantly influence the final quality of potatoes. High nutrient demand for optimal tuber quality necessitates substantial organic matter and nitrogen inputs (Amjad et al., 2020). Sustainable agricultural practices, such as balanced fertilization, enhance tuber quality and marketability, including tuber size. Increased nitrogen application has been demonstrated to decrease the levels of reducing sugars in potatoes. Conversely, phosphorus nutrition has been reported to elevate reducing sugars both at harvest and post-harvest (Kumar et al., 2004). These factors could also have influenced the physicochemical properties observed in the two locations.

Potato variety and growing location also influence cold-induced sweetening. According to Kalita & Jayanty, (2017) the primary pathway for acrylamide formation involves the deamination and decarboxylation of free asparagine at high temperatures, followed by its reaction with reducing sugars. Potatoes are significant contributors to dietary acrylamide, classified as Group 2A by the International Agency for Research on Cancer (IARC), which indicates a potential carcinogenic risk to humans (Alamar et al., 2017).

4.4 Post Harvest Changes in the Physicochemical Properties of the Two Potato Varieties under Cold And Ware Storage Conditions

4.4.1 Variations of Physicochemical Properties during Storage

In Kenya, potatoes are typically sold immediately after harvest, with storage for future use being uncommon. This practice persists despite experiencing surplus and low prices during the harvest period, followed by scarcity and elevated prices a few months later. Limited storage facilities and a lack of knowledge are key factors hindering the trade and utilization of potatoes in Kenya. Table 4.4 below presents the study findings on the impact of storage conditions both cold and ware storage on the physicochemical properties of stored potato tubers**.**

4.4.2 Ascorbic Acid Content

A significant difference ($P < 0.05$) was observed in ascorbic acid content, with a steady decline during the storage period regardless of the storage condition. At harvest, the Markies variety contained 8.05 mg/100 g of ascorbic acid, which decreased to 0.47 mg/100 g under cold storage and 0.22 mg/100 g under ware storage. For the Shangi variety, ascorbic acid content was 11.26 mg/100 g at harvest, dropping to 3.13 mg/100 g in cold storage and 2.17 mg/100 g in ware storage, as detailed in Table 4.4 below. These findings align with Abong *et al*., (2011), who reported that cultivar, storage conditions, and duration significantly affect ascorbic acid levels. Bandana *et al*. (2015) noted that the rapid decrease in ascorbic acid concentrations at the beginning of storage could be due to the intermediate reaction of ascorbic acid with dissolved oxygen in tuber tissues, where ascorbic acid oxidizes to dehydroascorbic acid in the presence of oxygen and the enzyme ascorbic oxidase.

Table 4.4: Changes in Chemical Properties for Markies and Shangi in Cold and Ware Storage Conditions

Storage months	**Potato variety**	**Storage conditions**	**Ascorbic Acid (mg/100 g)**	**Starch (mg/100 g)**	**Glucose (mg/100 g)**	**Fructose (mg/100g)**	**Sucrose (mg/100 g)**
At harvest	Markies	Ware storage	8.90 ± 0.43^{e}	142.23 ± 0.57^{k}	32.01 ± 0.74^{ab}	42.48 ± 1.25^{a}	64.67 ± 0.85^{d}
		Cold storage	9.63 ± 0.94^{ef}	137.65 ± 3.41^{j}	31.36 ± 1.36^{a}	42.74 ± 1.34^{a}	63.67 ± 0.85^{d}
	Shangi	Ware storage	11.27 ± 0.48^{f}	201.33 ± 3.15^{m}	43.19 ± 1.07^{b}	59.49 ± 1.25^{b}	90.34 ± 0.96^{d}
		Cold storage	11.27 ± 0.48^{f}	196.16 ± 3.15^{l}	43.19 ± 1.07^{b}	59.58 ± 0.25^{b}	90.34 ± 0.96^{cd}
1	Markies	Ware storage	8.06 ± 1.22^{e}	123.2 ± 3.67^{i}	44.35 ± 0.74^{bc}	43.49 ± 0.08^{a}	64.41 ± 2.51^{b}
		Cold storage	8.06 ± 1.20^{e}	109.82 ± 2.33^{h}	52.09 ± 0.98^{ab}	45.55 ± 0.10^{a}	65.83 ± 0.81^{cd}
	Shangi	Ware storage	6.00 ± 0.19^{d}	117.55 ± 4.56^{e}	64.69 ± 0.19^{bc}	60.17 ± 1.82^{e}	89.57 ± 1.95^{a}
		Cold storage	7.54 ± 0.26^{de}	104.43 ± 2.15^{g}	86.35 ± 1.35^{bc}	69.78 ± 0.77^{d}	91.47 ± 0.57^{c}
2	Markies	Ware storage	2.16 ± 0.04^{bc}	48.9 ± 3.67^{i}	54.76 ± 0.23^{bc}	43.41 ± 0.21^{a}	65.97 ± 0.33^{a}
		Cold storage	3.14 ± 0.48^{c}	65.44 ± 2.33^{h}	62.52 ± 1.52^{ab}	48.88 ± 0.16^{a}	68.95 ± 0.49^{b}
	Shangi	Ware storage	2.17 ± 0.06^{bc}	57.55 ± 4.56^{d}	84.76 ± 0.23^{e}	63.43 ± 2.56^{g}	63.22 ± 1.21^{a}
		Cold storage	3.14 ± 0.48^{c}	52.2 ± 2.07^{d}	92.52 ± 1.88^{d}	74.43 ± 2.56^{g}	64.56 ± 0.43^{a}
3	Markies	Ware storage	1.81 ± 0.34^{b}	34.53 ± 0.59^{b}	56.32 ± 0.72^{d}	44.66 ± 2.01^{c}	65.75 ± 0.16^{a}
		Cold storage	1.55 ± 0.03^{b}	33.96 ± 3.78^{ab}	68.32 ± 0.72^{c}	61.17 ± 9.06^{d}	69.79 ± 0.10^{a}
	Shangi	Ware storage	FS	FS	FS	FS	FS
		Cold storage	FS	FS	FS	FS	FS
4	Markies	Ware storage	0.23 ± 0.02^{a}	33.96 ± 3.18^{b}	60.39 ± 0.20^{g}	47.74 ± 2.09^{f}	66.71 ± 0.06^{a}
		Cold storage	0.48 ± 0.03^{a}	31.59 ± 3.78^{a}	68.54 ± 2.70^{f}	60.74 ± 2.09^{f}	69.66 ± 0.07^{a}
	Shangi	Ware storage	FS	FS	FS	FS	FS
		Cold storage	FS	FS	FS	FS	FS
P value			<0.001	<0.001	0.029	0.048	0.009

Values are means ± SD. Means with different superscript letters along the columns are significantly different at $p<0.05$. FS (fully sprouted)

Ascorbic acid is a crucial antioxidant that enhances the absorption of dietary iron and zinc from plant sources due to its role as a strong reducing agent in metabolism. However, the Markies and Shangi varieties cannot be considered adequate sources of ascorbic acid in the human diet, as their ascorbic acid content falls short of the recommended daily intake of 40 - 120 mg (Abdullah *et al*., 2022). As the primary vitamin in potatoes, the rate of ascorbic acid loss during storage is influenced by both temperature and storage duration, with crop maturity and variety affecting the final ascorbic acid (Pinhero *et al*., 2009). The decline in ascorbic acid in Irish potatoes during storage is mainly driven by temperature effects, oxidative degradation, enzymatic activity, varietal differences, and physical damage (Robertson *et al.,* 2018).

4.4.3 Starch Content

A significant difference ($P < 0.05$) was observed in the starch content between the Markies and Shangi varieties. Starch content declined in both ware and cold storage conditions. Starch in potatoes can undergo conversion during storage, particularly under low-temperature conditions. Cold storage can result in the breakdown of starch into sugars through mechanisms such as cold sweetening. This process involves the degradation of potato starch primarily by starch phosphorylase, leading to the accumulation of reducing sugars through various enzymatic reactions (Kumar et al., 2004).

Different potato varieties exhibit varying starch contents and may respond differently to storage conditions, with some varieties being more susceptible to sprouting than others. In this study, Shangi sprouted more quickly than Markies. These findings are consistent with those reported by Abong *et al*., (2015). The quality of potatoes is dynamic and evolves due to physiological activities, such as the accumulation of reducing sugars and the depletion of starch (Pinhero *et al*., 2009).

Sugars and starch are key components affected by postharvest metabolism in potato tubers, influencing their sensory attributes, cooking qualities, and processing characteristics. The starch structure can undergo changes due to sweetening, which is heavily influenced by low-temperature storage and the cultivar's tolerance, as noted by Pinhero *et al*. (2009). Starch content is crucial in potato processing because it impacts the yield, texture, and oil content of fried products. Ware storage was identified as the most suitable storage condition, with minimal changes in starch content for tubers intended for French fries and crisps. Conversely, cold storage may be more appropriate for tubers intended for other applications, such as dehydration.

4.4.4 Reducing Sugars

Sugars play a crucial role in determining the quality of potato products, with low sugar content generally indicating better processing quality, particularly for frying and dehydration Ndungutse *et al*., (2019). Additionally, sugars are a significant factor influencing the color of processed potato products (Kumar *et al*., 2004). A significant difference ($p = 0.029$) in glucose content was observed. Glucose concentration in tubers increased under both storage conditions, with the highest increase recorded in tubers stored in cold storage. The Shangi variety exhibited a higher rate of glucose accumulation compared to the Markies variety. This accumulation of glucose may have resulted from the breakdown of starch into simple sugars through hydrolysis (Malone et al., 2006).

Varietal differences result in varying degrees of susceptibility to sugar accumulation during storage. Some cultivars are more prone to higher sugar levels due to their genetic makeup and specific metabolic pathways. For example, certain varieties may start with higher initial sugar levels or possess different enzyme activities that facilitate the conversion of starch to sugars more readily (Das et al., 2021).The accumulation of glucose can pose a significant challenge in the cold storage of Irish potatoes, as it may lead to undesirable characteristics in fried products, such as dark coloration and a bitter taste, due to Maillard reactions during cooking (Wiberley-Bradford et al., 2014).

A significant difference ($p = 0.048$) was observed in fructose accumulation between the two potato varieties. Fructose content increased in both the Markies and Shangi varieties under all storage conditions, with the highest concentrations found in tubers stored in cold storage and the lowest in those stored in ware storage. The rise in fructose content can be attributed to the breakdown of starch, similar to glucose. Additionally, the increase in fructose at room temperature may be related to senescence sweetening, a process resulting from cellular breakdown that leads to the depolymerization of structural and non-structural carbohydrates by hydrolytic enzymes (Alamar et al., 2017).

The sucrose content of both Shangi and Markies varieties increased under all storage conditions ($p = 0.009$). However, no significant accumulation of sucrose was observed between the two varieties in either storage condition. The lower rate of sucrose accumulation at room temperature for the Shangi variety may be associated with the high sprouting rate of the tubers. Morales-Fernández et al., (2018) reported that sucrose transport to tuber buds is essential for inducing sprouting, which concurrently leads to a reduction in simple sugar content.

Sucrose is crucial in determining the quality of potatoes post-storage, serving as a substrate for reducing sugar production through the enzyme invertase, which is activated during storage (Kumar et al., 2004). Maintaining the quality of potato tubers during storage is vital for processing and avoiding economic loss. This can be achieved through strategies such as controlling and monitoring storage conditions and selecting suitable varieties. Such measures can significantly enhance the quality retention of tubers during storage (Chemeda et al., 2014).

Potato processing industries commonly use reducing sugar concentration as an indicator of quality to predict chip color. According to Amjad et al., (2020), the extent of sugar accumulation is cultivar-dependent. They reported that the inactivation of the enzyme phosphofructokinase at low temperatures leads to the accumulation of hexose phosphates, which subsequently increases sucrose levels. Different cultivars exhibit varied responses in the extent of sugar accumulation due to low-temperature storage.

Clonal variations in reducing sugar formation during storage are influenced by factors such as invertase activity and sucrose compartmentalization among different clones. Although glucose and fructose are produced in equimolar amounts, glucose tends to be present at higher concentrations in potato cells during both growth and storage. This may be attributed to the high levels of fructokinase in potato extracts, which can recycle fructose back into the hexose-phosphate pool (Kumar et al., 2004).

The quality of potatoes is dynamic and evolves due to physiological processes, including the accumulation of reducing sugars and the depletion of starch. Consequently, sugar and starch are critical components affected by post-harvest metabolism, which in turn impacts the cooking, sensory, and processing characteristics of potatoes (Pinhero *et al.*, 2009) The findings suggest that both varieties are suitable for processing into French fries and crisps directly from ware storage, with Markies being viable for up to 4 months and Shangi for up to 2 months. However, in subsequent lower-temperature storage, reducing sugar levels increased in Markies, indicating that reconditioning may be necessary before processing.

Clones also vary in their ability to form reducing sugars in storage because of invertase activity and or compartmentalization of sucrose among clones. Even though glucose and fructose are produced in equimolar amounts, glucose is present at a higher concentration in potato cells during growth and in storage. This may be due, in part to high concentrations of fructokinase found in potato extracts that could cycle fructose back into the pool of hexose-phosphates (Kumar et al., 2004).

