

**CHEMICAL COMPOSITION OF SEEDS FROM MAJOR PASSION FRUIT SPECIES**

*(Passiflora edulis Sim, Passiflora eduli F flavicarpa and Passiflora maliformis)*

**GROWN IN UGANDA**

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## DECLARATION

I Atuhwera Agnes Judith declare that the content of this dissertation presented for the award of a Master of Science in Food Technology has never been wholly or partially submitted for any other degree award in any institution of higher learning.

Signed..........

Date........

## APPROVAL

This is to certify that Atuhwera Agnes Judith conducted a study titled “Chemical composition of seeds from major passion fruit species (*Passiflora edulis* Sim, *Passiflora eduli* F *flavicarpa* and *Passiflora maliformis*) grown in Uganda” under our supervision. We approve the submission of this dissertation.

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## **DEDICATION**

I dedicate this dissertation to my family and the Agro processing industry in Uganda.

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## TABLE OF CONTENTS

DECLARATION .....	ii
APPROVAL.....	iii
DEDICATION .....	iv
ACKNOWLEDGEMENT .....	v
ABBREVIATIONS/ACRYNOMS.....	xi
ABSTRACT.....	xii
CHAPTER 1: INTRODUCTION .....	1
1.1 Background .....	1
1.2 Problem statement.....	2
1.3 Justification .....	3
1.4 Objectives of the study.....	4
1.4.1 General objective.....	4
1.4.2 Specific objectives.....	4
1.5 Null Hypothesis.....	4
CHAPTER 2: LITERATURE REVIEW .....	6
2.1 Taxonomy of the passion fruit .....	6
2.2 Description of passion fruits species.....	6
2.3 Overview of Passion fruit production .....	8
2.4 Economic and nutritional importance of passion fruits .....	10
2.5 Health and nutritional benefits of passion fruits .....	10
2.6 Utilization and health benefits of passion fruits seeds .....	11

2.7 General composition of passion fruit seeds.....	12
2.9 Fatty acid profile of oil from passion fruit seeds .....	16
2.10 Stability of passion fruit seed oil.....	19
2.11 Carotenoids.....	20
2.12 Anti-nutrition factor in passion fruit seeds.....	21
CHAPTER 3: MATERIALS AND METHODS.....	22
3.1 Materials.....	22
3.2 Sample preparation.....	22
3.3 Methods.....	22
3.3.1 Determination of moisture .....	22
3.3.2 Determination of oil yield .....	23
3.3.3 Determination of crude protein .....	23
3.3.4 Determination of crude ash .....	24
3.3.5 Determination of crude fibre .....	24
3.3.6 Determination of carbohydrate.....	25
3.3.7 Determination of mineral content .....	25
3.3.8 Determination of fatty acid composition of the seed oil .....	26
3.3.9 Stability tests for extracted seed oil.....	27
3.3.9.1 Acid value .....	27
3.3.9.2 Peroxide value.....	27
3.3.9.3 Iodine value .....	28
3.3.9.4 Saponification value.....	28
3.3.9.5 Determination of concentration of total carotenoids.....	29
3.7 Statistical Analysis of data .....	29
CHAPTER 4: RESULTS AND DISCUSSION .....	30
4.1 Proximate composition of seeds from passion fruit species grown in Uganda.....	30
4.1.1. Moisture content of dry seeds .....	30

4.1.2 Ash content.....	30
4.1.3 Oil yield.....	31
4.1.4 Protein content.....	32
4.1.5 Crude fibre content.....	32
4.1.6 Carbohydrate content .....	33
4.2 Mineral content (mg/100g) of seeds from passion fruit species grown in Uganda.....	33
4.3 Fatty acid composition of the oil from seeds of passion fruits grown in Uganda.....	36
4.4 Oil stability.....	39
4.4.1 Acid value .....	39
4.4.2 Peroxide value .....	39
4.4.3 Iodine value .....	40
4.4.4 Saponification value (Sv).....	40
4.4.5 Total carotenoids content of the oil from seeds of passion fruit species grown in Uganda	41
CHAPTER 5: CONCLUSION AND RECOMMENDATIONS .....	43
5.1 Conclusion.....	43
5.2 Recommendation.....	43
REFERENCES.....	45
APPENDICES.....	54

## LIST OF TABLES

Table 1: Passion fruits producing regions and countries with average production in metric tonnes in (2015-2017) .....	9
Table 2: Proximate composition (g/100g on dry-basis) of different passion fruit seed species in different countries .....	14
Table 3: Mineral content (mg/100g on dry-basis) of different passion fruit seed species in different countries .....	15
Table 4: Fatty acid composition (%) of oil from seeds of different passion fruit species in different countries .....	18
Table 5: Stability tests for oil from seeds from the passion fruit species in different countries...	20
Table 6: Proximate composition (g/100g on dry-basis) of seeds from passion fruit species grown in Uganda dry weight basis) .....	31
Table 7: Mineral composition (mg/100g on dry-basis) of seeds from passion fruit species grown in Uganda.....	35
Table 8: Fatty acid composition (%) of the seeds from passion fruit species grown in Uganda..	38
Table 9: Stability tests for oil from seeds of passion fruit species grown in Uganda.....	41

## TABLE OF FIGURES

Figure 1: Purple passion fruit ( <i>Passiflora edulis</i> Sims).....	7
Figure 2: Yellow passion fruit ( <i>Passiflora edulis</i> F. <i>flavicarpa</i> ).....	8
Figure 3: Sweet calabash passion fruit ( <i>Passiflora maliformis</i> L).....	8
Figure 4: Carotenoid content of oil from seeds of passion fruit species grown in Uganda.....	42

## ABBREVIATIONS/ACRYNOMS

FAO	– Food and Agriculture Organisation
AOAC	– Association of Analytical Chemists
WHO	– World Health Organisation
CODEX	– Codex Alimentarius Commission
MT	– Metric tonnes
AAS	– Atomic Absorption Spectrometer
ICP-OES	– Inductively Coupled Plasma – Optical Emission Spectrometer
GC-FID	– Gas-Chromatography - Flame Ionisation Detector
UV-spec	– Ultra-Violet Spectrometer
UIRI	– Uganda Industrial Research Institute
NaCRRI	– National Crops Resources Research Institute
ISO	– International Standardisation Organisation
DRI	– Daily Recommended Intake
UFA	– Unsaturated Fatty Acids
SFA	– Saturated Fatty Acids
PUFA	– Poly unsaturated Fatty Acids
MUFA	– Monounsaturated Fatty acids

## ABSTRACT

Passion fruit (*Passiflora* spp.) seeds are usually discarded after extraction of the juice. The seeds, however, represent an important source of edible oil with a high proportion of polyunsaturated fatty acids and other vital components required for good health. The study determined the proximate composition, mineral content and fatty acid profile of the seeds of major passion fruit species (*Passiflora edulis* Sims, *Passiflora edulis* F. *flavicarpa* and *Passiflora maliformis* L) grown in Uganda. In addition, stability tests including total carotenoids of oil extracted from these seeds were determined. Passion fruit seeds presented substantial amounts of oil, crude fibre and carbohydrates in the respective ranges of 24.70±0.29 to 37.24±0.09%, 31.56±0.43 to 36.28±0.50% and 16.19±1.71 to 22.53±0.03% with significant differences at  $p \leq 0.05$ . Crude ash content ranged from 1.36±0.10 to 2.32±0.01% with significant difference at  $p \leq 0.05$ . The seeds had substantial amounts of proteins which ranged between 10.68±0.96 and 11.72±0.06% with no significant difference at  $p \leq 0.05$ . Mineral composition analysed included Potassium (K), Sodium (Na), Calcium (Ca), Zinc (Zn), Copper (Cu), Iron (Fe), Selenium (Se) and Manganese (Mn) using AAS. The dominant mineral element was Potassium, highest in *Passiflora maliformis* L at 9.52±0.00 mg/100g and lowest at 4.77±0.00mg/100g in *Passiflora edulis* Sims followed by Fe, Zn, Ca, Cu, Se, Mn, then Na in their respective ranges of 2.32±0.008 to 5.98±0.002 mg/100g, 1.19±0.007 to 6.71±0.008 mg/100g, 1.45±0.035 to 2.01±0.033 mg/100g, 1.34±0.006 to 1.94±0.001 mg/100g, 0.20±0.011 to 2.09±0.013 mg/100g, 0.77±0.008 to 1.82±0.001 mg/100g and 0.15±0.00 to 0.19±0.00 mg/00g with significant differences at  $p \leq 0.05$ . Passion fruit seed oil contained 14 detectable and quantifiable fatty acids including 4 major essential ones (linoleic acid, oleic acid, palmitic acid and stearic acid). The amount of linoleic acid and oleic acid were in the ranges of 67.57±0.85 to 72.18±0.86% and 14.59±0.17 to 16.41±0.21% of fatty acids, respectively with significant differences at  $p \leq 0.05$ . Palmitic acid ranged between 8.68±0.11 and 11.18±0.14%. Levels of Stearic acid were the lowest in the oil in the range of 2.78±0.03 and 3.16±0.04% with significant differences at  $p \leq 0.05$ . The unsaturated fatty acid content in oil was found to be high ranging from 85.68±0.98 to 87.60±0.15% with significant differences at  $p \leq 0.05$ . Iodine values ranged from 125.25±0.04 to 135.35±0.02 g/100g of oil while saponification values ranged from 174.98±1.45 to 191.74±1.32 mgKOH/g of oil with significant differences at  $p \leq 0.05$ . The peroxide value was 0.10±0.00 meqO<sub>2</sub>/kg in all species with no significant difference at  $p \leq 0.05$ . These results were within the recommended ranges by WHO and Codex standards for edible oils. Total carotenoids expressed as mg β-carotenoid/100g of oil were significantly higher ( $p < 0.05$ ) in *Passiflora edulis* F. *flavicarpa* with value of 21.41±0.4 mg β-carotenoid/100g.

In general, passion fruit seed oil contains substantial amounts of unsaturated fatty acids and is stable to peroxidation and can therefore be utilized in the human diet for health benefits.

...KEYWORDS; Passion fruit seeds, composition, minerals, fatty acids, oxidative stability, health benefits...

## CHAPTER 1: INTRODUCTION

### 1.1 Background

Passion fruits (*Passiflora* spp), are extensively grown in tropical and sub-tropical regions of the world for their edible fruits, ornamental flowers and pharmaceutical uses (Shiamala *et al.*, 2018). It is estimated that the global annual production of passion fruits was approximately 1.47 million metric tonnes by 2017 (Altendorf, 2018). Brazil accounts for 65% of the total passion fruit production followed by Indonesia at 8%, and Africa's at 3% (Ramaiya *et al.*, 2019). In the East African region, Kenya is the leading producer and exporter of passion fruits estimated at 10,593 tonnes (Vera *et al.*, 2003). Over 500 species of the fruit exist but only 20 are known to be edible, of which three species are preferred and commonly grown in Uganda. These include *Passiflora edulis* Sims, *Passiflora edulis* F. *flavicarpa*, and *Passiflora maliformis* L (Nyanzi *et al.*, 2005).

Passion fruit seeds provide nutritional and health benefits including antioxidant protection, maintenance of healthy cardiovascular and intestinal systems (Mishra & Sushma, 2016). Passion fruit seeds are a good source of insoluble dietary fibre, which plays a role in reducing the risks of cardiovascular disease (CVD), colon cancer, obesity and chronic respiratory diseases (Angonese *et al.*, 2016). The pulp residue and seeds from passion fruit juice processing are largely used as an animal feed due to their potent source of nutrients such as proteins and carbohydrates (Fachinello *et al.*, 2016). On the other hand, passion fruit seeds have potential to provide nutritive and calorific values that are desirable in human diets. Passion fruit seeds have been reported to be rich in oil, which is similar in composition to the popular sunflower oil, and are a modest source of proteins (*ca.* 10%) (Malacrida & Jorge, 2012). Nutritionally, 100g passion fruit seed contain 275kcal energy, 64.29g carbohydrates, 1.79g proteins, 10.7g fibre, 107mg calcium, 0.64mg iron and 139mg

sodium. In addition, the seeds contain minerals including potassium (K), sodium (Na), iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), selenium (Se) and phytochemicals such as tocopherols, carotenoids, and phenolic compounds (Silva *et al.*, 2015).

Passion fruits are widely used in traditional medicine, food, pharmaceutical, and cosmetics industries (Correa *et al.*, 2016). They are consumed fresh and used for production of juice for domestic and regional markets. The juice is used in the production of cordials, alcoholic beverages, ice creams, confectionery and mixed fruit blends. The *Passiflora edulis* F. *flavicarpa* fruit yields heavier fruits and contains plenty of juice compared to *Passiflora edulis* Sims. However, *Passiflora edulis* Sims is more preferred for its flavour and aroma (Joy, 2010). The passion fruit juice industry uses only the passion fruit pulp and over 60% are the processing by-products comprising of rinds and seeds (Lousada *et al.*, 2006; Ramaiya *et al.*, 2019). These waste materials produced by fruit processing can be used as a source of phytochemicals and antioxidants, this will ultimately add value to the passion fruit (Joshi *et al.*, 2012). Passion fruit seeds can therefore play an important role in human nutrition and health (Oliveira *et al.*, 2016).

## **1.2 Problem statement**

In Uganda, there has been underutilization of processing by-products (waste) from passion fruits most especially the seeds. Moreover, majority of the consumers and fruit processing industries only utilize the passion fruit pulp, the rinds and the seeds are dumped as waste representing over 60% of the fruit (Silva *et al.*, 2015). The underutilisation could be due to consumers having limited knowledge of the nutritional importance of the passion fruit seeds that in turn limits potential for value addition. Therefore, studies that demonstrate presence of health promoting nutritive components in the passion fruit seeds would broaden knowledge about the value of these seeds

that are currently discarded as waste. Consequently, this will boost efforts to use passion fruit seeds as raw materials for production of novel food and cosmetic products. Therefore, the aim of this study was to determine the chemical composition of seeds from the major passion fruit species grown in Uganda.

### **1.3 Justification**

Cultivation of passion fruits has been mainly for their edible fruits, ornamental flowers, and pharmaceutical uses. The juice industry uses the passion fruit pulp and the remaining 60% comprising of the rinds and seeds is discarded as processing waste (Lousada *et al.*, 2006). Passion fruit seeds are edible, rich in oil (24 to 30%) and can provide nutrients in diets in terms of fibre, protein (10 to 13%), carbohydrate (60 to 71%), unsaturated fatty acids (85 to 88%), mineral content represented by crude ash (1 to 2%) and antioxidant vitamins (Silva *et al.*, 2015). These are health promoting substances and could therefore be used in formulation of food/feed supplements as well as in pharmaceutical and cosmetic applications (Malacrida & Jorge, 2012). The seed oil has physicochemical characteristics relatively similar to those of other edible seed oils such as sun flower, soybean (Kobori & Jorge, 2005; Lousada *et al.*, 2006). In spite of their nutritional value, majority of consumers and fruit processors in Uganda dispose-off the seeds as waste. Therefore, data on the chemical composition of passion fruits seeds will widen the knowledge on possible ways of adding value to the agro-industry waste giving it a better economic value.

## **1.4 Objectives of the study**

### **1.4.1 General objective**

To assess the chemical composition of seeds from the three major passion fruit species (*Passiflora edulis* Sim, *Passiflora eduli* F *flavicarpa* and *Passiflora maliformis*) grown in Uganda.

### **1.4.2 Specific objectives**

1. To determine the proximate composition (moisture content, crude ash, oil yield, crude fibre, proteins and carbohydrates) of seeds from *Passiflora edulis* Sim, *Passiflora eduli* F *flavicarpa* and *Passiflora maliformis* grown in Uganda.
2. To determine the mineral content (Na, K, Ca, Zn, Cu, Fe, Se, and Mn) of seeds from *Passiflora edulis* Sim, *Passiflora eduli* F *flavicarpa* and *Passiflora maliformis* grown in Uganda.
3. To determine the fatty acid composition of oil extracted from seeds of *Passiflora edulis* Sim, (*Passiflora eduli* F *flavicarpa* and *Passiflora maliformis* grown in Uganda.
4. To determine the oxidative stability (acid value, peroxide value, iodine value, saponification value and total carotenoid content) of oil extracted from seeds of *Passiflora edulis* Sim, *Passiflora eduli* F *flavicarpa* and *Passiflora maliformis* grown in Uganda.

## **1.5 Null Hypothesis**

1. There is no significant difference ( $p \leq 0.05$ ) in proximate composition of seeds obtained from *Passiflora edulis* Sim, *Passiflora eduli* F *flavicarpa* and *Passiflora maliformis* grown in Uganda.

2. There is no significant difference ( $p \leq 0.05$ ) in mineral content of seeds of *Passiflora edulis* Sim, *Passiflora eduli* F *flavicarpa* and *Passiflora maliformis* grown in Uganda.
3. There is no significant difference ( $p \leq 0.05$ ) in fatty acid composition of oil from seeds of *Passiflora edulis* Sim, *Passiflora eduli* F *flavicarpa* and *Passiflora maliformis* grown in Uganda.
4. Extracted oil from seeds of major passion fruit species grown in Uganda, does not differ in oxidative stability.

## CHAPTER 2: LITERATURE REVIEW

### 2.1 Taxonomy of the passion fruit

Passion fruit belongs to the Kingdom: Plantae; Class: Magnoliopsida; Order: Maipighiales; Family: Passifloraceae; Genus: *Passiflora*. The family *Passifloraceae* includes 550 species in 12 genera and is represented by more fruiting species than any other plant family (Kundan *et al.*, 2006). Currently, nearly 400 species of the genus *Passiflora* are known, most of which its origin has in the Tropical America, with 120 of them being native from Brazil and about 40 species in Asia, Australia and the South Pacific and one in Madagascar (Bernacci *et al.*, 2003; Kundan *et al.*, 2006). The most popular passion fruit cultivated for their edible fruits are; the purple passion fruit (*Passiflora edulis* Sims), the yellow passion fruit (*Passiflora edulis* forma *flavicarpa*), the giant granadilla (*Passiflora quadrangularis* L and the sweet calabash known as *Passiflora maliformis* L (Kundan *et al.*, 2006).

### 2.2 Description of passion fruits species

There are over 500 species of passion fruits but only 20 are edible to humans and are distinguished by different size, colour and taste. Of the twenty, the mainly grown species worldwide include the purple fruit (*Passiflora edulis* Sims), sweet granadilla (*Passiflora ligularis* Juss), banana passion fruit (*Passiflora molissima* Bailey), giant granadilla (*Passiflora quadrangularis* L) and sweet calabash (*Passiflora maliformis*) (Yockteng *et al.*, 2011). Of these species, *Passiflora edulis* has been extensively used commercially for its fruits (Joy, 2010), due to its distinctive aroma and flavour. *Passiflora edulis* has got two common varieties; the purple passion fruit (*P. edulis* Sims var. *edulis*) which is dark purple or nearly black egg rounded with diameter of 4 to 8 cm and 30 to 45 g weight when fully ripe and the yellow variety (*P. edulis* Sims var. *flavicarpa*) which is

spherical to oblong having a smooth tougher pericarp, deep yellow surface of length 6 to 12 cm, diameter 4 to 7 cm and weighing 60 to 150 g (Mishra & Sushma, 2016). Other species are also distinguished by different size, colour and taste and they include; the giant granadilla that produces the largest thick, yellowish green of fruit of length 26 cm, diameter 18 cm and weighing between 2.8 to 4 kg (Mishra & Sushma, 2016) with a wonderful aroma and flavor among other species within the genus (Fischer, 2018); the sweet calabash with a yellow to orange ripe fruit which is oval, 5 cm long, 3 cm wide and a toughest pericarp. The sweet calabash is mostly eaten fresh or used to flavor drinks (Kundan *et al.*, 2006).

In Uganda, the commonly grown varieties for commercial purposes include the purple passion fruit, the yellow passion fruit, the KPF4 (cross between the yellow and purple) and the sweet calabash passion fruit (*Passiflora maliformis* L) (Nyanzi *et al.*, 2005). The yellow passion fruit is high yielding and highly resistant to *Fusarium* wilt. The purple variety has a distinctive aroma and flavour although susceptible to *Fusarium* wilt (Ssekyewa *et al.*, 1999). For this reason, the KPF4 which is high yielding and resistant to *Fusarium* wilt was bred to bridge the gap (Katende *et al.*, 1995).



**Figure 1: Purple passion fruit (*Passiflora edulis* Sims)**



**Figure 2: Yellow passion fruit (*Passiflora edulis* F. *flavicarpa*)**



**Figure 3: Sweet calabash passion fruit (*Passiflora maliformis* L)**

### **2.3 Overview of Passion fruit production**

Brazil is the world's largest producer and consumer of fresh and processed yellow passion fruit, accounting for 50 to 65% of the total world production (Oliveira *et al.*, 2016). Globally, an estimated 1,468,800 MT of Passion fruits are produced per annum with Brazil being the largest producer (948,100 MT) then Africa (39,100 MT) (Altendorf, 2018). The purple and yellow passion

fruit are native to Brazil and commonly grown in tropical regions of the world (Chau & Huang, 2004).

For African countries like Kenya, small-scale farmers that use manual operations with limited irrigation system, dominate the production of passion fruits with the majority located in Kenya's rift valley, Nyanza, and Western provinces (John *et al.*, 2012). Uganda's popular districts known for production of passion are Masaka, Kasese, Kabale and Mbale and farmers cultivating a hectare can harvest 100 kg of passion fruits per week (Mukasa *et al.*, 2016).

**Table 1: Passion fruits producing regions and countries with average production in metric tonnes in (2015-2017)**

Regions and countries	Average production in metric tons in (2015-2017)
World	1,468,800
Asia	181,500
Africa	39,100
Central America & Caribbean	6,300
S. America	1,241,800
Indonesia	114,600
Thailand	10,000
Vietnam	20,000
Brazil	948,100
Malaysia	500
Pakistan	200
Philippines	400

Source: (Altendorf, 2018)

#### **2.4 Economic and nutritional importance of passion fruits**

Passion fruits are listed among the minor tropical fruits that are gaining importance globally due to their health benefits and also as a source of income accounting for 75% of entire income of a small rural farmer (Altendorf, 2018). The major economic importance of passion fruits in Uganda is juice production for both local consumers and industrial processors (Mukasa *et al.*, 2016).

Passion fruits are grown for eating fresh or their juice, which is sometimes added to other fruit juices to enhance aroma. The fruit can be eaten alone or in fruit salads, sherbets, ice cream, jams, cool drinks and as concentrates (Thokchom & Mandal, 2017). The sweet passion fruit juice is processed for specific applications for example as an ingredient in final products such as dairy drinks, yogurts, desserts among others (Marlene *et al.*, 2017).

#### **2.5 Health and nutritional benefits of passion fruits**

Plants are known to supply the needed nutrients important for human health, most affordable for African families (Liu *et al.*, 2008). The passion fruit provides a good source of nutrients such as protein; a rich source of amino acids in human diet, Vitamin A, B<sub>2</sub>, C, non-nutritive phytochemicals like carotenoids, polyphenols and minerals like Potassium (K), Sodium (Na) Calcium (Ca), Iron (Fe), Manganese (Mn), Selenium (Se) and Cupper (Cu) (Thokchom & Mandal, 2017). The minerals play a vital role in the human body for example K and Na are essential in regulating blood pressure, Calcium combined with Phosphorus form a relatively insoluble compound called calcium phosphate, which gives strength and rigidity to bones and teeth. Magnesium plays a prominent role in human health particularly in carbohydrate metabolism while Iron helps in formation of sufficient blood to prevent anemia thus important in pregnant mothers

and infants (Shiamala *et al.*, 2018). The passion fruit is highly acidic (pH~ 3.2) due to the predominance of two acids, citric and malic acid (Joy, 2010).