The quality of potatoes is dynamic and continues to change as a result of physiological activity owing to the accumulation of reducing sugars and the depletion of starch. Therefore, sugar and starch are the main components affected by post-harvest metabolism in potato tubers, which ultimately affects potatoes' cooking, sensory, and processing characteristics (Pinhero et al., 2009).The results imply that both varieties can be used to process French fries and crisps directly at ware storage which can only be possible for up to 4 months for Markies but up to 2 Months for Shangi. At subsequent lower temperature storage reducing sugars increased in Markies and may require reconditioning before processing. Cold-induced sweetening results in an increase in reducing sugars due to the activation of carbohydrate-splitting enzymes, particularly vacuolar invertase. This enzyme catalyzes the conversion of sucrose into glucose and fructose (Wiberley-Bradford et al., 2014).

4.5 Changes in Physical Properties during Storage

The following discussion addresses the impact of storage conditions on specific gravity, texture, and color. The physical changes observed in the two potato varieties, Markies and Shangi, under ware and cold storage conditions are detailed in **Table 4.5** and discussed below.

4.5.1 Specific Gravity

No significant difference ($p = 0.152$) in specific gravity was observed between the two potato varieties. However, a gradual decline was noted over the storage period, with the Shangi variety exhibiting a more pronounced decrease compared to the Markies variety under both storage conditions. The Shangi variety showed the greatest reduction in specific gravity, decreasing from 1.21±0.06 at harvest to 1.03±0.05 under cold storage and 1.08±0.02 under ware storage. This variation can be attributed to genetic differences between the varieties. Specific gravity reflects the dry matter content of potatoes, which significantly impacts processing quality. The specific gravity values for both Shangi and Markies varieties remained within the recommended processing range of 1.07 ((Kabira & Lemaga, 2003) indicating that the storage conditions did not adversely affect the specific gravity of the tubers.

Table 4.5: Changes in Physical Properties for Markies and Shangi in Cold and Ware Storage Conditions

Storage months	Potato variety	Storage conditions	Specific gravity	Texture (N)	Lightness	Redness	Yellowness
At harvest	Markies	Ware storage	1.17±0.05^{a}	4.18±0.11^{ab}	67.60±1.06^{b}	-6.92±0.09^{c}	22.20±0.62^{a}
		Cold storage	1.17±0.05^{a}	4.18±0.11^{ab}	67.60±1.06^{b}	-6.77±0.23^{c}	23.20±0.62^{ab}
	Shangi	Ware storage	1.21±0.06^{a}	4.48±0.06^{b}	70.43±2.29^{a}	-5.69±0.13	21.36±1.62^{a}
		Cold storage	1.21±0.06^{a}	4.48±0.06^{b}	70.43±2.29^{a}	-6.65±0.14^{c}	21.36±1.62^{a}
1	Markies	Ware storage	1.12±0.04^{a}	3.76±0.09^{ab}	71.46±0.88^{a}	-5.63±0.14^{b}	24.50±0.58^{b}
		Cold storage	1.09±0.04^{a}	3.84±0.09^{ab}	69.17±0.44b	-5.92±0.64^{b}	23.86±0.71^{ab}
	Shangi	Ware storage	1.07±0.07^{a}	3.19±0.09^{a}	68.55±0.33^{b}	-5.69±0.13^{b}	25.86±0.44^{bc}
		Cold storage	1.12±0.04^{a}	4.48±0.06^{b}	68.02±0.79^{b}	-6.10±0.13^{bc}	22.59±0.49^{a}
2	Markies	Ware storage	1.10±0.03^{a}	3.70±0.05^{a}	72.91±1.15^{ab}	-5.04±0.40^{b}	25.20±0.51^{bc}
		Cold storage	1.07±0.02^{a}	3.73±0.07^{a}	70.06±0.75^{a}	-5.04±0.40^{b}	24.91±0.65^{b}
	Shangi	Ware storage	1.03±0.05^{a}	3.99±0.09^{ab}	68.73±0.82^{b}	-4.90±0.09^{ab}	26.29±0.54^{bc}
		Cold storage	1.08±0.02^{a}	3.55±0.09^{a}	68.25±0.82^{b}	-4.71±0.33^{ab}	23.37±0.88^{ab}
3	Markies	Ware storage	1.08±0.04^{a}	3.67±0.07^{a}	73.01±0.71^{b}	-4.82±0.41^{ab}	27.76±0.54^{c}
		Cold storage	1.06±0.02^{a}	3.55±0.11^{a}	71.18±0.78^{a}	-5.00±0.28^{b}	25.42±0.51^{bc}
	Shangi	Ware storage	fs	fs	fs	fs	fs
		Cold storage	fs	fs	fs	fs	fs
4	Markies	Ware storage	0.92±0.08^{a}	3.43±0.05^{a}	75.46±0.62^{bc}	-3.72±1.65^{a}	27.51±0.40^{c}
		Cold storage	1.08±0.02^{a}	3.48±0.03^{a}	71.19±0.57^{a}	-3.46±0.12^{a}	25.32±0.57^{bc}
	Shangi	Ware storage	fs	fs	fs	fs	fs
		Cold storage	fs	fs	fs	fs	fs
P value			0.152	0.047	0.132	0.049	0.041

Values are means ± SD. Means with different superscript letters along the columns are significantly different at $p<0.05$. fs (fully sprouted)

Changes in specific gravity may be influenced by the moisture content of the air in the storage environment, which is a critical factor affecting specific gravity during storage. Additionally, variations in specific gravity during storage can differ significantly among potato varieties, reflecting differences in shrinkage and moisture loss.

4.5.2 Texture

There was a significant change in tuber hardness (p=0.04) observed in both varieties under both storage conditions. The mean hardness of the tubers at harvest was higher than that measured at the end of the storage period. At harvest, the Markies variety had a mean hardness of 4.18 ± 0.11 N, which decreased to 3.63 ± 0.05 N under ware storage and 3.48 ± 0.03 N under cold storage. For the Shangi variety, the mean hardness at harvest was 4.48 ± 0.06 N, which reduced to 3.99 ± 0.09 N with ware storage and 3.55 ± 0.09 N with cold storage, as illustrated in Figure 4.6. Previous studies have indicated that low-temperature storage alters the starch-to-sugar ratio in potatoes, which in turn affects the physical and biochemical quality properties, including tuber hardness during storage (Singh *et al.,* 2016).

4.5.3 Color Changes during Storage

Appearance plays a crucial role in the sensory evaluation and marketing of both fresh and processed food products, with color being a key factor influencing consumer perception and acceptance (Pathare & Opara, 2013). In this study, there was no significant difference (p=0.132) in lightness, as both varieties showed minimal changes in this attribute. However, a significant difference was observed in yellowness (p=0.041), with a slight increase in b* values. This increase may be due to cold sweetening, where the conversion of starch to sugars contributes to a shift in b* values. Additionally, redness showed a significant difference (p=0.049), with a slight increase in a* values over storage time. At harvest, the Markies variety had a* value of -6.92 ± 0.09c, which changed to -3.72 ± 1.65 at cold storage and -3.46 ± 0.12 at ware storage after 4 months. This change in color could be attributed to the conversion of starch to sugars, which affects the color of the potatoes during storage.

4.5.4 Sprouting for Shangi and Markies Varieties at Ware and Cold Storage Conditions

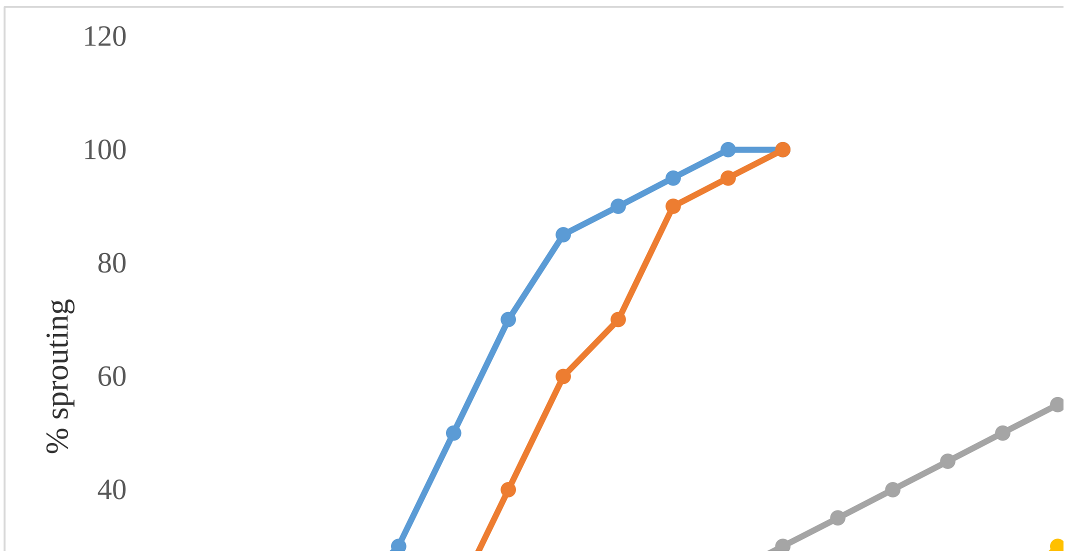

Figure 4.1: Sprouting for Shangi and Markies Potato Varieties Stored under Ware and Cold Storage Conditions

In ware storage, sprouting in the Shangi variety began after 10 days, whereas sprouting in the Markies variety commenced on the 25th day of storage. A significant difference ($p<0.05$) in the sprouting rate was observed for the Shangi variety, while no significant difference ($p>0.05$) in sprouting rate was noted for the Markies variety at room temperature throughout the 4-month storage period. Under cold storage conditions, the Shangi variety began sprouting on the 15th day, whereas sprouting in the Markies variety started on the 70th day. By the 60th day, the Shangi variety showed 100% sprouting, whereas the Markies variety reached 100% sprouting by the 120th day, as depicted in Figure 4.1 above. The Shangi variety sprouted the fastest and could only be stored for up to 2 months. Sprouting was less pronounced in both varieties under cold storage. The Shangi variety has a short dormancy period, making it challenging to store for future processing, while the Markies variety exhibited a longer dormancy period of four months compared to the Shangi variety.

The dormancy period of potatoes is influenced by both genetic and environmental factors. Sprouting involves the mobilization of carbohydrates, primarily through the hydrolysis of starch within the tuber, leading to an increase in reducing sugars. These findings align with those of Abong et al., (2015) who reported that in their study on the physicochemical changes in popular Kenyan processing potato varieties under different storage conditions, the Shangi variety began sprouting after just two weeks of storage, with sprouting accelerating over time at ambient temperatures. This rapid sprouting soon after harvesting presents significant challenges for storage intended for processing.

Sprouting adversely affects tuber appearance and reduces marketability. It also results in moisture loss, weight loss due to increased respiration, accelerated starch degradation, elevated glycoalkaloid levels, increased physiological aging, and decreased ascorbic acid content (Pinhero et al., 2009). Furthermore, potato dormancy duration is inversely proportional to temperature (Pinhero & Yada, 2016). Higher temperatures lead to increased metabolic activity, enzyme activation, hormonal changes, and elevated respiration rates (Kwambai et al., 2023). These factors contribute to a shorter dormancy period and earlier sprouting, which negatively impacts the storage and processing quality of potatoes (Kwambai et al., 2023).

4.6 Product Development

4.6.1 Textural Changes in Fresh Cut Potato Slices under Normal and Vacuum Sealing at Different Treatments of Citric Acid and Ascorbic Acid

The results of the textural analysis for AA and CA treatments under vacuum sealing conditions showed no significant difference ($P>0.05$) in hardness between the Markies and Shangi varieties at 0% treatment. However, samples that were normally sealed demonstrated a slower reduction in hardness compared to those sealed under vacuum, as illustrated in Figure 4.2 A and B below. The appearance of fresh horticultural products significantly influences quality perception and consumer purchasing decisions. Firmness and hardness are important attributes that affect mouthfeel and taste, serving as key quality parameters that impact consumers' decisions to repurchase. In food science, texture is defined as "all the rheological and structural (geometric and surface) attributes of a product as perceived through mechanical, tactile, visual, and auditory receptors" (Pieniazek & Messina, 2017).

Textural changes in fresh-cut Irish potato slices can be caused by several factors, including enzymatic activity, moisture loss cell degradation, and storage conditions. French–cut potatoes are prone to moisture loss due to increased surface area after cutting. Cell wall degradation as a result of pectic substances in the cell wall is a major contributor to textural changes. Enzymes such as pectin methylesterase (PME) and polygalacturonase (PG) degrade pectin, leading to cell wall softening and loss of cell wall integrity (Ali et al., 2021). This could also be attributed to oxidative stress in potato slices leading to accelerated aging senescence. these physiological changes can lead to cell membrane degradation and loss of turgor pressure resulting in a softer texture (Gil et al., 2006).