The passion fruit vine contains anti-inflammatory, anti-convulsant, anti-microbial, anticancer, anti-diabetic, antihypertensive, anti-sedative, antioxidant properties and various remedial measures for treating conditions like osteoarthritis, asthma and act as colon cleanser (Zas & John, 2016). The different parts of the plants have also been used for treatment of ulcers haemorrhoids, as sedatives, remedy for insomnia, digestive stimulant and remedy for gastric carcinoma (Thokchom & Mandal, 2017).

## **2.6 Utilization and health benefits of passion fruits seeds**

Passion fruit seeds represent 6 to 12 % of the fruit weight (Marlene *et al.*, 2017). Utilization of the seeds includes oil extraction and bioactive compounds (Jorge & Silva, 2014). The seed oil extracted has a high content of unsaturated fatty acids, especially linoleic acid that is applied in food, pharmaceutical and cosmetic industries (Oliveira *et al.*, 2016). The seeds of the passion fruit are edible and provide a little crunch when eaten with the fruit pulp or added to salads, sauces and as a topping of ice creams (Shiamala *et al.*, 2018). Also due to their oil content, the passion fruit seeds are used in manufacture of animal feeds (Zanetti *et al.*, 2017). The seed oil extracted by Soxhlet, has significant antioxidant activity and can serve as a source of natural antioxidants in foods, thus increasing the stability and quality of food products. This oil can also be successfully used, in the production of margarine, which is consumed without heat treatment and therefore less susceptible to oxidation (Silva *et al.*, 2015).

Passion fruit seeds are a good source of food fiber especially insoluble dietary fiber which reduces risks of cardiovascular disease, colon cancer and obesity (Shiamala *et al.*, 2018). Chau & Huang,

(2004) suggested that the passion fruit seed insoluble fibers can be an effective functional ingredient to promote intestinal function and health. According to (Chau *et al.*, 2005), some dietary fibers in passion fruit seeds decrease the digestion and absorption of carbohydrate and postprandial serum glucose levels.

Presence of several substances such as linoleic and oleic acids in oil from passion fruit seeds plays a vital role in human health that includes maintaining cardiovascular and mental health (Oliveira *et al.*, 2016). In addition, phenolic compounds such as resveratrol, piceatannol and scirpusin B present antioxidant activity that inhibits oxidative damage and may consequently prevent inflammatory conditions, neuro-degenerative diseases and delay ageing (Angonese *et al.*, 2016). Passion fruit seed extracts play an important role in reducing oxidation stress in the body tissues which increases the risk of developing diabetes mellitus (Kandandapani *et al.*, 2015). When incorporated in human food, the extracts not only preserve the quality of food, but also help reduce the risk of the development of non-communicable diseases such as arteriosclerosis and cancer (Silva *et al.*, 2015).

## **2.7 General composition of passion fruit seeds**

General composition of passion fruit seeds in terms of proximate composition, expresses the nutritive value of a specific food and corresponds to homogeneous groups of substances present in 100g of the considered food and these substances considered to be present in all foods include; moisture, lipid, protein, fibre, ash, and carbohydrates (Araujo *et al.*, 2018). Each of the substances has a role in determining the value of food in a diet for example; moisture affects the physical and chemical aspects of food (storage stability) hence determining the quality of the food (Regis *et al.*, 2015); lipids are source of energy and essential fatty acids that are necessary in biological

functioning of the body cells and their deficiency can lead to abnormalities in children and infants like decreased growth, poor vision, poor wound healing and nerve disorders (Chang *et al.*, 2009); ash content in food constitutes total mineral content that plays a prominent role in human health; protein is the major source of amino acids in a diet; carbohydrates are a major source of energy and roughages in food/ feeds (Ramaiya *et al.*, 2018) and insoluble fibre in a diet helps to remove cholesterol and protect the colon mucus membrane from cancer causing chemical attack by acting as a bulk laxative (Araujo *et al.*, 2018).

The passion fruit seeds are rich in lipids, insoluble dietary fibre, carbohydrates, minerals and proteins (Chau & Huang, 2004; Liu *et al.*, 2008). A study by Malacrida & Jorge (2012) and Chau & Huang (2004) on proximate composition of *Passiflora edulis flavicarp* (Yellow type) indicated (on dry-basis) moisture content of fresh seeds to be 7.45%, lipid content was 30.39%, dietary fiber was 64.8% and protein was 12.23%. This showed that passion fruit seeds are a good source of oil and have substantial amounts of dietary fiber (Jorge & Silva, 2014). (Ramaiya *et al.*, 2018) studied the proximate composition of seeds of *Passiflora Sims edulis*, *Passiflora quadrangularis*, *Passiflora maliformis*, plus other seeds. Fresh passion fruit seeds (on dry-basis) contained approximately 9 to 11% moisture, 1.32 to 2.35% ash content, 10.44 to 12.71% crude protein, 24.34 to 29.65% crude lipid, and 22.01 to 26.98% crude fibre.

Since the passion fruit seeds are rich in fibre, minerals and lipids, with good amount of proteins, it is possible to exploit them as alternative sources of nutrients for human consumption (Angonese *et al.*, 2016). The USDA National Nutrient database gives the nutritional value of 100 g passion fruit seeds as 23.38 g carbohydrates, 2.20 g protein, 0.70 g total fat and 10.4 g dietary fibre (Muriithi, 2014). *Passiflora edulis* has the highest ash content in the seed, which is followed by the outer coat and other parameters that are highest in seed (and followed by outer coat) include

protein, fat, fibre and carbohydrate (Adeyeye & Aremu, 2017). Table 2 summarises the proximate composition of passion fruit seeds reported by different scholars.

**Table 2: Proximate composition (g/100g on dry-basis) of different passion fruit seed species in different countries**

Country	Species	Crude				Crude ash	Reference
		Moisture	fat	Protein	Carb		
India	<i>P. edulis</i> Sims	46	15	13	70	15	1
	<i>P. edulis</i> flavicarpa	-	12.3	13.1	71.1	3.56	1
	<i>P. maliformis</i>						
Malaysia	<i>P. edulis</i> Sims	9	30	13	43	1	2
	<i>P. edulis</i> flavicarpa	11	26	11	35	2	2
	<i>P. maliformis</i>	9	24	10	33	2	2
Brazil	<i>P. edulis</i> Sims	-	-	-	-	-	
	<i>P. edulis</i> flavicarpa	7.4	30.4	12.2	48.7	1.3	3
	<i>P. maliformis</i>						
Brazil	<i>P. edulis</i>	6.0	27.5	13.1	56.6	1.4	4
Nigeria	<i>P. edulis</i>	11.5	1.2	-	77.6	2.3	5

<sup>1</sup> Reis *et al.* (2018), <sup>2</sup>Ramaiya *et al.* (2018), <sup>3</sup> Malacrida & Jorge, (2012), <sup>4</sup> Morais *et al.* (2017), <sup>5</sup>Adeyeye & Aremu. (2017)

## 2.8 Mineral content of passion fruit seeds

The human body requires minerals to maintain good health. These minerals include both trace and macro-mineral elements (Morais *et al.*, 2017). Metals Mn, Fe, Cu, Zn, and the non-metal Se are considered “trace elements” because of their essential role in very limited quantity whereas K, Na and Ca are considered as “macro-elements” because they are required in large quantities in human bodies and their deficiency leads to undesirable healthy conditions (Lakatos *et al.*, 2006; Prashanth *et al.*, 2015). Their dietary reference intakes are provided by Scientific Committee on food (2006), for guidance to prevent toxic effects (Fraga, 2005). The trend of mineral content

reported was not consistent within species, for instance *P. edulis* (Purple) the trend was K > Na > Ca > Mg > P > Fe > Zn > Cu whereas for *P. quadrangularis* was Na > K > Ca > P > Mg > Zn > Fe > Ca.

The mineral composition (on dry-basis) of passion fruit seeds reported by (Liu *et al.*, 2008) had high level of sodium (2.980 mg/g), followed by magnesium (1.540mg/g) and phosphorus (1.250mg/g). The content of potassium and calcium were 0.850 mg/g and 0.540mg/g, respectively. Other elements present in the seeds were iron, zinc, manganese and copper, their contents were 0.200 mg/g, 0.055 mg/g, 0.014mg/g and 0.013 mg/g, respectively. Recent studies conducted in different countries have documented the mineral content of passion fruit seeds as indicated in Table 3 below.

**Table 3: Mineral content (mg/100g on dry-basis) of different passion fruit seed species in different countries.**

Country	Species/varieties	Na	K	Zn	Fe	Se	Ca	Cu	Mn	Reference
India	<i>P. edulis</i> Sims	5	112	5	4	—	6	0.7	2.3	1
	<i>P. edulis</i> F <i>flavicarpa</i>	4	760	4	5	—	30	0.9	2.2	1
Nigeria	<i>P. edulis</i>	24.3	27.1	0.11	2.43	—	21	0.02	0.21	2
Brazil	<i>P. edulis</i> Sims	11.2	362.6	3.6	6.2	—	332.1	8	0.9	3
Malaysia	<i>P. edulis</i> Sims	241.7	352.5	0.05	0.1	—	1.73.1	1.4	—	4
	<i>P. maliformis</i> L	241.7	210.4	0.1	0.04	—	174.2	2.4	—	4
China	Tainung No 1	298	85	5.5	20	—	54	1.3	1.4	5

<sup>1</sup>Reis *et al.* (2018), <sup>2</sup>Adeyeye & Aremu. (2017), <sup>3</sup>Morais *et al.* (2017), <sup>4</sup>Ramaiya *et al.* (2018), <sup>5</sup>Liu *et al.* (2008)

## 2.9 Fatty acid profile of oil from passion fruit seeds

Fatty acids are carboxylic acids with a long aliphatic chain, which is either saturated or unsaturated. Most naturally occurring fatty acids have unbranched chains of even number of carbon atoms, from 4 to 28 (Rana & Blazquez, 2008). There are three main classes of esters: triglycerides, phospholipids, and cholesterol esters (FAO, 2008). In any of these forms, fatty acids are both important dietary sources of energy for animals and they are important structural components of cells (Moss & Vaughan, 1995). In the study conducted by (Rana & Blazquez, 2008), the fatty acids and other components of passion fruit (*Passiflora edulis*) seed oil was determined by analysing their methyl esters using gas chromatography - mass spectrometry (GC-MS). The seed oil contains high amount of linoleic acid (74.3%), oleic acid (13.6%), palmitic acid (8.8%) and stearic acid (2.2%) as the main fatty acids (Nyanzi *et al.*, 2005). Passion fruit seeds are known to contain low levels (14%) of saturated fatty acids but high in unsaturated fatty acids with levels of approximately 85.7% (Ramaiya *et al.*, 2019). The high amount of unsaturated fatty acids is mostly contributed by linoleic acid. The seed oil has been found to be mainly composed of linoleic acid (67.8%) (Piombo *et al.*, 2006). This essential fatty acid helps in preventing cardiovascular disorders such as coronary heart diseases, atherosclerosis and high blood pressure. Linoleic acid derivatives serve as structural components of the plasma membrane and as precursors of some metabolic regulatory compounds (Waisundara & Blumenberg, 2018).

Passion fruit seeds contain up to 30% lipids implying they are a good source of oil compared to other oil seeds such as soybean, which contains about 20% oil (Malacrida & Jorge, 2012). Zanetti *et al.* (2017) used passion fruit seeds in the diets for broilers and detected 24.5% of seed lipids to be present in the broiler meat implying they are essential lipids.

Passion fruit seed oil is high in unsaturated fatty acids, which indicates that it has potential for use in both human food and animal feed as well as in the cosmetic industry (Ramaiya *et al.*, 2019). Table 4 shows the fatty acid profile of oil from passion fruit seeds in different countries.