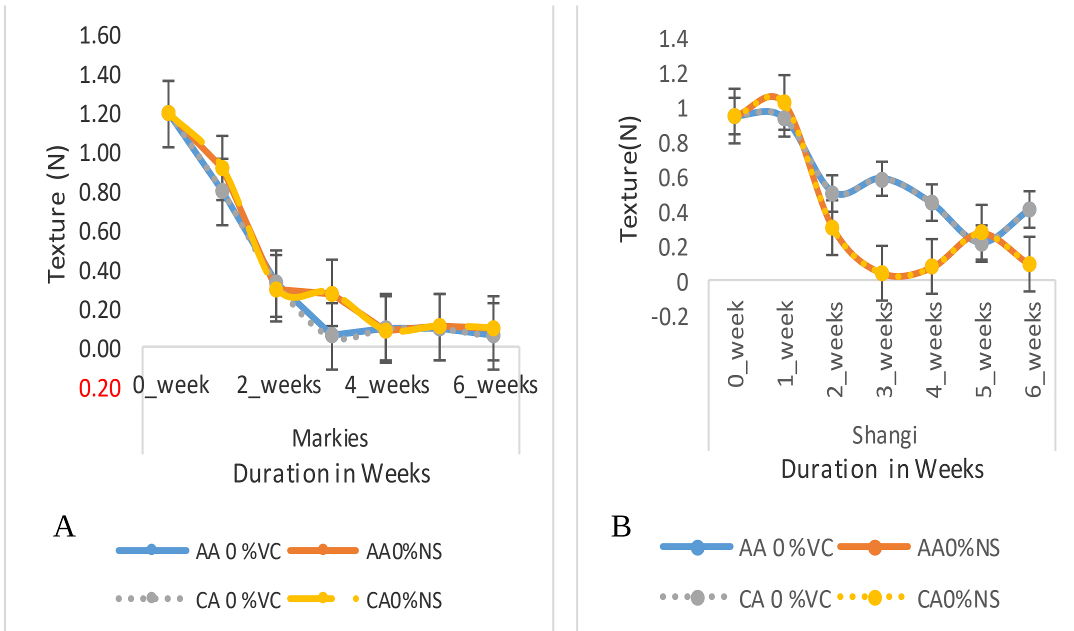

Figure 4.2: A&B: Effect of Normal and Vacuum Sealing on Texture at 0 % Treatment of Ascorbic and Citric Acid on Markies and Shangi potato varieties

There was no significant difference (P>0.05) in the hardness of fresh-cut potato slices treated with 2% concentrations of ascorbic acid or citric acid combined with vacuum sealing, compared to samples sealed under normal conditions. However, changes in hardness were observed in the fourth week of storage, as shown in Figure 4.3 below**.** The observed results could be due to the removal of air from the packaging, which significantly reduces oxidative stress and the activity of oxidative enzymes. The combination of vacuum packaging with ascorbic acid treatment effectively reduces enzymatic activity and the growth of spoilage microorganisms. The low-oxygen environment created by vacuum packaging, along with the antimicrobial properties of ascorbic acid, creates an unfavorable environment for microbial growth, which can produce enzymes that contribute to tissue breakdown and softening (Boz et al., 2018).

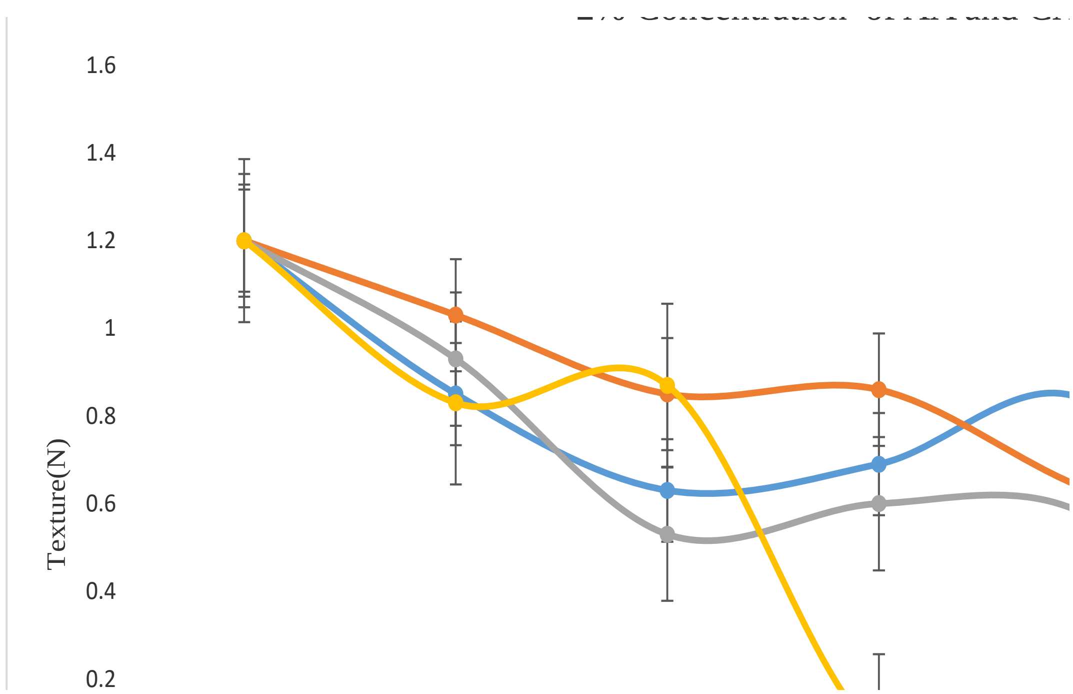

Figure 4.3: Effect of Normal and Vacuum Sealing on Texture at 2 % Concentration of Ascorbic Acid and Citric Acid Concentrations in Markies Potato Variety

There was no significant difference (P>0.05) in the hardness of potato samples treated with a 5% concentration of either ascorbic acid or citric acid, as shown in Figure 4.4. However, when comparing the two sealing methods, samples stored under vacuum sealing exhibited better results, with minimal changes in hardness observed towards the end of the 6-week storage period.

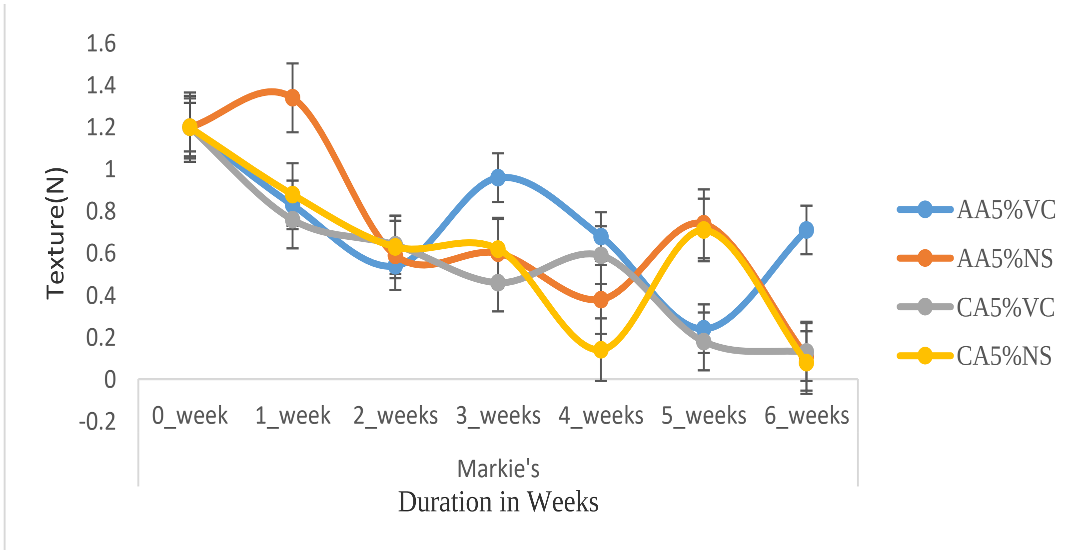

Figure 4.4: Effect of Normal and Vacuum Sealing on Texture at 5 % Concentration of Ascorbic Acid and Citric Acid Concentrations in Markies Potato Variety

For the Shangi variety, a 2% concentration of both ascorbic acid (AA) and citric acid (CA) treatments showed no significant difference ($p<0.05$) in hardness for samples under vacuum packaging. However, at the same 2% concentration of both AA and CA, samples sealed normally exhibited changes in hardness, as illustrated in Figure 4.5 below.

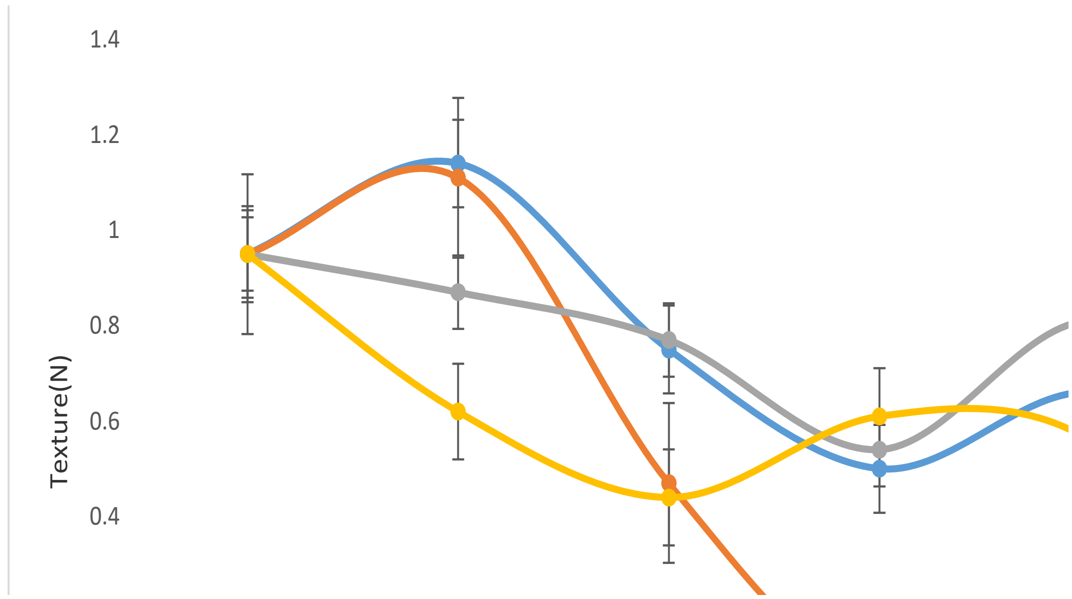

Figure 4.5: Effect of Normal and Vacuum Sealing on Texture at 2 % Concentration of Ascorbic Acid and Citric Acid Concentrations in Shangi Potato Variety

There was no significant difference (p>0.05) in the hardness of potato samples treated with a 5% concentration of both ascorbic acid (AA) and citric acid (CA) under vacuum packaging. In contrast, samples subjected to the same treatment but sealed normally exhibited changes in hardness, as shown in Figure 4.6 below.

The results indicated that fresh-cut potato slices stored under vacuum sealing for both varieties, at 2% and 5% concentrations of ascorbic acid (AA) and citric acid (CA), did not exhibit significant changes in hardness throughout the entire storage period. In contrast, samples sealed normally at the same concentrations showed notable changes in hardness. These findings are consistent with those reported by Ali *et al.*, (2021). Rocculi *et al*., (2009), also observed that texture loss increased with storage time.

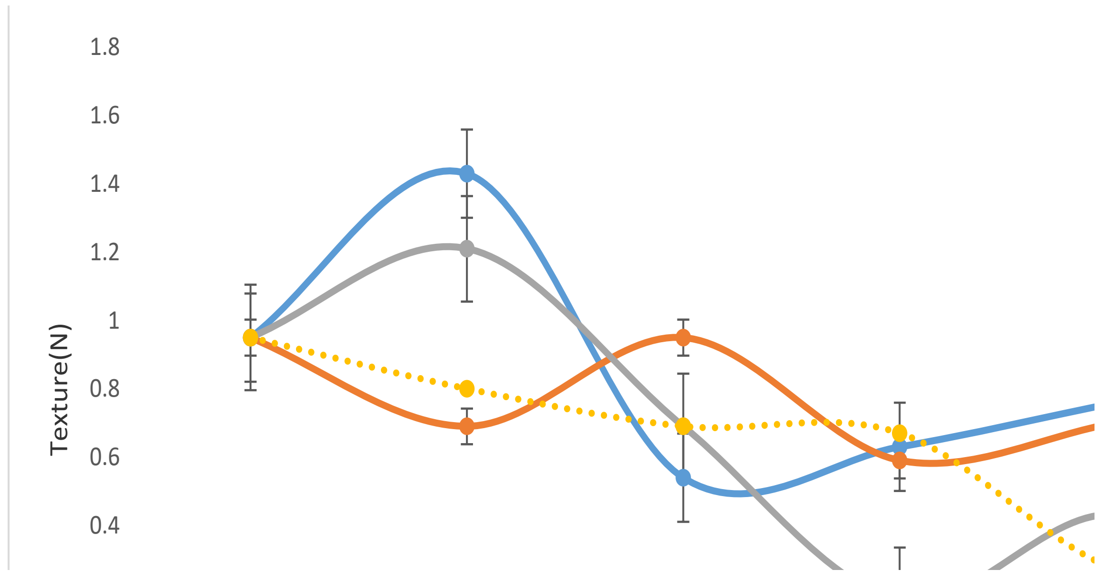

Figure 4.6: Effect of Normal and Vacuum Sealing on Texture at 5 % Concentration of Ascorbic Acid and Citric Acid Concentrations in Shangi Potato

Textural changes in potatoes are also linked to the gelatinization and retrogradation of starch, as well as the degradation of cell wall and middle lamella structural components. Given that starch constitutes a major component of the dry matter in potatoes, its molecular organization and interactions with non-starch polysaccharides and sugars are critical factors affecting the texture of potatoes (Pieniazek & Messina, 2017).

Tissue softening, along with the associated loss of structural integrity and leakage of juice from fresh-cut potatoes, can significantly impact quality and marketability. During peeling and cutting, enzymes responsible for softening, such as pectinesterase, polygalacturonase, and β-galactosidase, interact with their substrates, accelerating the softening process. The removal of the protective periderm and the reduction in bulk tissue contribute to increased water loss, which leads to textural changes in fresh-cut potatoes (Rocculi et al., 2009).

Ascorbic acid and citric acid treatments helps in maintaining the firmness of fresh cut potatoes by stabilizing cell walls. Ascorbic acid promotes the formation of intermolecular cross links between pectin molecules,reinforcing the cell wall structure and slowing down the degradation of pectin, which is a major cause of textural changes (Ali et al., 2021). Citric acid mainly helps in the pH which reduces the activity of pectolytic enzymes such as PME, and PG, enzymes that are responsible for breaking the cell wall components (Gil et al., 2006).

The combined use of vacuum packaging with ascorbic or citric acid helps maintain the textural quality and extends the shelf life of fresh–cut Irish potato slices by preserving firmness, browning, and reducing spoilage. The synergistic effect of these treatments delays physiological processes that lead to quality deterioration, thereby ensuring that texture remains closer to that of fresh potatoes for a longer period (Bico et al., 2009).

4.6.2 Color Changes of Fresh-Cut Potato Slices During Storage

In color measurement, L* represents lightness, a* denotes chromaticity on a green (-) to red (+) axis, and b* indicates chromaticity on a blue (-) to yellow (+) axis. A decrease in the L* value coupled with an increase in the a* value serves as a reliable indicator of darkening during storage (Rocha *et al*., 2003).

4.6.3 Lightness

Fresh-cut potato slices treated with ascorbic acid (AA) and citric acid (CA) showed no significant difference (P>0.05) in lightness over a 6-week storage period. These results suggest that both AA and CA treatments, at concentrations of 2% and 5%, effectively preserved the lightness of the potato slices for up to 6 weeks, as illustrated in Table 4.6 below . These findings are consistent with the study by Nascimento *et al*., (2020) which demonstrated that AA and vacuum packaging maintained the quality of fresh-cut potatoes for more than 6 weeks. Similarly, Nascimento & Canteri (2020) found that the L* value remained stable with ascorbic acid treatment. Additionally, Vasconcelos et al., (2015) reported no variation in L* values when using a combination of AA, CA, and tartaric acid.

4.6.4 Redness

The color parameter a* ranges from green (-) to red (+), with increased redness indicating tuber browning. The results revealed a significant difference ($P>0.05$) in redness for samples with 0% treatment, suggesting a higher intensity of browning in these samples. In contrast, there was no significant difference ($P<0.05$) in redness for samples treated with 2% and 5% concentrations of ascorbic acid (AA) and citric acid (CA). However, browning was observed in the 0% concentration samples. Additionally, vacuum sealing provided better results compared to normal sealing, as shown in Table 4.8. An increase in the a* value signifies browning, indicating enzymatic browning activity. A decrease in L* value coupled with an increase in a* is a reliable indicator of darkening during storage (Rocha *et al*., 2003).

There was no significant difference ($p>0.05$) in yellowness throughout the 6-week storage period, although a slight decline in yellowness was observed during the 5th and 6th weeks. Both ascorbic acid (AA) and citric acid (CA) treatments effectively maintained the b* value, which did not increase. Nascimento et al., (2020) reported that an increase in b* value is linked to the development of browning reactions due to the formation of intermediate chlorogenic quinones, which can produce yellow solutions. Following quinone formation, the enzymatic browning reaction continues irrespective of the presence of polyphenol oxidase (PPO) and oxygen. Liu et al., (2019) also noted that an increase in b* value is associated with browning reactions. The use of AA significantly impacts the b* value, indicating that this antioxidant helps to reduce the formation of dark pigments resulting from browning reactions (Nascimento & Canteri, 2020).

Vacuum packaging extends the shelf life of fresh-cut produce (FCP) over extended periods. This technique involves removing air from the package using a suction machine, which slows down the progression of enzymatic reactions. By rapidly establishing a modified atmosphere, vacuum packaging enhances both the shelf life and quality of the products.

Consumers often link color with texture, flavor, safety, storage duration, and nutritional value because it correlates strongly with physicochemical and sensory attributes. In addition to color, texture is also a critical factor in the overall acceptance of food quality by consumers (Pieniazek & Messina, 2017).

Recently, packers have begun supplying peeled raw potatoes to restaurants and producers of French fries and potato chips. These pre-peeled raw potatoes often discolor within minutes, turning brown or black. Enzymatic browning, a significant industrial challenge in fresh-cut potato products, occurs due to the oxidation of phenolic compounds. This oxidation leads to deterioration and loss of quality in processed potato products, adversely affecting their physical and nutritional properties

Table 4.6: Color Parameter (Lightness) of Fresh Cut Potato Slices Treated with AA and CA

Weeks	Conc	Markies Ascorbic acid Vacuum packaged	Normal sealed	Citric acid Vacuum packaged	Normal sealed	Shangi Ascorbic acid Vacuum packaged	Normal sealed	Citric acid Vacuum packaged	Normal sealed
0	0%	66.70±0.21^{i}	66.67±0.28^{i}	66.70±0.21^{i}	66.67±0.28^{i}	64.27±0.31^{ij}	63.77±0.49^{ij}	64.27±0.31^{ij}	63.77±0.49^{ij}
	2%	66.67±0.37^{i}	65.07±0.11^{h}	65.27±0.65^{h}	63.27±0.65^{g}	65.03±0.86^{j}	63.67±0.59^{ij}	63.50±0.10^{ij}	63.33±0.31ij
	5%	67.53±1.31^{i}	65.27±0.35^{h}	66.20±0.36^{i}	65.87±0.75^{h}	64.17±0.50^{ij}	64.00±0.20^{ij}	64.37±0.42^{ij}	63.03±0.45^{ij}
1	0%	63.93±0.90^{g}	62.03±0.15^{fg}	63.93±0.90^{g}	62.03±0.15^{fg}	60.83±0.21^{hi}	59.40±0.53^{h}	60.83±0.21^{hi}	59.40±0.53^{h}
	2%	65.47±0.37^{h}	61.03±0.12^{f}	63.40±0.34^{g}	61.27±0.25^{f}	63.33±0.35^{ij}	62.27±0.87^{i}	60.67±0.31^{hi}	60.20±0.25^{hi}
	5%	65.87±0.15^{h}	62.80±0.26^{fg}	63.77±0.42^{g}	61.60±1.31^{f}	62.47±0.81^{i}	62.90±1.00^{i}	62.00±0.56^{i}	61.33±0.42^{hi}
2	0%	60.60±0.53^{ef}	59.40±0.60^{ef}	60.60±0.53^{ef}	59.40±0.60^{ef}	57.10±0.46^{gh}	55.13±0.15^{g}	57.10±0.46^{gh}	55.13±0.15^{g}
	2%	63.67±0.42^{g}	57.83±0.74e^{f}	62.47±0.89^{fg}	57.53±1.30^{ef}	62.47±0.20^{i}	60.53±0.51^{hi}	59.50±0.80^{h}	58.17±0.61^{gh}
	5%	65.66±0.77^{fg}	60.63±0.49^{f}	64.20±0.53^{gh}	61.10±0.26^{f}	62.57±0.70^{i}	61.07±0.53^{hi}	60.73±1.02^{hi}	59.47±1.20^{h}
3	0%	59.13±0.75^{e}	53.00±0.56^{cd}	59.13±0.75^{e}	53.00±0.56^{cd}	51.63±0.85^{e}	50.30±0.26^{e}	51.63±0.85^{e}	50.30±0.26^{e}
	2%	61.77±0.42^{f}	55.73±0.31^{d}	59.37±0.72^{ef}	54.60±0.72^{d}	61.37±0.45^{hi}	59.23±0.29^{h}	58.10±0.10^{gh}	57.37±0.15^{gh}
	5%	62.77±0.21^{f}	58.13±0.25^{e}	61.20±0.53^{f}	59.17±0.40^{ef}	60.20±0.35^{hi}	59.07±0.15^{h}	59.57±0.60^{h}	55.20±1.13^{g}
4	0%	54.33±0.61^{d}	49.43±0.60^{c}	54.33±0.61^{d}	49.43±0.60^{c}	47.17±0.23^{de}	45.00±0.36^{d}	47.17±0.23^{de}	45.00±0.36^{d}
	2%	58.80±0.26^{e}	53.83±0.59^{cd}	57.27±0.23^{e}	50.93±0.31^{c}	59.70±0.35^{h}	55.80±0.30^{g}	54.93±0.35^{fg}	53.70±0.31^{f}
	5%	61.20±1.05^{f}	55.83±0.21^{d}	59.00±0.26^{e}	55.90±0.46^{d}	59.13±0.21^{h}	57.10±0.60^{gh}	56.23±0.47^{g}	53.40±0.64^{f}
5	0%	49.50±0.78^{c}	44.63±0.35^{b}	49.50±0.78^{c}	44.63±0.35^{b}	41.57±0.55^{c}	40.00±0.10^{bc}	41.57±0.55^{c}	40.00±0.10^{bc}
	2%	56.70±0.36^{de}	50.93±0.83^{c}	54.70±0.46^{d}	48.37±0.40^{c}	54.43±0.15^{fg}	53.00±0.47^{f}	52.67±0.49^{ef}	51.27±0.61^{e}
	5%	56.40±0.72^{de}	50.40±0.56^{c}	55.23±0.72^{d}	51.00±0.30^{c}	54.63±0.81^{fg}	53.67±0.36^{f}	55.67±0.31^{g}	52.63±1.52^{ef}
6	0%	44.97±0.15^{b}	40.77±0.75^{a}	44.97±0.15^{b}	40.77±0.75^{a}	38.27±0.64^{b}	35.47±0.50^{a}	38.27±0.64^{b}	35.47±0.50^{a}
	2%	50.93±0.87^{c}	47.20±0.85^{bc}	50.60±0.20^{c}	45.33±0.31^{b}	51.50±0.95^{e}	51.50±0.57^{e}	50.77±0.15^{e}	49.37±0.96^{de}
	5%	52.77±0.85^{cd}	46.73±0.96^{b}	52.27±0.21^{c}	49.07±0.35^{c}	52.10±0.75^{ef}	50.30±0.35^{e}	50.07±0.25^{e}	47.67±1.20^{de}
P value			<0.05				<0.05		

Values are means ± SD. Means with different superscript letters along the columns and across the rows are significantly different at $p<0.05$.

Table 4.7: Color Parameter (Redness) of Fresh Cut Potato Slices Treated with Ascorbic Acid and Citric Acid

Weeks	Conc	Markies Ascorbic acid		Citric acid		Shangi Ascorbic acid		Citric acid	
		Vacuum packaged	**Normal sealed**	**Vacuum packaged**	**Normal sealed**	**Vacuum packaged**	**Normal sealed**	**Vacuum packaged**	**Normal sealed**
0	0%	-5.30±0.20^{ef}	-5.23±0.25^{ef}	-5.30±0.20^{ef}	-5.23±0.25^{ef}	-5.53±0.07^{ef}	-4.23±0.15^{de}	-5.53±0.62	-4.23±0.62^{de}
	2%	-5.40±0.10^{f}	-5.40±0.10^{f}	-5.33±0.15^{ef}	-5.33±0.06^{ef}	-4.47±0.06^{e}	-4.47±0.06^{e}	-4.37±0.15^{e}	-4.27±0.06^{e}
	5%	-5.47±0.06^{f}	-5.33±0.06^{ef}	-5.47±0.06^{f}	-5.33±0.15^{ef}	-4.47±0.06^{e}	-4.43±0.06^{e}	-4.47±0.07^{e}	-4.37±0.15^{e}
1	0%	-4.17±0.30^{de}	-3.83±0.15^{d}	-4.17±0.30^{de}	-3.83±0.15^{d}	-4.10±0.10^{de}	-3.63±0.31^{d}	-4.10±0.10^{de}	-3.63±0.31^{d}
	2%	-4.97±0.21^{e}	-4.77±0.67^{e}	-4.50±0.20^{e}	-4.33±0.15^{e}	-4.27±0.15^{e}	-4.10±0.10^{de}	-4.07±0.15^{de}	-4.03±0.15^{de}
	5%	-5.23±0.12^{f}	-5.00±0.10^{ef}	-5.33±0.06^{ef}	-4.97±0.15^{e}	-1.50±0.14^{b}	-3.80±0.20^{d}	-4.17±0.06^{de}	-4.00±0.10^{de}
2	0%	-3.30±0.30^{d}	-2.90±0.26	-3.30±0.30^{d}	-2.90±0.26	-3.50±0.40^{d}	-3.17±0.21^{cd}	-3.50±0.40^{d}	-3.17±0.21^{cd}
	2%	-4.50±0.07^{e}	-3.33±0.15^{d}	-4.20±0.10^{e}	-4.10±0.10^{de}	-4.07±0.11^{de}	-3.80±0.30^{d}	-3.70±0.35^{d}	-3.40±0.26^{d}
	5%	-5.00±0.17^{ef}	-1.67±0.00^{b}	-5.13±0.15^{ef}	-4.67±0.21	-4.23±0.06^{de}	-3.73±0.06^{d}	-3.97±0.21^{d}	-3.77±0.06^{d}
3	0%	-2.83±0.21^{c}	-1.97±0.15^{b}	-2.83±0.21^{c}	-1.97±0.15^{b}	-2.83±0.29^{c}	-2.27±0.23^{bc}	-2.83±0.29^{c}	-2.27±0.23^{bc}
	2%	-4.73±0.49^{e}	-2.93±0.06^{c}	-3.87±0.15^{d}	-3.47±0.12^{d}	-3.83±0.12^{d}	-3.67±0.21^{d}	-3.97±0.15^{d}	-3.00±0.10^{cd}
	5%	-4.63±0.15^{e}	-4.17±0.21^{de}	-4.73±0.15^{e}	-4.23±0.21^{e}	-4.07±0.06^{de}	-3.37±0.15^{d}	-3.87±0.31^{d}	-3.50±0.10^{d}
4	0%	-2.00±0.40^{bc}	-1.17±0.25^{b}	-2.00±0.40^{bc}	-1.17±0.25^{b}	-2.67±0.23^{c}	-1.90±0.20^{b}	-2.67±0.62^{c}	-1.90±0.62^{b}
	2%	-4.10±0.36^{e}	-3.10±0.30^{cd}	-3.77±0.12^{d}	-3.17±0.21^{cd}	-3.60±0.10^{d}	-2.50±0.46^{c}	-3.47±0.32^{d}	-2.33±0.23^{c}
	5%	-4.57±0.12^{e}	-4.00±0.10^{de}	-4.47±0.12^{e}	-3.63±0.15^{d}	-3.27±0.25^{d}	-3.07±0.31^{cd}	-3.73±0.15^{d}	-3.43±0.12^{d}
5	0%	-1.20±0.36^{b}	-0.60±0.10^{ab}	-1.20±0.36^{b}	-0.60±0.10^{ab}	-1.50±0.36^{b}	-1.00±0.36^{ab}	-1.50±0.36^{b}	-1.00±0.36^{ab}
	2%	-3.97±0.29^{d}	-2.20±0.53^{c}	-3.40±0.36^{d}	-2.90±0.10^{c}	-3.37±0.15^{d}	-1.40±0.61	-2.73±0.06^{c}	-1.87±0.15^{b}
	5%	-4.30±0.10^{e}	-3.80±0.17^{d}	-4.30±0.10^{e}	-3.23±0.25^{d}	-2.97±0.06^{c}	-2.47±0.21^{c}	-3.43±0.06^{d}	-3.03±0.15^{cd}
6	0%	-0.43±0.15^{a}	-0.44±0.17^{a}	-0.43±0.15^{a}	-0.44±0.17^{a}	-1.00±0.10^{ab}	-0.2±0.10^{a}	-1.00±0.10^{ab}	-0.2±0.10^{a}
	2%	-2.63±0.45^{c}	-1.77±0.31^{b}	-2.83±0.83^{c}	-2.07±0.78^{c}	-3.13±0.45^{cd}	-0.6±0.20^{a}	-2.33±0.15^{c}	-1.20±0.36^{b}
	5%	-3.67±0.21^{d}	-2.77±0.71^{c}	-2.47±0.55^{c}	-2.47±0.50^{c}	-2.80±0.20^{c}	-2.00±0.66^{bc}	-2.60±0.20^{c}	-2.23±0.21^{c}
P value			<0.05				<0.05		