**Table 4: Fatty acid composition (%) of oil from seeds of different passion fruit species in different countries**

Country	Species/varieties	C14	C16	C16:1	C18:0	C18:1	C18:2	C18:3	C20:0	C22:0	Unsat	References
		Myristic	Palmitic	Palmitoleic	Stearic	Oleic	Linoleic	Linolenic	Araquidic	Behenic		
Pakistan	<i>P. edulis</i> Sims	0.12	10.5	0.23	3.13	14.5	70.4	0.57	0.23	0.12	85.7	1
	<i>P. edulis</i> F.	0.03	8.6	0.23	1.7	16.3	72.7	0.3			89.43	
	<i>Flavicarpa</i>											2
	<i>P. maliformis</i> L	0.14	9.7	0.23	2.4	14.1	68.41	0.4	0.12	0.13	83.13	2
Uganda	<i>P. edulis</i> Sims	—	8.8	—	2.2	13.6	74.3	0.4	—	—	88.6	3
	<i>P. edulis</i> F.	—	11	—	3.1	16.9	67.8	0.4	—	—	85.4	
	<i>Flavicarpa</i>											3
	<i>P. maliformis</i> L	—	9.2	—	2.3	15.3	71.9	0.3	—	—	87.9	3
France	<i>P. edulis</i> Sims	—	0.5	—	2.8	14.6	67.8	0.6	0.25	—	85.7	4
	<i>P. edulis</i> F.	—	9.7	0.11	2.6	13.8	73.14	0.41	0.10	—	87.6	
Brazil	<i>Flavicarpa</i>											5

<sup>1</sup>Ramaiya *et al.* (2019), <sup>2</sup>Malacrida & Jorge (2012), <sup>3</sup>Nyanzi *et al.* (2005), <sup>4</sup>Piombo *et al.* (2006), <sup>5</sup>Malacrida & Jorge (2012)

Several studies have been conducted to profile the fatty acid content in various *Passiflora* species. However, of the estimated 500 species of *Passiflora*, *Passiflora maliformis* seems to be having the least amount of literature on the profiling of fatty acids found in the seeds. Therefore, this study intends to explore and profile the fatty acid content of the *Passiflora maliformis* seeds in addition to some other common varieties produced in Uganda.

### **2.10 Stability of passion fruit seed oil**

Oxidative stability of oil is defined as its resistance to autoxidation during processing and storage which determines its shelf life (Shahidi & Zhong, 2010). This oxidation is influenced by exposure to air, antioxidants and the fatty acid composition of the oils (Naz *et al.*, 2014). The indicator parameters for oxidative stability of oil include its chemical characteristics and these are; acid value (AV), peroxide value (PV), and iodine value (IV) and saponification value (SV) (Liu *et al.*, 2008). Acid value indicates the level of rancidity of the oil. Recommendation of the acid value of oil by FAO is ( $\leq 0.6$  mgKOH/g) (Ramaiya *et al.*, 2019). Peroxide value (meqO<sub>2</sub>/kg oil) gives an indication of the primary oxidation state of the oil and is a measure of active oxygen content (Ramaiya *et al.*, 2019). The peroxide value given by CODEX standard of edible seed oil and other seed oils is  $\leq 10.0$  meqK/g. The peroxide value is also related to the development of hydrolytic and oxidative reaction (Malacrida & Jorge, 2012). Iodine value is related to the amount of unsaturation present in the oil (Silva *et al.*, 2015). Iodine value and Oleic acid (C18:1) to Linoleic acid (C18:2) ratio are used as a reliable criteria for stability of oils to oxidation and oil flavours (Nyanzi *et al.*, 2005). Oils with a higher iodine value usually possess a higher polyunsaturated fatty acid (Cuong *et al.*, 2019). Saponification value is the measure of the free and esterified acid present in the oil (Ramaiya *et al.*, 2019). The saponification value for most of the edible oil falls

within a range of 180 to 200 mgKOH/g. WHO stipulated allowable range of saponification value that is 188 to 194 mgKOH/g.

**Table 5: Stability tests for oil from seeds from the passion fruit species in different countries.**

Country	Variety	AV	PV	IV	SV	Reference
Pakistan	<i>P. edulis</i> Sims	2.64	1.43	129.33	194.67	1
	<i>P. edulis</i> F <i>flavicarpa</i>	2.11	2.23	119.9	176	1
	<i>P. maliformis</i> L	2.47	2.14	131	192.67	1
Vietnam	<i>Passiflora edulis</i>	2.16	3.6	125.77	174.96	2
Brazil	<i>P. edulis</i> Sims	0.75	0	132.33	192.84	3
	<i>P. edulis</i> F <i>flavicarpa</i>	1.63	1.54	109.48	173.95	4
China	<i>Tainung No 1'</i>	2.11	2.23	119.9	176	5

<sup>1</sup>Ramaiya *et al.*, (2019). <sup>2</sup>Dao Cuong. (2019) <sup>3</sup>Regil *et al.*, (2015) <sup>4</sup>Silva *et al.* (2015), <sup>5</sup>Liu *et al.* (2008)

## 2.11 Carotenoids

Passion seed oils contains bioactive compounds, such as tocopherols, phytosterols, carotenoids, and phenolic compounds, that are known for protecting PUFA against lipid oxidation (Fernanda *et al.*, 2015). The *Passiflora* fruit seed oil possess carotenoids that are precursors of vitamin A. Carotenoids are converted to vitamin A as the body needs, with varying degrees of conversion efficiency (Mezzomo & Ferreira, 2016). Fernanda *et al.*, (2015) analyzed the carotenoid content of *passiflora* seed oils of different sample and obtained range between 50.87 to 115.44 mg  $\beta$ -carotene/100g of oil. Furthermore, Silva & Jorge, (2014) observed that the seed oil from *Passiflora edulis* resulted in a carotenoid content of 0.67 mg/100 g.

### **2.12 Anti-nutrition factor in passion fruit seeds**

Anti-nutrition factors are chemicals synthesized by the plants and interfere with absorption of nutrients when consumed in appropriate amounts by humans (Wasagu *et al.*, 2016). The anti-nutrition factors imbedded in passion fruit seeds include tannins, saponin glycosides, phytates, oxalates, steroids and cyanides (Gemedede & Ratta, 2014). Phytate works in a broad pH-region as negatively charged ion, and therefore its presence in the diet has a negative impact on the bio-availability of divalent, and trivalent mineral ions such as  $Zn^{2+}$ ,  $Fe^{2+/3+}$ ,  $Ca^{2+}$ ,  $Mg^{2+}$ ,  $Mn^{2+}$  and  $Cu^{2+}$  (Gemedede & Ratta, 2014). Dietary oxalate has been known to complex with calcium, magnesium and iron leading to the formation of insoluble oxalate salts and resulting in oxalate stones (Wasagu *et al.*, 2016). Hydrogen cyanide inactivates the enzyme cytochrome oxidase and interferes with normal use of oxygen by nearly every body organ (Gemedede & Ratta, 2014). Presence of tannins in food products inhibit the activities of trypsin, chymotrypsin, amylase and lipase, decrease the protein quality of foods and interfere with dietary iron absorption, however the above anti-nutrients were found to be low in passion fruit seeds (Wasagu *et al.*, 2016).

## CHAPTER 3: MATERIALS AND METHODS

### 3.1 Materials

All chemicals and standards were of analytical grade purchased from LabX Scientific Ltd. The fully ripe passion fruits *Passiflora edulis Sims* - purple type, *Passiflora edulis F. flavicarpa* - yellow type and *Passiflora maliformis L* - sweet calabash) were sourced from National Crops Resources Research Institute (NaCRRI), Namulonge from where they were transported to the Chemistry laboratory at Uganda Industrial Research Institute (UIRI).

### 3.2 Sample preparation

The sample was prepared according to method described by (Araujo *et al.*, 2018). Ripe passion fruits (2 kg) were washed with clean tap water and sliced into two sections each to extract the pulp using a stainless-steel knife. Juice extraction was done using a sieve to separate the seeds from other rinds. Seeds were dried in an air oven at 45°C for 48 hours and cooled, this being the time needed for the samples to reach constant weight. The dried passion fruit seeds were thereafter milled into flour using mortar grinder RM 200, Retsch-US, the flour packed in an air tight sampling bag and stored in a cool dry place at room temperature (25°C) until analysis.

### 3.3 Methods

#### 3.3.1 Determination of moisture

Moisture content was determined using gravimetric method according to official methods of analysis of (AOAC, 2012). A previously conditioned metal dish at 103°C and cooled in a desiccator was weighed and its mass recorded as  $A_0$ . Well-mixed test portion of 5 g was added, and recorded as  $A_1$ . The dishes with samples were transferred into the oven and left for 3 hours set

at 105°C. The dishes were covered while still in the oven, transferred to the desiccator and weighed soon after attaining room temperature. The final weight of the dry sample into metal dish was recorded as  $A_2$ . The difference in weights was reported as moisture content of the passion fruit seed sample expressed as a percentage using the following formula. Analysis was conducted in triplicate.

$$\% \text{ Moisture} = (A_0 + A_1) - A_2 / \text{Sample weight} \times 100$$

### **3.3.2 Determination of oil yield**

Crude oil was determined using the Soxhlet method according to official methods of analysis of AOAC International (AOAC, 2012). A 5 g sample was weighed in a clean extraction thimble and inserted into the extraction column of the Soxhlet apparatus. An extraction flask was oven dried for 1 hour at 103°C and cooled in a desiccator before taking its initial weight ( $W_1$ ). Petroleum ether (50 ml) was used in the apparatus set at 60°C for 6 hours with the condenser connected. At the end of the extraction process, solvent was recovered using a rotary evaporator. The flask with the lipid extracted were transferred to the oven for 1 hour at 90°C to evaporate off the residual solvent and left to cool in a desiccator. The final weight of oil and flask was weighed and recorded as  $W_2$ . The difference in weight of the empty flask and weight of flask and sample ( $W_2 - W_1$ ) were reported as the crude lipid content of the sample expressed as a percentage using the following formula:

$$\% \text{ Crude lipid} = (W_2 - W_1) / \text{sample weight} \times 100$$

### **3.3.3 Determination of crude protein**

Protein content was determined using the Kjeldahl method as described by official methods of analysis of AOAC international (2012). The sample (2 g) was weighed into a digestion flask to

which a tablet of 0.5 g of copper II sulphate was added followed by 15 ml of concentrated  $H_2SO_4$  and mixed thoroughly. The digestion flask was heated at  $370^\circ C$  for 8 hours until the solution turned light green. The digested sample was cooled, diluted with 50 ml distilled water and transferred into a 250 ml conical flask. Excess 40% sodium hydroxide solution (15 ml) and 2 drops of mixed indicator (methylene red and methyl blue) were added before the next step. The digestion flask was heated and the liberated ammonia condensed and collected in 2% boric acid in a collection flask. The distillate was titrated with standardized 0.1N sulphuric acid to the end point and the crude protein calculated by multiplying the percentage total nitrogen with a correction factor of 6.25.

#### **3.3.4 Determination of crude ash**

Total ash was determined by dry ashing method of official methods of analysis of AOAC international (2012). A dry clean porcelain crucible was weighed and its mass recorded ( $M_1$ ). A 2 g sample was weighed into the crucible. Using a pair of tongs, the crucible containing the sample was transferred into a muffle furnace and incinerated for 3 hours at  $550^\circ C$  until ash was obtained. The crucible was cooled in a desiccator for 30 min and final weight of the sample and crucible after ashing ( $M_2$ ) were recorded. The difference in mass of empty crucible and mass of crucible plus sample after ashing ( $M_2 - M_1$ ) is expressed as a percentage and reported as total ash content of the sample.

#### **3.3.5 Determination of crude fibre**

Crude fibre was determined by fibre tech method described by official methods of analysis of AOAC international (AOAC, 2000). A clean dry crucible was weighed and its mass recorded. A sample of 2g was weighed into a pre-weighed Erlenmeyer flask and fixed into the digestion

Whatman No. 1 filter paper into a 100 ml volumetric flask and made up to mark with distilled water. The instrument was calibrated with standards (for Mn: 0.5 ppm, 1.5 ppm, 3.0 ppm, 4.5 ppm; for Ca: 5 ppm, 15 ppm, 30 ppm; for K: 2, 6, 10 ppm; and for Na: 2, 4, 6, 10 ppm). The sample was analyzed with AAS at corresponding wavelengths. The required hollow cathode lamp corresponding to the required mineral and holder in the lamp compartment was installed to determine the concentration of each mineral.

**Value (mg/1000g) =  $\frac{\text{Conc.} \times \text{DF} \times \text{Vol. of sample made-up (ml)}}{\text{Weight of sample (g)}}$**

Weight of sample (g)

Where; Conc. = Concentration, DF = Dilution Factor, Vol. = Volume

### **3.3.8 Determination of fatty acid composition of the seed oil**

Fatty acid composition was determined by preparation of fatty acid methyl esters as described by official methods of analysis of AOAC international (2000) and identification was performed by gas chromatography – flame ionization detection (GC-FID). Oil extraction was achieved by solvent extraction using petroleum ether at 60°C by soxhlet method as described in 3.3.2. According to ISO 5509:2000 trans-esterification method, the fatty acids were determined by their FAME using Varian GC-FID with the following settings; injector temperature of 250°C, oven temperature of 50°C to 220°C, hydrogen as a carrier gas at 30 ml/min flow-rate and GC Restek column with the length of 100 m, inner-diameter of 0.25 µm, film thickness of 0.20 µm. Fatty acid profiling was established by comparison of the relative retention times of fatty acid methyl ester peaks (standards) and those obtained from the samples.

### 3.3.9 Stability tests for extracted seed oil

#### 3.3.9.1 Acid value

The oil sample of 10 g was weighed into a clean flask in replicates. A hot neutralised 95% ethanol was used to dissolve the sample. Standardised solution of 0.1N Potassium Hydroxide was used in a titration with 5 drops of phenolphthalein indicator until an endpoint (pink color) was obtained.

Calculation:

**Acid Value (AV)**, (mg KOH/g) =  $(56.1 \times N \times V)/m$ ,

Where; N = molarity in moles per litre of KOH, V= Final volume of KOH used, m = mass of the sample

#### 3.3.9.2 Peroxide value

Oil was weighed (5 g) into a clean flask and dissolved in 30ml of a solvent (mixture of glacial acetic acid (3): chloroform (2)). 0.50 ml of saturated Potassium iodide was added, stirred and then let to stand for one minute. To stop the reaction, 50ml of distilled water were added and the mixture titrated with 0.1N sodium thiosulphate solution using 1.0 ml of starch indicator to colourless solution.

Calculation:

**Peroxide Value (PV)**, (mill equivalents oxygen/kg) =  $[(S-B) \times N \times 1000]/m$ ,

Where; N = molarity moles/litre of  $\text{Na}_2\text{S}_2\text{O}_3$ , S = the volume of  $\text{Na}_2\text{S}_2\text{O}_3$  used with the sample,

B = the volume of  $\text{Na}_2\text{S}_2\text{O}_3$  used with the blank, m = mass of the sample.

### 3.3.9.3 Iodine value

Oil was weighed (0.5 g) and dissolved in 20 ml of Wij's solution. The mixture was kept in dark for 30 min and then 15 ml of 10% KI solution and 100ml of distilled water were added. Using 0.10N sodium thiosulphate solution and 1.0 ml of starch indicator, the mixture was titrated till endpoint (colourless solution). Blank test was performed.

Calculation:

$$\text{Iodine Value (IV), (g/100g)} = [12.69N (B-S)]/m,$$

Where; N = molarity in moles/litre of  $\text{Na}_2\text{S}_2\text{O}_3$ , S = the volume of  $\text{Na}_2\text{S}_2\text{O}_3$  used with the sample, B = the volume of  $\text{Na}_2\text{S}_2\text{O}_3$  used with the blank.

### 3.3.9.4 Saponification value

The sample mass of 1 g was weighed into a 200 mL conical flask. Added 25.0 mL of 0.5N ethanolic potassium hydroxide. Gently heated the flask under reflux while occasionally shaking. After 30 min of heating the contents were immediately cooled and titrated with 0.5N HCl before the test liquid solidified using 5 drops of phenolphthalein indicator. A blank test was performed for 3 times to obtain mean value of titration volume of 0.5 mol/L hydrochloric acid.

$$\text{Saponification Value (SV) mg KOH/g} = 56.1 (B-S) N/ W,$$

Where, B = Volume in ml of standard hydrochloric acid required for the blank, S = Volume in ml of standard hydrochloric acid required for the sample, N = Normality of the standard hydrochloric acid and W = Weight of the oil taken for the test.

### 3.3.9.5 Determination of concentration of total carotenoids

Total carotenoids content expressed in terms of  $\beta$ -carotene was determined by UV Spectrophotometer (UV-1800 Shimadzu, Germany) according to the method described by (Ranjith *et al.*, 2006). The sample (1g) was weighed and dissolved in 10 ml of hexane. After addition of 0.5 ml of 0.5% NaCl, the vial was tightly sealed and vortexed for 30 sec to extract the carotenoids. Then the mixture centrifuged at 1500 rpm for 10 min. The supernatant was carefully collected into a clean volumetric flask and diluted. The calibration curve from the standards was used to obtain absorbance (A) of the samples read at 460 nm in UV-spectrophotometer.

$$\text{Total Carotenoid content } (\beta\text{-CE mg/100 g}) = \frac{\text{Abs} \times \text{vol. of sample extracted} \times 10^6}{100 \times \text{weight of sample} \times E}$$

Where E- Extinction coefficient for  $\beta$ -carotene

### 3.7 Statistical Analysis of data

The statistical software of SPSS was used for analyzing the data and the results were reported as mean  $\pm$  Standard deviation, significant differences in the nutritional content of the three passion fruit species were determined using one-way analysis of variance (ANOVA) and Duncan's test at  $p \leq 0.05$  among means.

## CHAPTER 4: RESULTS AND DISCUSSION

### 4.1 Proximate composition of seeds from passion fruit species grown in Uganda

#### 4.1.1. Moisture content of dry seeds

In Table 6, the moisture content of *Passiflora edulis* seeds ranged from 2.59 to 3.36% among all the varieties. Moisture content (2.59%) of *Passiflora maliformis* L was significantly ( $p < 0.05$ ) different from that of *Passiflora edulis* Sims (3.22%) and *Passiflora edulis flavicarpa* (3.36%). Moisture content of *Passiflora edulis flavicarpa* had the highest value (3.36%) whereas *Passiflora maliformis* L had the lowest value (2.59%) amongst the varieties. Studies show that moisture content of passion fruit seeds range from 9.18 to 11.09% (Ramaiya *et al.*, 2018) which is higher than the obtained results. Additionally, (Silva *et al.*, 2015) obtained 7.45% moisture content for *Passiflora edulis flavicarpa* that is also higher than results obtained in this study. Increased moisture content in seeds favours the action of enzyme lipase hydrolysing triglycerides reducing the oil quality. The variation in results was because the moisture content in this study was conducted using dried passion fruit seeds.

#### 4.1.2 Ash content

Crude ash content ranged from 1.36 to 2.32% as shown in table 6. Crude ash content of *Passiflora edulis* Sims and *Passiflora edulis flavicarpa* was 1.36% and 1.58% respectively with no significant difference. The two values were significantly different ( $p < 0.05$ ) from 2.32% obtained for *Passiflora maliformis* L. Ash content was lowest in *Passiflora edulis* Sims L and highest in the *Passiflora maliformis* (2.32±0.01%). Results in this study were comparable to those obtained by (Ramaiya *et al.*, 2018) which reported ash content of passion fruit seeds ranging between 1.35 and 2.35%. Similarly, (Silva *et al.*, 2015) obtained ash content of 2.05% in *Passiflora edulis flavicarpa*

seeds which is closely related to values in this study. Crude ash represents total amount of minerals present within the food material (Afify *et al.*, 2017), therefore seeds of *Passiflora maliformis* that have a higher ash content constitute a higher mineral content such as potassium, Iron, calcium and Selenium thus indicating a potential mineral source.

**Table 6: Proximate composition (g/100g on dry-basis) of seeds from passion fruit species grown in Uganda dry weight basis)**

Seeds	<i>Passiflora edulis</i> Sims	<i>Passiflora edulis flavicarpa</i>	<i>Passiflora maliformis</i>
Moisture	3.22±0.21 <sup>a</sup>	3.36±0.04 <sup>a</sup>	2.59±0.05 <sup>b</sup>
Crude Ash	1.36±0.10 <sup>a</sup>	1.58±0.15 <sup>a</sup>	2.32±0.01 <sup>b</sup>
Oil yield	24.70±0.29 <sup>c</sup>	29.37±0.29 <sup>b</sup>	37.24±0.09 <sup>a</sup>
Protein	11.72±0.06 <sup>a</sup>	10.74±0.06 <sup>a</sup>	10.68±0.96 <sup>a</sup>
Crude Fibre	36.28± 0.50 <sup>a</sup>	31.56± 0.43 <sup>b</sup>	31.95 ±1.03 <sup>b</sup>
Carbohydrates	22.53± 0.83 <sup>a</sup>	22.85± 0.03 <sup>a</sup>	16.19± 1.71 <sup>b</sup>

Values in rows followed by the same superscript letter are not significantly different at  $p \leq 0.05$

#### 4.1.3 Oil yield

The oil yield of the passion fruit seeds ranged from 24.70 to 37.24% with significant differences ( $p \leq 0.05$ ) among the varieties as reported in table 6. *Passiflora maliformis* L had the highest oil yield of 37.24% and *Passiflora edulis* Sims the lowest of 24.70%. According to a study conducted by (Nyanzi *et al.*, 2005), the highest oil yield was obtained from *Passiflora maliformis* L with value of 28.3% which is in agreement with this study. (Jorge & Silva, 2014) reported 24% of oil

yield from *Passiflora edulis flavicarpa* which is found to be in the same range as the values obtained in this study. (Reis *et al.*, 2020) reported a similar values of oil yield (i.e., 21 and 29% for *Passiflora edulis flavicarpa* and *Passiflora edulis* Sims seeds respectively). This oil yield in passion fruit seeds was higher compared to soybean seed which was found to contain 20% lipids, making the seeds a good source of oil (Malacrida & Jorge, 2012). The differences in oil yield can be attributed to variety, climate or geographical differences in the growing area (Nyanzi *et al.*, 2005) since the values are from different independent studies.

#### **4.1.4 Protein content**

The content of protein in the seeds ranged from 10.68 to 11.72% (Table 6). Protein content was not significantly different ( $p \leq 0.05$ ) among passion fruit seed varieties. Similarly, (Ramaiya *et al.*, 2018) obtained protein content of 12.71% in the passion fruit seeds. The protein content obtained in this study agrees well with 10.80% reported by (Liu *et al.*, 2008). The protein content of passion fruit seeds obtained in this study is comparable to that found in some common cereal grains used in food formulation such as corn (10.2%), oats (11.3%) and wheat (12.2%) (Malacrida & Jorge, 2012). Therefore, the passion fruit seeds can be utilised in food/feed formulation.

#### **4.1.5 Crude fibre content**

Crude fibre ranged from 31.56 to 36.28% in all varieties (Table 6). Crude fibre content of *Passiflora edulis* Sims (36.28%) was significantly different ( $p \leq 0.05$ ) from 31.56% for *Passiflora edulis flavicarpa* and 31.95% for *Passiflora maliformis* L. The *Passiflora edulis* Sims had the highest value (36.28%) amongst all varieties. Values obtained in this study were higher than 17.48% and 6.16% obtained by (Liu *et al.*, 2008) and (Adeyeye & Aremu, 2017) respectively. The crude fibre content was relatively higher than what has been reported in grains like maize (1.04%)

and oats (9.10%) which are commonly used as a source of dietary fibre (Padovani *et al.*, 2007). Fibre in a diet is very vital in assisting the digestion process, removal of cholesterol from the body, reduction of carbohydrate absorption and providing support in control of diabetes mellitus (Araujo *et al.*, 2018). Insoluble dietary fibre acts as a laxative that shields the colon membrane from binding with cancer causing chemicals/toxins (Adeyeye & Aremu, 2017). Since, the daily recommended intake of dietary fibre is between 20 to 38g/day for adults (Jones, 2004), passion fruit seeds can be used as a potential source of dietary fibre.