Values are means ± SE. Means with different superscript letters along the columns and across the rows are significantly different at $p<0.05$.

4.6.5 Yellowness

Table 4.8: Color Parameter (Yellowness) of Fresh Cut Potato Slices Treated with Ascorbic Acid and Citric Acid

Weeks	Conc	Markies Ascorbic acid Vacuum packaged	Normal sealed	Citric acid Vacuum packaged	Normal sealed	Shangi Ascorbic acid Vacuum packaged	Normal sealed	Citric acid Vacuum packaged	Normal sealed
0	0%	12.93±0.12^{i}	12.00±0.10^{hi}	12.93±0.12^{i}	12.00±0.10^{hi}	15.77±0.25^{f}	14.97±0.72^{f}	15.77±0.25^{f}	14.97±0.72^{f}
	2%	12.97±0.06^{i}	12.40±0.30^{i}	12.53±0.15^{i}	12.00±0.35^{hi}	15.63±0.32^{f}	15.10±0.10^{f}	14.87±0.15^{f}	14.33±0.30^{f}
	5%	12.93±0.06^{i}	12.70±0.10^{i}	12.60±0.17^{i}	12.50±0.17^{i}	15.77±0.21^{f}	14.97±0.06^{f}	15.30±0.26^{f}	14.07±0.42^{f}
1	0%	11.73±0.84^{h}	10.07±0.15^{g}	11.73±0.84^{h}	10.07±0.15^{g}	14.33±0.25^{f}	10.93±0.49^{d}	14.33±0.25^{f}	10.93±0.49^{d}
	2%	12.10±0.30^{hi}	11.53±0.40^{h}	11.43±0.40^{h}	10.67±0.31^{g}	14.33±0.25^{f}	13.43±0.31^{ef}	13.90±0.17^{e}f	12.50±0.05^{e}
	5%	12.13±0.15^{hi}	11.53±0.25^{h}	11.53±0.25^{h}	11.13±0.42^{h}	14.63±0.40^{f}	14.36±0.32^{f}	15.00±0.10^{f}	13.20±0.53^{ef}
2	0%	10.60±0.52^{g}	8.80±0.50^{e}	10.60±0.52^{g}	8.80±0.50^{e}	12.50±0.36^{e}	8.60±0.30^{c}	12.50±0.44^{e}	8.60±0.44^{c}
	2%	11.00±0.53^{gh}	10.47±0.12^{g}	10.40±0.20^{g}	9.63±0.25^{f}	13.37±0.23^{ef}	12.40±0.26^{e}	13.30±0.36^{ef}	11.40±0.36^{de}
	5%	11.77±0.25^{h}	10.70±0.36^{g}	10.83±0.15^{g}	9.70±0.26^{f}	13.60±0.10^{ef}	12.80±0.20^{e}	12.70±0.30^{e}	11.53±0.31^{de}
3	0%	9.30±0.26^{f}	7.30±0.17^{d}	9.30±0.26^{f}	7.30±0.17^{d}	10.73±0.21^{d}	7.63±0.38^{bc}	10.73±0.21^{d}	7.63±0.38^{bc}
	2%	10.50±0.17^{g}	9.37±0.25^{f}	9.83±0.21^{f}	9.10±0.10^{f}	12.33±0.64^{e}	11.57±0.06^{de}	11.97±0.38^{de}	10.03±0.25^{d}
	5%	11.47±0.42^{h}	10.37±0.25^{g}	10.40±0.40^{g}	8.60±0.36^{e}	12.60±0.20^{e}	11.73±0.55^{de}	12.00±0.40^{e}	10.63±0.55^{d}
4	0%	7.87±0.64^{d}	6.77±0.15^{c}	7.87±0.64^{d}	6.77±0.15^{c}	9.63±0.15f^{cd}	6.50±0.26^{b}	9.63±0.15f^{cd}	6.50±0.26^{b}
	2%	9.90±0.10^{f}	8.63±0.21^{e}	9.20±0.40^{ef}	8.53±0.31^{e}	10.67±0.45^{d}	9.97±1.18^{cd}	10.00±0.80^{d}	9.67±0.15^{cd}
	5%	10.40±0.17^{g}	9.63±0.23^{f}	9.77±0.15^{f}	7.83±0.15^{d}	11.23±0.31^{de}	11.00±0.20^{de}	10.37±0.55^{d}	9.60±0.26^{cd}
5	0%	7.03±0.47^{cd}	5.30±0.40^{b}	7.03±0.47^{cd}	5.30±0.40^{b}	8.57±0.25^{c}	5.57±0.25^{ab}	8.57±0.25^{c}	5.57±0.25^{ab}
	2%	9.50±0.40^{f}	8.13±0.45^{e}	8.00±0.56^{de}	6.77±0.75^{c}	9.67±0.06^{cd}	7.90±0.10^{bc}	8.87±0.15^{c}	8.50±0.10^{c}
	5%	9.73±0.12^{f}	9.23±0.32^{f}	9.10±0.10^{f}	7.30±0.26^{d}	9.93±0.12^{cd}	9.70±0.26^{cd}	9.50±0.10^{cd}	8.73±0.32^{c}
6	0%	5.33±0.35^{b}	4.33±0.12^{a}	5.33±0.35^{b}	4.33±0.12^{a}	6.87±0.35^{b}	4.30±0.00^{a}	6.87±0.35^{b}	4.30±0.00^{a}
	2%	8.60±0.29^{e}	6.03±0.32^{c}	7.03±0.57^{cd}	5.50±0.44^{b}	7.80±0.40^{bc}	7.30±0.26^{bc}	7.87±0.55^{bc}	7.20±0.20^{bc}
	5%	8.70±0.56^{e}	8.63±0.06^{e}	8.56±0.21^{e}	6.63±0.15^{c}	8.17±0.64^{c}	7.87±0.89^{bc}	7.37±0.95^{bc}	6.77±0.38^{b}
P value			<0.05				<0.05		

Values are means ± SE. Means with different superscript letters along the columns and across the rows are significantly different at $p<0.05$

The results indicate that enzyme activity was effectively reduced by ascorbic acid at concentrations of 2% and 5%. The combination of ascorbic acid with vacuum packaging significantly slowed the browning of potato slices, yielding better results compared to citric acid treatment at the same concentrations of 2% and 5%.

Ascorbic acid functions as an antioxidant in the food industry by scavenging free radicals and preventing oxidation, primarily by reducing o-quinones to diphenols, thus mitigating enzymatic browning. In contrast, citric acid acts as an acidulant by lowering the pH.Treatment with ascorbic acid significantly reduces browning, with its effectiveness increasing with concentration; higher concentrations result in significantly lower polyphenol oxidase (PPO) activity and reduced browning compared to lower concentrations(Yıldız, 2019) The combination of ascorbic acid with vacuum packaging is more effective than ascorbic acid alone. Yıldız, (2019) found that the optimal concentration of ascorbic acid for preventing enzymatic browning in Irish potatoes is 2%.

4.7 Sensory Evaluation

Among the two varieties studied, the Markies variety achieved the highest color score with both 2% and 5% concentrations of ascorbic acid (AA) treatment. The flavor of French fries was most favored for the Shangi variety when treated with 2% concentration**s** of both ascorbic and citric acids. Texture was particularly well-received for the Markies variety with 2% and 5% ascorbic acid treatments. Overall, samples treated with 2% concentrations of both ascorbic and citric acids received high acceptability ratings for both varieties. Sensory evaluation indicated that 2% concentrations of both ascorbic and citric acids were the most effective, providing an optimal solution for processors aiming to extend the shelf life of fresh-cut potato slices.

The findings align with those reported by Xu et al., (2022) who investigated the effects of vacuum packaging combined with ascorbic acid on the quality of fresh-cut potatoes. Their study found that this combination effectively reduced browning and preserved firmness. Additionally, taste and flavor assessments indicated that vacuum packaging and ascorbic acid treatment maintained these sensory attributes. The treatment inhibited aldehyde formation from fatty acid degradation, thereby suppressing rancid flavors in fresh-cut potatoes. The results suggest that combining vacuum packaging with ascorbic acid is a promising preservation method for extending the shelf life of fresh-cut potatoes. Ascorbic acid, classified as Generally Recognized As Safe (GRAS), is a natural antioxidant that mitigates cell damage by degrading hydrogen peroxide through the ascorbate-glutathione cycle and interacts directly with reactive oxygen species (ROS) to reduce oxidative damage (Xu et al., 2022) .

Table 4.9: Sensory Evaluation of the Quality Characteristics of French Fries (Chips) Made from Fresh-Cut Potatoes Treated with 2% and 5% Concentrations of Ascorbic Acid and Citric Acid, and Packaged Under Vacuum Conditions

Treatment	Conc.	Color	Flavor	Texture	Acceptability
0 %	Markies	5	5	5	5
	Shangi	4	5	5	5
2% CA	Markies	7	6	6	6
	Shangi	6	7	5	6
5% CA	Markies	7	4	6	4
	Shangi	6	4	5	4
2% AA	Markies	7	6	6	7
	Shangi	6	7	5	7
5%AA	Markies	7	5	6	5
	Shangi	6	5	5	5

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The results revealed a significant influence of maturity stage, varietal characteristics, and location on the examined components of potato tuber cultivars for processing as summarized below.

- The optimal harvesting stage was the 3rd maturity stage (75-85 days) for Shangi and (105-125 days) for Markies after flowering.
- The location had effects on the physicochemical characteristics of the two Irish potato varieties which could be attributed to cultural practices and soil types.
- Ware storage was best suited for ware potatoes used for processing fried potato products.
- A combination of ascorbic acid treatment at 2% concentration, blanching, and vacuum packaging appeared to be an effective method for extending the shelf life of fresh-cut potato slices.

5.2 Recommendations

- Since the two varieties, Markies and Shangi were found suitable for processing they should be promoted for cultivation and adopted in the industry for processing
- The current research was done in only two locations Githioro and Kipipiri and therefore there is a need to determine tuber processing suitability for additional locations where Irish potatoes are cultivated for processing purposes

- The 3rd maturity stage was determined as the stage where the physicochemical traits were at their optimum, hence farmers can adopt the 3rd maturity stage for harvesting their tubers.
- Further work can be done to develop other products and establish other treatment methods that can be used to extend the shelf life of fresh-cut potato slices.