#### **4.1.6 Carbohydrate content**

The amount of carbohydrates in the seeds ranged from 16.19 to 22.85%. Carbohydrate content in *Passiflora maliformis* L (16.19%) was significantly lower than that of *Passiflora edulis* Sims at 22.53% and *Passiflora edulis flavicarpa* at 22.85%. Results obtained from this study were lower than 36.06% and 77.6% reported by (Liu *et al.*, 2008) and (Adeyeye & Aremu, 2017) respectively. However, carbohydrate content (1.11%) of seeds obtained by (Chau & Huang, 2004) was lower because the sample that was used is free from digestible starch unlike in this study. The carbohydrate content in *Passiflora edulis* seeds was relatively higher than the content in maize (18.59%) which is commonly used in feed formulation (Padovani *et al.*, 2007) indicating that it is possible to use these seeds as a source of roughages and energy in feeds.

#### **4.2 Mineral content (mg/100g) of seeds from passion fruit species grown in Uganda.**

Minerals are important in maintaining the overall well-being of the body. Major minerals (K, Na and Ca) and trace elements (Cu, Fe, Mn, Zn and Se) are essential in human nutrition but become toxic at increased concentration. K and Na play vital role in amino acid synthesis and body fluid balancing thus maintaining good health. The results for the mineral element composition of

passion fruit seeds are presented in Table 7. Generally, Potassium was the most prevalent mineral compared to other minerals analysed in this study, ranging from 4.77 mg/100g to 9.52 mg/100g. Potassium concentrations were significantly different ( $p \leq 0.05$ ) among passion fruit species. *Passiflora maliformis L* had the highest concentration (9.52 mg/100g) whereas *Passiflora edulis Sims* showed the lowest concentration (4.77 mg/100g). The concentrations of K obtained in this study were lower than those obtained by Reis *et al.* (2018) (306.8 mg/100g to 353 mg/100g).

Sodium (Na) was the least prevalent mineral amongst all minerals analysed, ranging from 0.15 to 0.19mg/100g with no significant differences among the seeds. (Ramaiya *et al.*, 2018) reported higher concentrations of sodium ranging from 210 to 290mg/100g and 24mg/100g, respectively compared to that obtained in this study. These variations might be attributed either to species, environmental factors and locational effects (Araujo *et al.*, 2018).

Calcium concentration obtained from this research study ranged from 1.45 to 2.01mg/100g with *Passiflora edulis flavicarpa* showing the lowest concentration whereas *Passiflora maliformis L* has the highest (2.01mg/100g) among the three varieties. (Liu *et al.*, 2008) and (Adeyeye & Aremu, 2017) found higher Ca concentrations of 54mg/100g and 21.0mg/100g respectively, compared to concentrations reported in this study. Calcium (2+) is necessary in bone formation and strength.

**Table 7: Mineral composition (mg/100g on dry-basis) of seeds from passion fruit species grown in Uganda**

Variety	<i>Passiflora edulis Sims</i>	<i>Passiflora edulis f flavicarpa</i>	<i>Passiflora maliformis</i>
Potassium (K)	4.77±0.000 <sup>c</sup>	5.25±0.000 <sup>b</sup>	9.52±0.000 <sup>a</sup>
Sodium (Na)	0.15±0.000 <sup>a</sup>	0.19±0.000 <sup>a</sup>	0.17±0.000 <sup>a</sup>
Calcium (Ca)	1.78±0.033 <sup>b</sup>	1.45±0.035 <sup>c</sup>	2.01±0.033 <sup>a</sup>
Zinc (Zn)	1.57±0.005 <sup>b</sup>	6.71±0.008 <sup>a</sup>	1.19±0.007 <sup>c</sup>
Copper (Cu)	1.34±0.006 <sup>c</sup>	1.49±0.007 <sup>b</sup>	1.97±0.001 <sup>a</sup>
Iron (Fe)	2.32±0.008 <sup>c</sup>	5.57±0.016 <sup>b</sup>	5.98±0.002 <sup>a</sup>
Selenium (Se)	0.20±0.011 <sup>c</sup>	1.09±0.014 <sup>b</sup>	2.09±0.013 <sup>a</sup>
Manganese (Mn)	0.77±0.008 <sup>c</sup>	1.82±0.001 <sup>a</sup>	1.21±0.005 <sup>b</sup>

Values in each row followed by the same superscript letter are not significantly different at  $p \leq 0.05$ .

From table.7, zinc content was significantly higher in *Passiflora edulis flavicarpa* (6.71 mg/100g) than *Passiflora maliformis* (1.19 mg/100g) and *Passiflora edulis Sims*. The range (4 to 5 mg/100g) of Zinc content reported by (Reis *et al.*, 2020) is relatively similar to what was obtained this study. *Passiflora maliformis L* had the highest amount (1.97mg/100g) of Copper whereas *Passiflora edulis Sims* had the lowest (1.34 mg/100g). The lowest value of copper obtained from the research is similar to the value of 1.3mg/100g obtained by (Liu *et al.*, 2008). Zn, Cu, Mn and Se mediate vital biochemical reactions by acting as cofactors for many enzymes, as well as act as centres for stabilizing structures of enzymes and proteins.

Iron content was highest in *Passiflora maliformis* L (5.98 mg/100g) and lowest in *Passiflora edulis* Sims (2.32 mg/100g). According to Scientific committee on food, (2006) the daily recommended intake of Fe for adults is 8 to 10 mg/day. One needs just approximately 200g of passion fruit seeds in the diet to meet this requirement. Iron is very important in formation of red blood cells and a vital trace-element in the diet of pregnant women, and infants (Prashanth *et al.*, 2015). Iron is required for energy and endurance because it delivers oxygen throughout the body. Selenium content was significantly higher in *Passiflora maliformis* L with a value of 2.09 mg/100g and lowest in *Passiflora edulis* Sims (0.20 mg/100g). Manganese content significantly differed in all varieties and *Passiflora edulis* Sims had the lowest value of 0.77mg/100g. (Adeyeye & Aremu, 2017) found a lower content of manganese (0.21mg/100g) in *Passiflora edulis* seeds than the content presented herein.

#### **4.3 Fatty acid composition of the oil from seeds of passion fruits grown in Uganda.**

*Passiflora* spp (*P. edulis* Sims, *P. maliformis* L and *P. edulis flavicarpa*) had 14 different FA detected and quantified of which seven were saturated and seven unsaturated. The most predominant FA were Oleic and Linoleic (unsaturated FA) and myristic, palmitic & stearic (saturated FA). In all the three species, Linoleic acid (C18:2) was the most prevalent FA ranging from 67.57 to 72.18%. This was followed by Oleic acid (C18:1) in the range from 14.59 to 16.14%. Others included palmitic, stearic and myristic acids in the ranges from 8.68 to 11.18%, 2.78 to 3.16% and 0.60 to 0.80% respectively. The less prevalent FA included; palmitoleic acid (C16:1), heptadecanoic acid (C17:0), arachidic acid (C20:0), oicosenoic acid (C20:1), heneicosanoic acid (C20:3), benenic acid (C21:0), eicosatrienoic acid (C22:0) and docosadienoic acid (C22:2). Then octadecenoic acid (C18:1trans) and heneicosanoic acid (C20:3) were below detection limit <0.05% in *Passiflora edulis sims* variety but detectable in other remaining varieties as shown in the table

8. The passion fruit seeds contained essential omega 6 Fatty acids (Linoleic acids) whose percentage was the highest among all FA in all the oil analysed. Previous studies conducted by (Liu *et al.*, 2008; Malacrida & Jorge, 2012; Nyanzi *et al.*, 2005), are in agreement with results obtained in this study. Essential FA are associated with brain development, regulation of metabolic processes, skin and hair development (Chang *et al.*, 2009).

The total saturated fatty acids (SFA) in the 3 species ranged from 12.40 to 15.30%; the value obtained was close to 10.26% reported by (Liu *et al.*, 2008). From this study, *Passiflora edulis* F. *flavicarpa* had the highest percentage (15.30%) of SFA among all species close to 14.1% and 12.41% reported by (Nyanzi *et al.*, 2005) and (Malacrida & Jorge, 2012) respectively for the same species.

Furthermore, the percentage of total unsaturated fatty acids (UFA) obtained from this study ranged from 85.86% to 87.60% similar to 82.84 to 89.43% (Ramaiya *et al.*, 2019) and 85.4 to 88.6% (Nyanzi *et al.*, 2005) with *P. maliformis* L having the highest UFA content. The SFA/UFA ratio for both *P. edulis* Sims and *P. maliformis* L is 1/6 and for *P. flavicarpa* is 1/5. The high ratios in human diet are associated with reduced risk of cardiovascular diseases and it is also recommended for cooking, salads and in preparation of margarine and mayonnaise (Lucarini. *et al.*, 2019).

**Table 8: Fatty acid composition (%) of the seeds from passion fruit species grown in Uganda.**

<b>Fatty Acids %</b>	<i>Passiflora edulis</i> Sims	<i>Passiflora edulis</i> F. <i>flavicarpa</i>	<i>Passiflora maliformis</i> L
Myristic acid (C14:0)	0.06±0.00 <sup>b</sup>	0.06±0.00 <sup>b</sup>	0.08±0.001 <sup>a</sup>
Palmitic acid (C16:0)	9.16±0.11 <sup>b</sup>	11.18±0.14 <sup>a</sup>	8.68±0.11 <sup>c</sup>
Palmitoleic acid (C16:1)	0.17±0.00 <sup>c</sup>	0.20±0.00 <sup>b</sup>	0.30±0.00 <sup>a</sup>
Heptadecanoic acid (C17:0)	0.12±0.00 <sup>a</sup>	0.09±0.00 <sup>a</sup>	0.10±0.00 <sup>a</sup>
Stearic acid (C18:0)	2.78±0.03 <sup>b</sup>	3.16±0.04 <sup>a</sup>	2.86±0.04 <sup>b</sup>
Octadecenoic acid ) (C18:1trans)	<0.05	0.07±0.00 <sup>a</sup>	<0.05
Oleic acid (C18:1cis)	14.59±0.17 <sup>c</sup>	16.41±0.21 <sup>a</sup>	15.65±0.20 <sup>b</sup>
Linoleic acid (C18:2)	72.18±0.86 <sup>a</sup>	67.57±0.85 <sup>b</sup>	71.39±0.84 <sup>a</sup>
Arachidic acid (C20:0)	0.09±0.08 <sup>a</sup>	0.17±0.00 <sup>a</sup>	0.13±0.001 <sup>a</sup>
Oicosenoic acid (C20:1)	0.27±0.09 <sup>a</sup>	0.30±0.00 <sup>a</sup>	0.23±0.00 <sup>a</sup>
Heneicosanoic acid (C20:3)	<0.05	0.16±0.00 <sup>a</sup>	0.17±0.01 <sup>a</sup>
Behenic acid (C21:0)	0.31±0.00 <sup>b</sup>	0.38±0.00 <sup>a</sup>	0.38±0.001 <sup>a</sup>
Eicosatrienoic acid (C22:0)	0.11±0.00 <sup>b</sup>	0.12±0.00 <sup>a</sup>	0.08±0.00 <sup>c</sup>
Docosadienoic acid (C22:2)	0.15±0.01 <sup>a</sup>	0.08±0.00 <sup>b</sup>	<0.05
<b>Saturated fatty acids (SFA)</b>	<b>12.81±0.13<sup>b</sup></b>	<b>15.30±0.26<sup>a</sup></b>	<b>12.40±0.38<sup>b</sup></b>
<b>Mono-unsaturated (MUFA)</b>	<b>14.85±0.07<sup>b</sup></b>	<b>16.87±0.62<sup>a</sup></b>	<b>16.08±0.03<sup>a</sup></b>
<b>Poly-unsaturated (PUFA)</b>	<b>72.33±0.30<sup>b</sup></b>	<b>68.78±0.17<sup>a</sup></b>	<b>71.52±0.48<sup>b</sup></b>
<b>Total unsaturated (UFA)</b>	<b>87.19±0.55<sup>a</sup></b>	<b>85.68±0.98<sup>a</sup></b>	<b>87.60±0.15<sup>a</sup></b>

Values in each row followed by the same superscript letter in each variety are not significantly different at  $p \leq 0.05$

#### **4.4 Oil stability**

Oil stability defines the susceptibility of edible oil to oxidation that leads to rancidity and it tends to determine its shelf life. Oxidation results into off-flavours, nutritional losses and other deteriorative changes in oil arising from reaction with atmospheric oxygen (Naz *et al.*, 2014).