REFERENCES

Abdullah, M., Jamil, R. T., & Attia, F. N. (2022). Vitamin C (Ascorbic Acid). *Encyclopedia of Toxicology: Third Edition*, 962–963. https://doi.org/10.1016/B978-0-12-386454-3.01250-1

Abedi, G., Abdollahpour, S., & Bakhtiari, M. R. (2019). The physical and mechanical properties of potato (Solanum tuberosum L.) tubers as related to the automatic separation from clods and stones. *Research in Agricultural Engineering*, *65*(3), 77–84. https://doi.org/10.17221/24/2018-RAE

Abong', G. O., & Kabira, J. N. (2011). Suitability of two established and three newly released Kenyan potato varieties for processing into crisps and French fries. *African Journal of Food, Agriculture, Nutrition and Development*, *11*(6), 5266–5281. https://doi.org/10.4314/ajfand.v11i6.CITATIONS

Abong, G. O., Okoth, M. W., Imungi, J. K., & Kabira, J. N. (2011). Losses of ascorbic acid during storage of fresh tubers, frying, packaging and storage of potato crisps from four kenyan potato cultivars. *American Journal of Food Technology*, *6*(9), 772–780. https://doi.org/10.3923/ajft.2011.772.780

Abong, G. O., Okoth, M. W., Kabira, J. N., Ogolla, J., Ouma, J., Ngunju, C. W., & Oded, K. (2015). Physico-chemical changes in popular Kenyan processing potato varieties as influenced by storage condition. *Current Research in Nutrition and Food Science*, *3*(2), 112–120. https://doi.org/10.12944/CRNFSJ.3.2.03

Abong, G., Okoth, M., Imungi, J., & Kabira, J. (2010). Evaluation of selected Kenyan potato cultivars for processing into potato crisps. *Agriculture and Biology Journal of North America*, *1*(5), 886–893. https://doi.org/10.5251/abjna.2010.1.5.886.893

Abong, G., Okoth, M., Karuri, E., Kabira, J., & Mathooko, F. (2009). Influence of potato cultivar and stage of maturity on oil content of French fries (chips) made from eight

Kenyan potato cultivars. *African Journal of Food, Agriculture, Nutrition and Development*, *9*(8), 1667–1682. https://doi.org/10.4314/ajfand.v9i8.48405

Alamar, M. C., Tosetti, R., Landahl, S., Bermejo, A., & Terry, L. A. (2017). Assuring potato tuber quality during storage: A future perspective. *Frontiers in Plant Science*, *8*(November 2017), 1–6. https://doi.org/10.3389/fpls.2017.02034

Ali, M. R., Parmar, A., Niedbała, G., Wojciechowski, T., El-Yazied, A. A., Abd El-Gawad, H. G., Nahhas, N. E., Ibrahim, M. F. M., & El-Mogy, M. M. (2021). Improved shelf-life and consumer acceptance of fresh-cut and fried potato strips by an edible coating of garden cress seed mucilage. *Foods*, *10*(7). https://doi.org/10.3390/foods10071536

Altemimi, A. B. (2018). Extraction and optimization of potato starch and its application as a stabilizer in yogurt manufacturing. *Foods*, *7*(2). https://doi.org/10.3390/foods7020014

Amjad, A., Javed, M. S., Hameed, A., Hussain, M., & Ismail, A. (2020). Changes in sugar contents and invertase activity during low temperature storage of various chipping potato cultivars. *Food Science and Technology (Brazil)*, *40*(2), 340–345. https://doi.org/10.1590/fst.00219

Amsel, N., Bishop, E., & Science, T. (2008). *Potatoes Scientific Classification and Description*. *March*. http://www.experiencefestival.com/a/Potato/id/1896689

Andati, P., Majiwa, E., Ngigi, M., Mbeche, R., & Ateka, J. (2023). Effect of climate smart agriculture technologies on crop yields: Evidence from potato production in Kenya. *Climate Risk Management*, *41*, 100539. https://doi.org/10.1016/j.crm.2023.100539

AOAC. (1995). AOAC Official Methods of Analysis. In *Association of Official Agricultural Chemists. Washington, D.C.* (16th ed., Vol. 1).

Arvanitoyannis, I. S., & Dionisopoulou, N. (2014). Acrylamide: Formation, Occurrence in Food Products, Detection Methods, and Legislation. *Critical Reviews in Food Science and Nutrition*, *54*(6), 708–733. https://doi.org/10.1080/10408398.2011.606378

Bandana, Sharma, V., Raigond, P., Singh, B., & Kaushik, S. K. (2015). Ascorbic acid losses during storage of potato tubers. *Potato Journal*, *42*(1), 76–79.

Beals, K. A. (2018). *Potatoes , Nutrition and Health*.

Beliyu, L., & ederose, T. (2014). Knowledge gaps in potato technology adoption: The case of central highlands of Ethiopia. *Journal of Agricultural Extension and Rural Development*, *6*(8), 259–266. https://doi.org/10.5897/jaerd2014.0604

Benkeblia, N., Alexopoulos, A. A., & Passam, H. C. (2008). Physiological and Biochemical Regulation of Dormancy and Sprouting in Potato Tubers (Solanum tuberosum L .). *Fruit, Vegetable and Cereal Science and Biotechnology*, *2*(1), 54–68.

Bethke, P. C., Sabba, R., & Bussan, A. J. (2009). Tuber water and pressure potentials decrease and sucrose contents increase in response to moderate drought and heat stress. *American Journal of Potato Research*, *86*(6), 519–532. https://doi.org/10.1007/s12230-009-9109-8

Bico, S. L. S., Raposo, M. F. J., Morais, R. M. S. C., & Morais, A. M. M. B. (2009). Combined effects of chemical dip and/or carrageenan coating and/or controlled atmosphere on quality of fresh-cut banana. *Food Control*, *20*(5), 508–514. https://doi.org/10.1016/j.foodcont.2008.07.017

Bista, B., & Bhandari, D. (2019). Potassium Fertilization in Potato. *International Journal of Applied Sciences and Biotechnology*, *7*(2), 153–160. https://doi.org/10.3126/ijasbt.v7i2.24636

Borda, D., & Alexe, P. (2011). *Acrylamide levels in food*. *1*(1), 3–15.

Bordoloi, A., Kaur, L., & Singh, J. (2012). Parenchyma cell microstructure and textural characteristics of raw and cooked potatoes. *Food Chemistry*, *133*(4), 1092–1100. https://doi.org/10.1016/j.foodchem.2011.11.044

Boz, Z., Brecht, J. K., Welt, B. A., Pelletier, W., Mclamore, E., Kiker, G., & Butler, J. E. (2018). Challenges and Advances in Development of Active Components to Modify Headspace Gases in Packaging of Fresh Produce and Muscle Foods. *Journal of Applied Packaging Research*, *10*(1), 62–97. https://scholarworks.rit.edu/japr/vol10/iss1/5/

Bubeníčková, A., Simeonovová, J., Kumbár, V., Jůzl, M., & Nedomová, Š. (2011). Mathematical Descriptive Characteristics of Potato Tubers ' Shape. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis*, *59*(6), 63–68.

Burgos, G., Auqui, S., Amoros, W., Salas, E., & Bonierbale, M. (2009). Ascorbic acid concentration of native Andean potato varieties as affected by environment, cooking and storage. *Journal of Food Composition and Analysis*, *22*(6), 533–538. https://doi.org/10.1016/j.jfca.2008.05.013

Camire, M. E., Kubow, S., & Donnelly, D. J. (2009). Potatoes and Human Health. *Critical Reviews in Food Science and Nutrition*, *49*(10), 823–840. https://doi.org/10.1080/10408390903041996

Chemeda, A. S., Bultosa, G., & Dechassa, N. (2014). Effect of Variety and Storage on the Tuber Quality of Potatoes Cultivated. *Science, Technology and Arts Research Journal*, *3*(1), 84–89.

Chepkoech, B. (2022). Socio-Demographic Characteristics and Potato Production Practices of Smallholder Potato Farmers in Molo Sub-County, Kenya. *East African Scholars Journal of Agriculture and Life Sciences*, *5*(6), 112–122.

https://doi.org/10.36349/easjals.2022.v05i06.004

Christopher, N., & Gershom, N. (2024). Irish Potato Value Addition Innovations and Utilization of Value Added Products on Livelihood Improvement Among Utilizers in Kitumba and Bubare Sub-Counties, Kabale District. *International Journal of Sustainable Development Research*, *10*(1), 16–23. https://doi.org/10.11648/j.ijsdr.20241001.13

Consolata, M. N. (2018). *GLYCOALKALOIDS IN COMMERCIAL KENYAN POTATO VARIETIES : EFFECT OF POST-HARVEST HANDLING AND STORAGE CONDITIONS BSc . Foods , Nutrition and Dietetics (Kenyatta University) A dissertation submitted in partial fulfillment for the Degree of Master of Science*. *December*.

Das, S., Mitra, B., Saha, A., Mandal, S., Paul, P. K., El-Sharnouby, M., Hassan, M. M., Maitra, S., & Hossain, A. (2021). Evaluation of quality parameters of seven processing type potato (Solanum tuberosum l.) cultivars in the eastern sub-himalayan plains. *Foods*, *10*(5), 1–9. https://doi.org/10.3390/foods10051138

De Meulenaer, B., Medeiros, R., & Mestdagh, F. (2016). Acrylamide in Potato Products. In *Advances in Potato Chemistry and Technology: Second Edition* (Second Edi, Issue Figure 1). Elsevier Inc. https://doi.org/10.1016/B978-0-12-800002-1.00018-2

de Vasconcelos, N. C. M., Salgado, S. M., Livera, A. V. S., de Andrade, S. A. C., de Oliveira, M. G., & Stamford, T. L. M. (2015). Influence of heat treatment on the sensory and physical characteristics and carbohydrate fractions of french-fried potatoes (Solanum tuberosum L.). *Food Science and Technology (Brazil)*, *35*(3), 561–569. https://doi.org/10.1590/1678-457X.6685

Devaux, A., Goffart, J. P., Kromann, P., Andrade-Piedra, J., Polar, V., & Hareau, G. (2021). The Potato of the Future: Opportunities and Challenges in Sustainable Agri-food Systems. *Potato Research*, *64*(4), 681–720. https://doi.org/10.1007/

s11540-021-09501-4

Devaux, A., Kromann, P., & Ortiz, O. (2014). Potatoes for Sustainable Global Food Security. *Potato Research*, *57*(3–4), 185–199. https://doi.org/10.1007/s11540-014-9265-1

do Nascimento, R. F., & Canteri, M. H. G. (2020). Use of sodium metabisulfite and ascorbic acid as anti-browning agents in processed potatoes. *British Food Journal*, *122*(2), 380–389. https://doi.org/10.1108/BFJ-05-2019-0322

do Nascimento, R. F., Canteri, M. H. G., Rodrigues, S. Á., & Kovaleski, J. L. (2020). Use of Sodium Metabisulphite and Ascorbic Acid to Control Browning in Ready-to-Eat Processed Potatoes during Prolonged Storage. *Potato Research*, *63*(4), 615–625. https://doi.org/10.1007/s11540-020-09461-1

Dramićanin, A. M., Andrić, F. L., Poštić, D., Momirović, N. M., & Milojković-Opsenica, D. M. (2018). Sugar profiles as a promising tool in tracing differences between potato cultivation systems, botanical origin and climate conditions. *Journal of Food Composition and Analysis*, *72*(May), 57–65. https://doi.org/10.1016/j.jfca.2018.06.005

Driskill, E. P., Knowles, L. O., & Knowles, N. R. (2007). Temperature-induced changes in potato processing quality during storage are modulated by tuber maturity. *American Journal of Potato Research*, *84*(5), 367–383. https://doi.org/10.1007/BF02987183

Eaton, T. E., Azad, A. K., Kabir, H., & Siddiq, A. B. (2017). Evaluation of Six Modern Varieties of Potatoes for Yield, Plant Growth Parameters and Resistance to Insects and Diseases. *Agricultural Sciences*, *08*(11), 1315–1326. https://doi.org/10.4236/as.2017.811095

Fajardo, D., Haynes, K. G., & Jansky, S. (2013). Starch Characteristics of Modern and

Heirloom Potato Cultivars. *American Journal of Potato Research*, *90*(5), 460–469. https://doi.org/10.1007/s12230-013-9320-5

FAO. (2022). *FAOSTAT*. https://www.fao.org/faostat/en/#data/QCL

Friedman, M. (2006). Potato glycoalkaloids and metabolites: Roles in the plant and in the diet. *Journal of Agricultural and Food Chemistry*, *54*(23), 8655–8681. https://doi.org/10.1021/jf061471t

Furrer, A. N., Chegeni, M., & Ferruzzi, M. G. (2018). Impact of potato processing on nutrients, phytochemicals, and human health. *Critical Reviews in Food Science and Nutrition*, *58*(1), 146–168. https://doi.org/10.1080/10408398.2016.1139542

Gamea, G. R., Abd El-Maksoud, M. A., & Abd El-Gawad, A. M. (2009). Physical Characteristics and Chemical Properties of Potato Tubers Under Different Storage Systems. *Misr Journal of Agricultural Engineering*, *26*(1), 385–408. https://doi.org/10.21608/mjae.2020.110155

García-Segovia, P., Andrés-Bello, A., & Martínez-Monzó, J. (2008). Textural properties of potatoes (Solanum tuberosum L., cv. Monalisa) as affected by different cooking processes. *Journal of Food Engineering*, *88*(1), 28–35. https://doi.org/10.1016/j.jfoodeng.2007.12.001

Gikundi, E. N., Sila, D. N., Orina, I. N., & Buzera, A. K. (2021). Physico-chemical properties of selected Irish potato varieties grown in Kenya. *African Journal of Food Science*, *15*(1), 10–19. https://doi.org/10.5897/ajfs2020.2025

Gikundi, N. E. (2021). *Physico-Chemical Properties And Storability of Selected Irish Potato Varieties Grown In Kenya Evelyne Nkirote Gikundi Master of Science (Food Science and Technology) Jomo Kenyatta University of Agricuture and Technology.*

Gil, M. I., Aguayo, E., & Kader, A. A. (2006). Quality changes and nutrient retention in fresh-cut versus whole fruits during storage. *Journal of Agricultural and Food Chemistry*, *54*(12), 4284–4296. https://doi.org/10.1021/jf060303y

Gilsenan, C., Burke, R. M., & Barry-Ryan, C. (2010). A study of the physicochemical and sensory properties of organic and conventional potatoes (Solanum tuberosum) before and after baking. *International Journal of Food Science and Technology*, *45*(3), 475–481. https://doi.org/10.1111/j.1365-2621.2009.02148.x

Gladys Maingi, W. K. and B. W. O. (2015). *Potato Market Assessment for East Africa 2015*.