##### **4.4.1 Acid value**

Acid values indicate levels of rancidity arising from autoxidation. Acid value obtained from all passion fruit seeds in this study were not significantly different as shown in table 9. Oil from *Passiflora edulis* Sims, *Passiflora edulis flavicarpa* and *Passiflora maliformis* L seeds had values of 1.03, 0.75 and 0.84 mgKOH/g, respectively. These values were below the maximum acidity index of 4.0 mgKOH/g recommended for oils meant for human consumption as per Codex Alimentarius Commission (CODEX, 2008). Therefore, oil obtained from these seeds have shown resistance to autoxidation that could have occurred during processing and storage. Studies by (Liu *et al.*, 2008) and (Silva *et al.*, 2015) reported higher acidity values of 2.11 mgKOH/g and 1.63 mgKOH/g, respectively. The values obtained were all within recommended limits by edible oil international standards.

##### **4.4.2 Peroxide value**

Oil from the three species of passion fruit seeds had low peroxide values (0.10 meqO<sub>2</sub>/kg), with no significant difference (table 9). Peroxide values suggest that oil could be stored for a long period without deterioration (Liu *et al.*, 2008). CODEX (2008) established maximum peroxide value for crude oils at 15 meqO<sub>2</sub>/kg. The results of this study were close to those obtained by (Silva *et al.*,

2015) which were at 1.5 meqO<sub>2</sub>/kg. Passion fruit seed oil was generally stable to peroxidation given the low values below limits set by CODEX.

#### **4.4.3 Iodine value**

Iodine values were 135.35, 125.23 and 133.31 g/100g for *Passiflora edulis* Sims, *Passiflora edulis flavicarpa* and *Passiflora maliformis* L, respectively (Table 9). The values were significantly different in all the varieties of *Passiflora* seeds. *Passiflora edulis flavicarpa* showed the lowest iodine value. Iodine values for passion fruit seed oil have been reported by (Nyanzi *et al.*, 2005) in the range of 133.0 to 141.1 g/100g. These results are close to the values obtained in this study. (Silva *et al.*, 2015) got a lower iodine value of 109.48g/100 g for passion fruit seed oil. Iodine value measures the degree of unsaturation in oil and high Iodine value indicates susceptibility to oxidation (Ramaiya *et al.*, 2019). It is notable that the passion fruit seed oil is mostly composed of unsaturated fatty acids.

#### **4.4.4 Saponification value (Sv)**

Saponification value is a measure of free and esterified acid present in the oil (Ramaiya *et al.*, 2019). From table 9, the saponification value of *Passiflora* seeds ranged from 174.98 to 191.74 mgKOH/g of oil. *Passiflora maliformis* L had the highest saponification value of 191.74 mgKOH/g which was significantly different from the value of 174.98 mgKOH/g oil obtained in *Passiflora edulis flavicarpa* and 175.65 mgKOH/g oil in *Passiflora edulis* Sims. The saponification values for edible oils range from 188 to 194mgKOH/g as recommended by WHO. This range is comparable to values obtained in this study. The data from this study was relatively close to 174.96 mgKOH/g oil reported by (Cuong *et al.*, 2019) and 176.0 mgKOH/g oil reported by (Liu *et al.*, 2008).

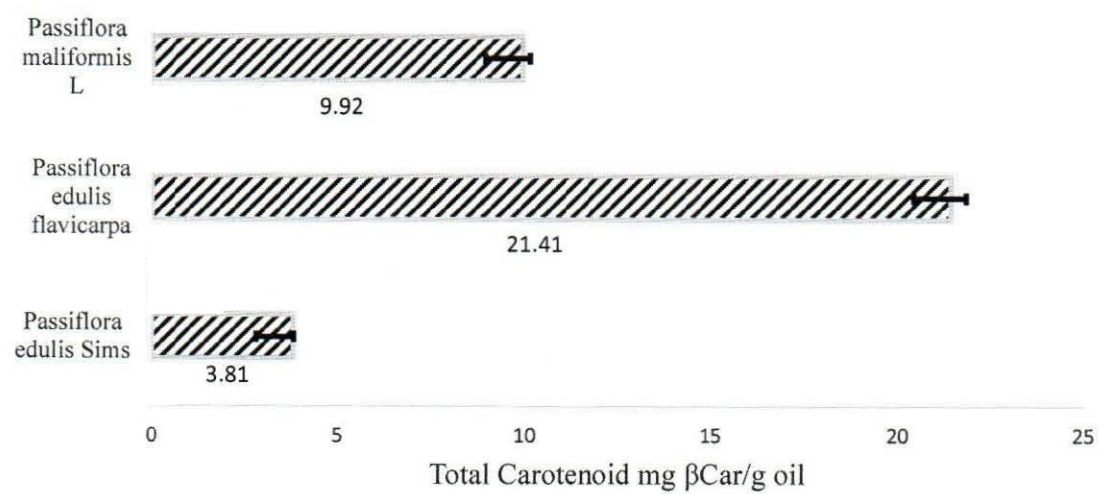
**Table 9: Stability tests for oil from seeds of passion fruit species grown in Uganda.**

Variety	<i>Passiflora edulis Sims</i>	<i>Passiflora edulis flavicarpa</i>	<i>Passiflora maliformis L</i>
Acid value (mgKOH/g)	1.03±0.14 <sup>a</sup>	0.75±0.00 <sup>a</sup>	0.84±0.13 <sup>a</sup>
Peroxide value (meqO <sub>2</sub> /kg)	0.10±0.00 <sup>a</sup>	0.10±0.00 <sup>a</sup>	0.10±0.00 <sup>a</sup>
Iodine value(gI/100g)	135.35±0.02 <sup>a</sup>	125.23±0.04 <sup>c</sup>	133.31±0.04 <sup>b</sup>
Saponification value (mgKOH/g oil)	175.65±0.98 <sup>b</sup>	174.98±1.45 <sup>b</sup>	191.74±1.32 <sup>a</sup>

Values in each row followed by the same superscript letter in each variety are not significantly different at  $p \leq 0.05$ .

#### 4.4.5 Total carotenoids content of the oil from seeds of passion fruit species grown in Uganda

Carotenoids expressed in terms of  $\beta$ -carotene are bioactive non-nutritive chemical compounds found in plants and are essential to human health (Araujo *et al.*, 2018; Wasagu *et al.*, 2016). As shown in Figure 4; the total carotenoids content in the major passion fruit seed oils (*Passiflora edulis Sims*, *Passiflora edulis F. flavicarpa* and *Passiflora maliformis L*) varied from 3.81 to 21.41 mg  $\beta$ -carotene/100 g of oil. Significant differences ( $p \leq 0.05$ ) were observed in the total carotenoid content among all the seeds with the highest value (21.41 mg  $\beta$ -carotene/100 g of oil) observed in the *Passiflora flavicarpa* and lowest value obtained in *Passiflora edulis Sims* (3.18 mg  $\beta$ -carotene/100g of oil). The results of this study are similar to the carotenoid content (9.0 mg/100g oil) in *Passiflora maliformis L* obtained by (Araujo *et al.*, 2018). Furthermore, (Jorge & Silva, 2014) reported carotenoid content of 0.67 mg/100g oil from *Passiflora edulis* seeds which is lower than that obtained from this study. (Fernanda *et al.*, 2015) analyzed the carotenoid content of passion fruit seed oil and obtained values in the range of 50.87 to 115.44 mg  $\beta$ -carotene/100g which were higher than what was obtained in this study.



**Figure 4: Carotenoid content of oil from seeds of passion fruit species grown in Uganda.**

## **CHAPTER 5: CONCLUSION AND RECOMMENDATIONS**

### **5.1 Conclusion**

Based on the present study, passion fruit seeds are edible with nutritive values in-terms of oil, crude fibre, proteins, carbohydrates, mineral elements and carotenoids which are vital in maintenance of a healthy body. The oil is also rich in unsaturated fatty acids (linoleic and oleic acids) are associated with reduced risk of developing non-communicable diseases. The seed oil possesses good oxidative stability attributed to presence of natural antioxidants inform of carotenoids and polyunsaturated fatty acid giving seed by-products longer shelf-life.

The passion fruit, in addition to being processed for juice, more useful products can be developed from the waste especially seeds therefore adding to the fruit's economic value. This will add value to the agro-industry.

### **5.2 Recommendation**

Basing on the findings, passion fruit seeds inform of dried flour can be incorporated in other foods to improve on their fibre content and stability. The oil may also be used in different fields for example in pharmaceutical industry as food supplements based on carotenoid extractions and cosmetic industry for oil products with anti-aging properties attributed by antioxidants present.

Data generated from this study can be added to food data-base for Ugandan fruit products as a novel food source generating interest for commercialisation for better economic value through value addition.

Further studies are required to determine other bioactive compounds, polyphenols and amino acid composition of passion fruit waste to widen the scope of passion fruit seeds and rinds' usefulness generated from understanding their composition.

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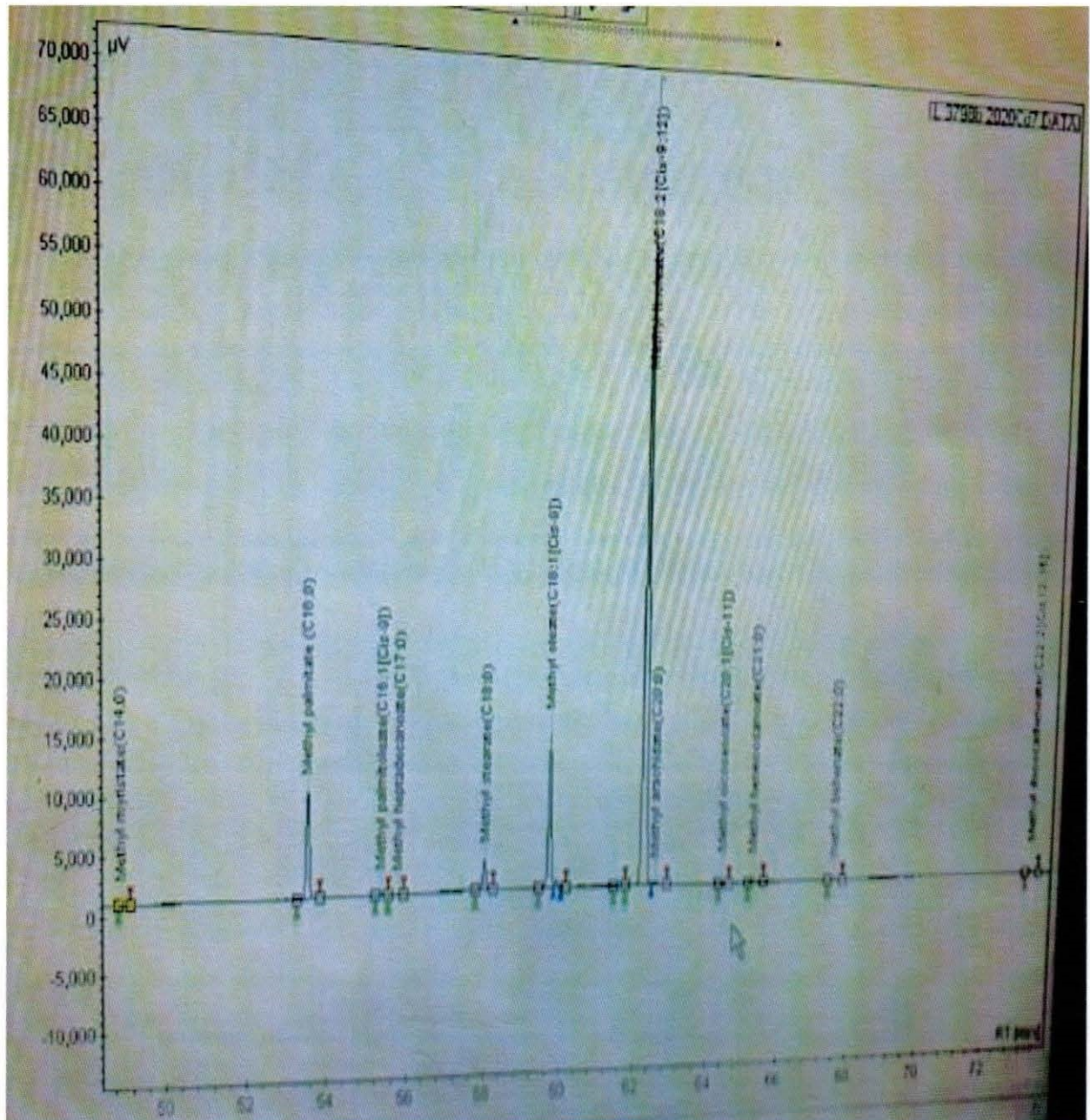
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## APPENDICES