Heltoft, P., Molteberg, E. L., Nærstad, R., & Hermansen, A. (2015). Effect of Maturity Level and Potato Cultivar on Development of Fusarium Dry Rot in Norway. *Potato Research*, *58*(3), 205–219. https://doi.org/10.1007/s11540-015-9300-x

Heltoft, P., Wold, A. B., & Molteberg, E. L. (2017). Maturity indicators for prediction of potato (Solanum tuberosum L.) quality during storage. *Postharvest Biology and Technology*, *129*(1431), 97–106. https://doi.org/10.1016/j.postharvbio.2017.03.011

Irshad, M. F. A. F. N. and G. (2013). Important fungal diseases of potato and their management – a brief review Muhammad Fahim Abbas , Farah Naz and Gulshan Irshad. *Mycopath*, *11*(1), 45–50.

Irungu, F. G., Tanga, C. M., Ndiritu, F. G., Mathenge, S. G., Kiruki, F. G., & Mahungu, S. M. (2022). Enhancement of potato (Solanum tuberosum L) postharvest quality by use of magnetic fields – A case of shangi potato variety. *Applied Food Research*, *2*(2), 100191. https://doi.org/10.1016/j.afres.2022.100191

Jama-Rodzeńska, A., Walczak, A., Adamczewska-Sowińska, K., Janik, G., Kłosowicz, I., Głąb, L., Sowiński, J., Chen, X., & Pęczkowski, G. (2020). Influence of variation in the volumetric moisture content of the substrate on irrigation efficiency in early potato varieties. *PLoS ONE*, *15*(4). https://doi.org/10.1371/journal.pone.0231831

Jin, Y.-X., Kim, S.-M., Kim, S.-N., Kim, H.-R., Kim, S.-C., Hwang, J., & Choi, Y. (2016). Food Composition of Raw and Boiled Potatoes. *Korean Journal of Food & Cookery Science*, *32*(4), 517–523. https://doi.org/10.9724/kfcs.2016.32.4.517

Jones Jr., J. B. (2012). Plant Nutrition and Soil Fertility Manual. *Plant Nutrition and Soil Fertility Manual*, *2*. https://doi.org/10.1201/b11577

Kabira, J. N., & Lemaga, B. (2003). *Potato processing. Quality evaluation procedures for research and food industry applications in East and Central Africa*. 20.

Kafouris, D., Stavroulakis, G., Christofidou, M., Iakovou, X., Christou, E., Paikousis, L., Christodoulidou, M., Ioannou-Kakouri, E., & Yiannopoulos, S. (2018). Determination of acrylamide in food using a UPLC–MS/MS method: results of the official control and dietary exposure assessment in Cyprus. *Food Additives and Contaminants - Part A Chemistry, Analysis, Control, Exposure and Risk Assessment*, *35*(10), 1928–1939. https://doi.org/10.1080/19440049.2018.1508893

Kaguongo, W. (2014). *Post-harvest losses in potato value chains in Kenya Analysis and recommendations for reduction strategies*. *August*, 1–81. https://doi.org/10.13140/2.1.3761.3764

Kaguongo, W., Maingi, G., Rono, M., & Ochere, E. (2014). *USAID-KAVES: Potato Processing Study Report 2014*. 56.

Kaguongo, W., Nyangweso, A., Mutunga, J., Nderitu, J., Lunga'ho, C., Nganga, N., Kipkoech, D., Kabira, J., Gathumbi, M., Njane, P., Irungu, J., Onyango, A., Borus, K. D., & Schulte-Geldermann, E. (2013). *A policymakers' guide to crop diversification: The case of the potato in Kenya*. www.fao.org

Kajunju, N. H. B., Atukwase, A., Tumuhimbise, G. ., & Mugisha, J. (2021). Potato processing in Uganda: A technical review. *Journal of Agricultural and Environmental Sciences*, *10*(1), 60–81.

Kalita, D., & Jayanty, S. S. (2017). Nutrient composition of continuous and kettle cooked potato chips from three potato cultivars. *Current Research in Nutrition and Food Science*, *5*(2), 75–88. https://doi.org/10.12944/CRNFSJ.5.2.04

Kharin, V. V., Zwiers, F. W., Zhang, X., & Hegerl, G. C. (2007). Changes in temperature and precipitation extremes in the IPCC ensemble of global coupled model simulations. *Journal of Climate*, *20*(8), 1419–1444. https://doi.org/10.1175/JCLI4066.1

Kimathi, S. M., Ayuya, O. I., & Mutai, B. (2021). Adoption of climate-resilient potato varieties under partial population exposure and its determinants: Case of smallholder farmers in Meru County, Kenya. *Cogent Food and Agriculture*, *7*(1). https://doi.org/10.1080/23311932.2020.1860185

Kogo, B. K., Kumar, L., & Koech, R. (2021). Climate change and variability in Kenya: a review of impacts on agriculture and food security. *Environment, Development and Sustainability*, *23*(1), 23–43. https://doi.org/10.1007/s10668-020-00589-1

Kumar, D., Singh, B. P., & Kumar, P. (2004). An overview of the factors affecting sugar content of potatoes. *Annals of Applied Biology*, *145*(3), 247–256. https://doi.org/10.1111/j.1744-7348.2004.tb00380.x

Kumar, U., & Chandra, G. (2018). A brief review of potash management in potato (*Solanum tuberosum* L.). *Journal of Pharmacognosy and Phytochemistry. SP1*, *2004*, 1718–1721.

Kwambai, T. K., Griffin, D., Nyongesa, M., Byrne, S., Gorman, M., & Struik, P. C. (2023). Dormancy and Physiological Age of Seed Tubers from a Diverse Set of

Potato Cultivars Grown at Different Altitudes and in Different Seasons in Kenya. *Potato Research*, *66*(4), 1091–1115. https://doi.org/10.1007/s11540-023-09617-9

Kwambai, T. K., Griffin, D., Struik, P. C., Stack, L., Rono, S., Brophy, C., Nyongesa, M., & Gorman, M. (2024). Seed Quality and Variety Preferences Amongst Potato Farmers in North-Western Kenya: Lessons for the Adoption of New Varieties. *Potato Research*, *67*(1), 185–208. https://doi.org/10.1007/s11540-023-09626-8

Lal, M. K., Tiwari, R. K., Jaiswal, A. K., Kumar, R., Kumar, D., Kumar, A., Dutt, S., Kumar, D., & Singh, B. (2023). Post-harvest management and value addition in potato: emerging technologies in preserving quality and sustainability in potato processing. *XXII Biennial National Symposium Special Issue*, *68*(December), 241–261.

Lemos, L. B. (2004). *Technological Quality and Utilization*. 598–603.

Leonel, M., do Carmo, E. L., Fernandes, A. M., Soratto, R. P., Ebúrneo, J. A. M., Garcia, É. L., & dos Santos, T. P. R. (2017). Chemical composition of potato tubers: the effect of cultivars and growth conditions. *Journal of Food Science and Technology*, *54*(8), 2372–2378. https://doi.org/10.1007/s13197-017-2677-6

Levaj, B., Pelaić, Z., Galić, K., Kurek, M., Ščetar, M., Poljak, M., Dite Hunjek, D., Pedisić, S., Balbino, S., Čošić, Z., Dujmić, F., & Repajić, M. (2023). Maintaining the Quality and Safety of Fresh-Cut Potatoes (Solanum tuberosum): Overview of Recent Findings and Approaches. *Agronomy*, *13*(8). https://doi.org/10.3390/agronomy13082002

Liu, X., Wang, T., Lu, Y., Yang, Q., Li, Y., Deng, X., Liu, Y., Du, X., Qiao, L., & Zheng, J. (2019). Effect of high oxygen pretreatment of whole tuber on anti-browning of fresh-cut potato slices during storage. *Food Chemistry*, *301*(May), 125287. https://doi.org/10.1016/j.foodchem.2019.125287

Love, S. L., & Pavek, J. J. (2008). Positioning the potato as a primary food source of vitamin C. *American Journal of Potato Research*, *85*(4), 277–285. https://doi.org/10.1007/s12230-008-9030-6

Lutaladio, N. B., & Castaldi, L. (2009). Potato: The hidden treasure. *Journal of Food Composition and Analysis*, *22*(6), 491–493. https://doi.org/10.1016/j.jfca.2009.05.002

Mackay, G. R. (2009). New Light on a Hidden Treasure. *Experimental Agriculture*, *45*(3), 376–376.

Majeed, A., & Muhammad, Z. (2018). Potato production in pakistan: Challenges and prospective management strategies – A review. *Pakistan Journal of Botany*, *50*(5), 2077–2084.

Malone, J. G., Mittova, V., Ratcliffe, R. G., & Kruger, N. J. (2006). The response of carbohydrate metabolism in potato tubers to low temperature. *Plant and Cell Physiology*, *47*(9), 1309–1322. https://doi.org/10.1093/pcp/pcj101

Mareček, J., Ivanišová, E., Frančáková, H., Musilová, J., Krajčovič, T., & Mendelová, A. (2016). Evaluation of primary and secondary metabolites in selected varieties of potatoes. *Potravinarstvo*, *10*(1), 145–151. https://doi.org/10.5219/562

Mburu, H., Cortada, L., Haukeland, S., Ronno, W., Nyongesa, M., Kinyua, Z., Bargul, J. L., & Coyne, D. (2020). Potato Cyst Nematodes: A New Threat to Potato Production in East Africa. *Frontiers in Plant Science*, *11*(May), 1–13. https://doi.org/10.3389/fpls.2020.00670

Rahman, M.D. Mahfuzar. (2014). *Industry in Bangladesh Dhaka-1207 By*.

Mlaviwa, J., & Missanjo, E. (2019). Recent Trends and Future Directions on Value Addition of Irish potato Solanum Tuberosum L.) among Smallholder Farmers.

Emerging Science Journal, *3*(1), 41. https://doi.org/10.28991/esj-2019-01167

Mohammed, W. (2016). Specific Gravity, Dry Matter Content, and Starch Content of Potato (Solanum tuberosum L.) Varieties Cultivated in Eastern Ethiopia. *East African Journal of Sciences*, *10*, 87–102.

Morales-Fernández, S. D., Mora-Aguilar, R., Salinas-Moreno, Y., Rodríguez-Pérez, J. E., Colinas-León, M. T., & Lozoya-Saldaña, H. (2018). Crecimiento y contenido de azúcares de tubérculo de papa en cuatro estados de madurez en condiciones de invernadero. *Revista Chapingo, Serie Horticultura*, *24*(1), 53–67. https://doi.org/10.5154/r.rchsh.2016.11.029

Mugambi, I., Karanja, L., Macharia, I., Kaguongo, W., Ngundo, G., Amata, R., & Mulema, J. (2021). What influences uptake of alternative pest management practices by potato farmers? Evidence from six counties in Kenya. *Journal of Development and Agricultural Economics*, *13*(3), 205–214. https://doi.org/10.5897/JDAE2021.1278

Musita, C. N., Okoth, M. W., & Abong, G. O. (2019). Postharvest handling practices and perception of potato safety among potato traders in Nairobi, Kenya. *International Journal of Food Science*, *2019*. https://doi.org/10.1155/2019/2342619

Muthoni, J., Mbiyu, M. W., & Nyamongo, D. O. (2010). A Review of potato seed systems and germplasm conservation in Kenya. *Journal of Agricultural and Food Information*, *11*(2), 157–167. https://doi.org/10.1080/10496501003680565

National Potato Council of Kenya. (2016). *The National Potato Strategy 2016-2020*. https://npck.org/national-potato-strategy-2021-2025/

National Potato Council of Kenya. (2019a). Potato Variety. *Catalogue*.

National Potato Council of Kenya. (2019b). The Crops (Irish Potato) Regulations 2019 –

Kenya News Agency. *Kenya Gazette*. https://www.kenyanews.go.ke/tag/the-crops-irish-potato-regulations-2019/

National Potato Council of Kenya (. (2018). *Potato production handbook A guidline for farmers and Trainers*.

Naumann, M., Koch, M., Thiel, H., Gransee, A., & Pawelzik, E. (2020). The Importance of Nutrient Management for Potato Production Part II: Plant Nutrition and Tuber Quality. *Potato Research*, *63*(1), 121–137. https://doi.org/10.1007/s11540-019-09430-3

Ndungutse, V., Vasanthakaalam, H., Faraj, A. K., & Ngoda, P. (2019a). *(Solanum tuberosum l) Cultivars grown*. *August*.

Ndungutse, V., Vasanthakaalam, H., Faraj, A. K., & Ngoda, P. (2019b). Processing quality of selected potato (solanum tuberosum l.) Cultivars grown in Rwanda. *Potato Journal*, *46*(1), 48–55.

Noe, W., Ngome Precillia, T., Caroline Waingeh, N., Ousman, A., Eric Joel, N., Brice, S., Yvette, Y., Andre, N., Farida, A., Mireille, M., Claudette, D. V, & Justine, O. (2019). *Suitability of Different Processing Techniques and Sales Options for Irish Potato (Solanum Tuberusum) Cultivars in Cameroon*. *4*(4). www.faraafrica.org

Nyankanga, R. O., Murigi, W. W., & Shibairo, S. I. (2018). Effect of Packaging Material on Shelf Life and Quality of Ware Potato Tubers Stored at Ambient Tropical Temperatures. *Potato Research*, *61*(3), 283–296. https://doi.org/10.1007/s11540-018-9377-0

Ogola, R. J. O., & Ouko, K. O. (2021). Expert's opinion on Irish potato farmers awareness and preferences towards climate smart agriculture practices attributes in Kenya; A conjoint analysis. *Cogent Food and Agriculture*, *7*(1). https://doi.org/10.1080/23311932.2021.1968163

Ogolla, J. A. (2013). *Acrylamide Contamination in Commercial Potato Crisps in Kenya: Levels of Intake and Effects of Processing Parameters in Local Cultivars*. UON.

Ogolla, J. A., Abong, G. O., Okoth, M. W., Kabira, J. N., Imungi, J. K., & Karanja, P. N. (2015). Levels of Acrylamide in Commercial Potato Crisps Sold in Nairobi County, Kenya " Levels of Acrylamide in Commercial Potato Crisps Sold in Nairobi County. *Journal of Food and Nutrition Research*, *3*(8), 495–501. https://doi.org/10.12691/jfnr-3-8-4

Okaka, F. O., Omondi, P., Ndegwa, B. W., Okaka, F., & Omondi, P. P. (2020). Irish Potato Production In Relation To Climate Change and Variability In Ndaragwa Agro-Ecological Zone In Nyandarua County. Kenya. *Issue 3 Ser. I*, *13*(3), 27–35. https://doi.org/10.9790/2380-1303012735

Omayio, D. G., Abong, G. O., & Okoth, M. W. (2016). A review of occurrence of glycoalkaloids in potato and potato products. *Current Research in Nutrition and Food Science*, *4*(3), 195–202. https://doi.org/10.12944/CRNFSJ.4.3.05

Orlovius, K., & McHoul, J. (2015). Effect of Two Magnesium Fertilizers on Leaf Magnesium Concentration, Yield, and Quality of Potato and Sugar Beet. *Journal of Plant Nutrition*, *38*(13), 2044–2054. https://doi.org/10.1080/01904167.2014.958167

Oteino, N., Lally, R. D., Kiwanuka, S., Lloyd, A., Ryan, D., Germaine, K. J., & Dowling, D. N. (2015). Plant growth promotion induced by phosphate solubilizing endophytic Pseudomonas isolates. *Frontiers in Microbiology*, *6*(JUL), 1–9. https://doi.org/10.3389/fmicb.2015.00745

Pathare, P. B., & Opara, U. L. (2013). *Colour Measurement and Analysis in Fresh and Processed Foods : A Review Colour Measurement and Analysis in Fresh and Processed Foods : A Review*. *September 2015*. https://doi.org/10.1007/s11947-012-0867-9

Pedreschi, F., Mery, D., Bunger, A., & Yañez, V. (2011). Computer vision classification of potato chips by color. *Journal of Food Process Engineering*, *34*(5), 1714–1728. https://doi.org/10.1111/j.1745-4530.2009.00540.x

Petrucci, K. P. de O. S., Pereira, A. M., Moreira, M. A., Cecon, P. R., & Finger, F. L. (2021). Storage of markies cultivar potatoes for prossessing. *Revista Ceres*, *68*(2), 89–95. https://doi.org/10.1590/0034-737x202168020001

Phogat, N., Siddiqui, S., Dalal, N., Srivastva, A., & Bindu, B. (2020). Effects of varieties, curing of tubers and extraction methods on functional characteristics of potato starch. *Journal of Food Measurement and Characterization*, *14*(6), 3434–3444. https://doi.org/10.1007/s11694-020-00579-x

Pieniazek, F., & Messina, V. (2017). Texture and color analysis of freeze-dried potato (cv. Spunta) using instrumental and image analysis techniques. *International Journal of Food Properties*, *20*(6), 1422–1431. https://doi.org/10.1080/10942912.2016.1211143

Pinhero, R. G., Coffin, R., & Yada, R. Y. (2009). Post-harvest Storage of Potatoes. In *Advances in Potato Chemistry and Technology* (First Edit, Issue 5). Elsevier Ltd. https://doi.org/10.1016/b978-0-12-374349-7.00012-x

Pinhero, R. G., & Yada, R. Y. (2016). Postharvest Storage of Potatoes. In *Advances in Potato Chemistry and Technology: Second Edition* (Second Edi). Elsevier Inc. https://doi.org/10.1016/B978-0-12-800002-1.00010-8

PotatoPro. (2022). *Potatoes & Products: Industry, News, Stats, Prices, Markets & Trends*. https://www.potatopro.com/

Prabhat K Nema, N. R. (2013). potato glycoalkaloids ;formation and strategic for mitigatio. *Journal of the Science of Food and Agriculture*, *13*(2), 125–135. https://doi.org/10.1002/jsfa

Prokop, S., & Albert, J. (2008). Potatoes , nutrition and diet. *Food and Agriculture Organisation Factsheet*, 1–2. http://www.fao.org/potato-2008/en/potato/factsheets.html

Radeny, M., Rao, E. J. O., Ogada, M. J., Recha, J. W., & Solomon, D. (2022). Impacts of climate-smart crop varieties and livestock breeds on the food security of smallholder farmers in Kenya. *Food Security*, *14*(6), 1511–1535. https://doi.org/10.1007/ s12571-022-01307-7

Rahman, M. M., Roy, T. S., Chowdhury, I. F., Afroj, M., & Bashar, M. A. (2017). Identification of physical characteristics of potato varieties for processing industry in Bangladesh. *Bangladesh Journal of Botany*, *46*(3), 917–924.

Robertson, T. M., Alzaabi, A. Z., Robertson, M. D., & Fielding, B. A. (2018). Starchy carbohydrates in a healthy diet: The role of the humble potato. *Nutrients*, *10*(11). https://doi.org/10.3390/nu10111764

Rocculi, P., Romani, S., Gómez Galindo, F., & Dalla Rosa, M. (2009). Effect of Minimal Processing on Physiology and Quality of Fresh-Cut Potatoes: a Review Optimizing Quality Losses and Shelf-life in Bakery products by Edible coatings View project. *Global Sience Books*, *1*, 18–30. https://www.researchgate.net/publication/255701366

Rocha, A. M. C. N., Coulon, E. C., & Morais, A. M. M. B. (2003). *Peer review Effects of vacuum packaging on the physical quality of minimally processed potatoes*. 81–88.

Singh, J., Kaur, L., & Rao, M. A. (2009). Textural and Rheological Characteristics of Raw and Cooked Potatoes. In *Advances in Potato Chemistry and Technology* (First Edit). Elsevier Ltd. https://doi.org/10.1016/b978-0-12-374349-7.00009-x

Singh, J., Kaur, L., & Rao, M. A. (2016). Textural Characteristics of Raw and Cooked

Potatoes. In *Advances in Potato Chemistry and Technology: Second Edition* (Second Edi). Elsevier Inc. https://doi.org/10.1016/B978-0-12-800002-1.00016-9

Soboka, S., Asefa, G., & Beriso, M. (2018). Effect of varieties and growing environments on tuber yield, nutritional and process quality of potato grown in bale highlands, south eastern Ethiopia. *International Journal of Agricultural Research, Innovation and Technology*, *7*(2), 18–21. https://doi.org/10.3329/ijarit.v7i2.35317

Spooner, D. M., Ghislain, M., Simon, R., Jansky, S. H., & Gavrilenko, T. (2014). Systematics, Diversity, Genetics, and Evolution of Wild and Cultivated Potatoes. *Botanical Review*, *80*(4), 283–383. https://doi.org/10.1007/s12229-014-9146-y

Stephen Laititi, M. (2014). Potato Market Survey in Kenya: an Agricultural Product Value Chain Approach. *International Journal Of Business And Management Review*, *2*(6), 59–87. www.eajournals.org

Subramanian, N. K. (2012). *Genetics of mineral accumulation in potato tubers. September*.

Torres, M. D. Á., & Parreño, W. C. (2009). Thermal Processing and Quality Optimization. *Advances in Potato Chemistry and Technology*, *1853*, 163–219. https://doi.org/10.1016/b978-0-12-374349-7.00007-6

Ugonna, C. U., Jolaoso, M. O., & Onwualu, A. P. (2013). A technical appraisal of potato value chain in Nigeria Production Yield of Potato in Africa. *International Research Journal of Agricultural Science and Soil Science*, *3*(8), 291–301.

Vågen, T.-G., Vågen, T.-G., Shepherd, K. D., Walsh, M. G. ., Winowiecki, L. A. . T., amene Desta, L., & Tondoh, J. E. (2013). *Africa Soil Information Service (AfSIS) - Soil Health Mapping - ICRAF GeoScience Lab Dataverse* https://dataverse .harvard.edu/dataset.xhtml?persistentId=hdl:1902.1/19793

Valcarcel, J., Reilly, K., Gaffney, M., & O'Brien, N. (2015). Total Carotenoids and l-Ascorbic Acid Content in 60 Varieties of Potato (Solanum tuberosum L.) Grown in Ireland. *Potato Research*, *58*(1), 29–41. https://doi.org/10.1007/s11540-014-9270-4

Waaswa, A., Oywaya Nkurumwa, A., Mwangi Kibe, A., & Ngeno Kipkemoi, J. (2022). Climate-Smart agriculture and potato production in Kenya: review of the determinants of practice. *Climate and Development*, *14*(1), 75–90. https://doi.org/10.1080/17565529.2021.1885336

Wachira Kaguongo, Gladys Maingi, S. G. (2014a). Post-harvest losses in potato value chains in Kenya: Analysis and recommendations for reduction strategies. *Deutsche Gesellschaft Für Internationale Zusammenarbeit (GIZ) GmbH*, *August*, 1–80. https://doi.org/10.13140/2.1.3761.3764

Wachira Kaguongo, Gladys Maingi, S. G. (2014b). Post-harvest losses in potato value chains in Kenya Table of Contents. *Deutsche Gesellschaft Für Internationale Zusammenarbeit (GIZ) GmbH*.

Wang, S., Chang, T., Wang, C., Shi, L., Wang, W., Yang, H., & Cui, M. (2015). Effect of Particle Sizes of Soy Okara on Textural, Color, Sensory and Rheological Properties of Pork Meat Gels. *Journal of Food Quality*, *38*(4), 248–255. https://doi.org/10.1111/jfq.12144

Wayumba, B. O., Choi, H. S., & Seok, L. Y. (2019). Selection and evaluation of 21 potato (Solanum tuberosum) breeding clones for cold chip processing. *Foods*, *8*(3). https://doi.org/10.3390/foods8030098

Werij, J. S. (2011). *Genetic analysis of potato tuber quality traits*. https://edepot.wur.nl/183746

Wiberley-Bradford, A. E., Busse, J. S., Jiang, J., & Bethke, P. C. (2014). Sugar metabolism, chip color, invertase activity, and gene expression during long-Term cold storage of potato (Solanum tuberosum) tubers from wild-Type and vacuolar invertase silencing lines of Katahdin. *BMC Research Notes*, *7*(1), 1–10. https://doi.org/10.1186/1756-0500-7-801

Wijesinha-bettoni, R. (2019). *The Contribution of Potatoes to Global Food Security , Nutrition and Healthy Diets*. *Fao 2009*.

World Bank. (2017). Climate change risks and opportunities. *Potato Kenya*, *Figure 4*.

Xu, D., Chen, C., Zhou, F., Liu, C., Tian, M., Zeng, X., & Jiang, A. (2022). Vacuum packaging and ascorbic acid synergistically maintain the quality and flavor of fresh-cut potatoes. *LWT*, *162*(March), 113356. https://doi.org/10.1016/j.lwt.2022.113356

Yıldız, G. (2019). Control of Enzymatic Browning in Potato With Calcium Chloride and Ascorbic Acid Coatings. *Food and Health*, *5*(2), 121–127. https://doi.org/10.3153/fh19013

Zaheer, K., & Akhtar, M. H. (2016). Potato Production, Usage, and Nutrition—A Review. *Critical Reviews in Food Science and Nutrition*, *56*(5), 711–721. https://doi.org/10.1080/10408398.2012.724479

Zehra Ekin. (2011). Some analytical quality characteristics for evaluating the utilization and consumption of potato (Solanum tuberosum L.) tubers. *African Journal of Biotechnology*, *10*(32), 6001–6010. https://doi.org/10.5897/ajb11.042

Zhang, H., XU, F., Wu, Y., Hu, H. Hai, & Dai, X. Feng. (2017). Progress of potato staple food research and industry development in China. *Journal of Integrative Agriculture*, *16*(12), 2924–2932. https://doi.org/10.1016/S2095-3119(17)61736-2

Zheng, S. L., Wang, L. J., Wan, N. X., Zhong, L., Zhou, S. M., He, W., & Yuan, J. C. (2016). Response of potato tuber number and spatial distribution to plant density in different growing seasons in Southwest China. *Frontiers in Plant Science*, *7*(365), 2–9. https://doi.org/10.3389/fpls.2016.00365