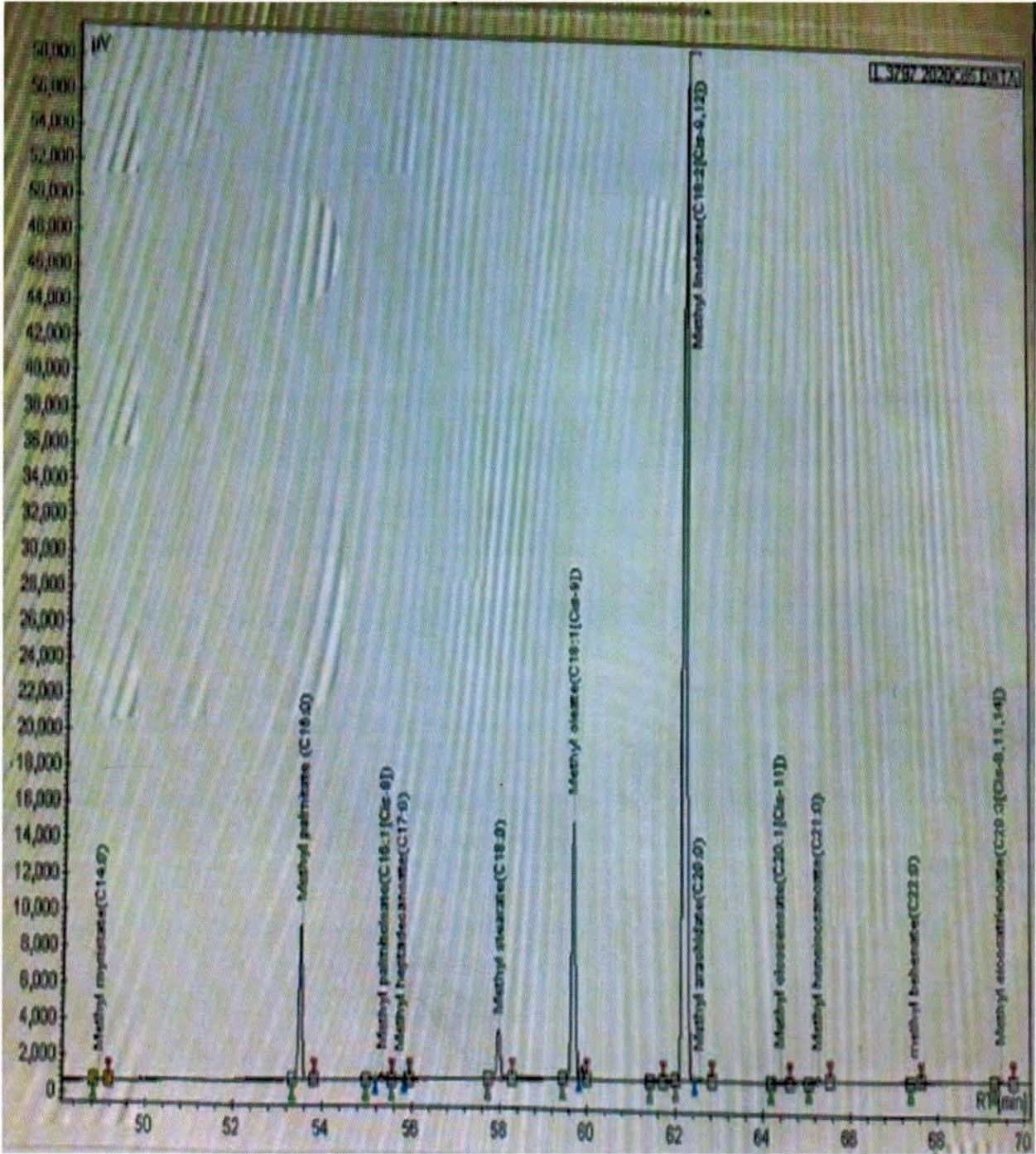
Appendix 1: Image of varieties of passion fruits seeds (*Passiflora edulis* Sims, *Passiflora edulis* F. *flavicarpa* and *Passiflora maliformis* L)



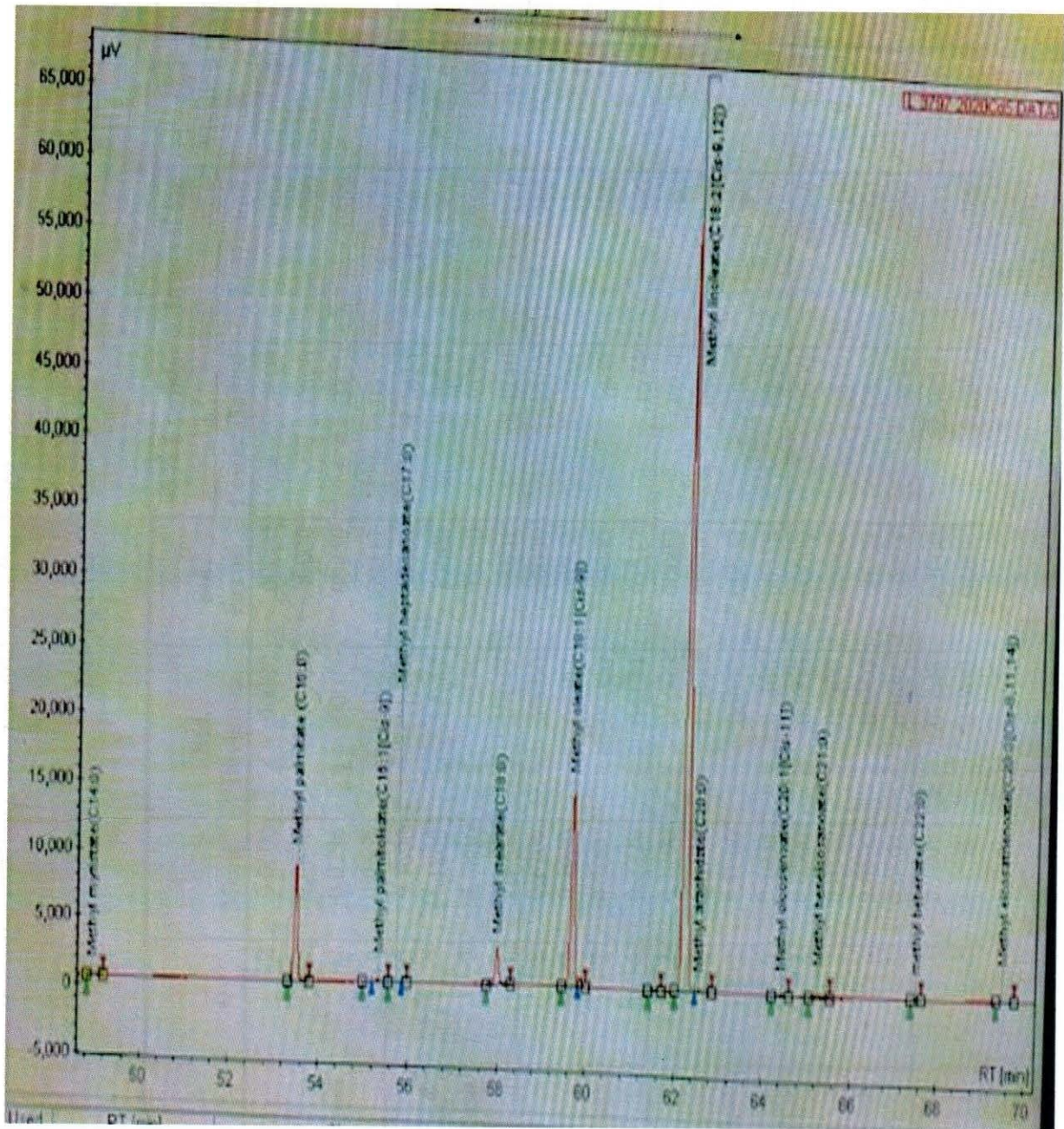
Appendix 2: Chromatogram of *Passiflora edulis* Sims seed oil



Appendix 3: Chromatogram of Passiflora edulis F flavicarpa seed oil



Appendix 4: Chromatogram of *Passiflora maliformis* L seed oil



Appendix 5: Statistic Descriptive for fatty acid composition in *Passiflora* seed oil

**Descriptives**

Fatty Acids	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum	
					Lower Bound	Upper Bound			
C14:0	Purple	2	0.0600	.00000	.00000	.0600	.0600	.06	.06
	Yellow	2	0.0600	.00000	.00000	.0600	.0600	.06	.06
	sweet calabash	2	0.0795	.00071	.00050	.0731	.0859	.08	.08
	Total	6	0.0665	.01007	.00411	.0559	.0771	.06	.08
C16:0	Purple	2	9.1600	.11314	.08000	8.1435	10.1765	9.08	9.24
	Yellow	2	11.1800	.14142	.10000	9.9094	12.4506	11.08	11.28
	sweet calabash	2	8.6800	.11314	.08000	7.6635	9.6965	8.60	8.76
	Total	6	9.6733	1.19047	.48601	8.4240	10.9227	8.60	11.28
c16:1	Purple	2	0.1700	.00000	.00000	.1700	.1700	.17	.17
	Yellow	2	0.1960	.00283	.00200	.1706	.2214	.19	.20
	sweet calabash	2	0.3000	.00000	.00000	.3000	.3000	.30	.30
	Total	6	0.2220	.06154	.02512	.1574	.2866	.17	.30
C17:0	Purple	2	0.1200	.00000	.00000	.1200	.1200	.12	.12
	Yellow	2	0.0900	.00000	.00000	.0900	.0900	.09	.09
	sweet calabash	2	0.1000	.00000	.00000	.1000	.1000	.10	.10
	Total	6	0.1033	.01366	.00558	.0890	.1177	.09	.12
C17:1	purple	2	0.0500	.00000	.00000	.0500	.0500	.05	.05
	Yellow	2	0.0510	.00000	.00000	.0510	.0510	.05	.05
	sweet calabash	2	0.0500	.00000	.00000	.0500	.0500	.05	.05
	Total	6	0.0503	.00052	.00021	.0498	.0509	.05	.05
C18:0	purple	2	2.7800	.02828	.02000	2.5259	3.0341	2.76	2.80
	Yellow	2	3.1580	.03960	.02800	2.8022	3.5138	3.13	3.19

	sweet calabash	2	2.8600	.04243	.03000	2.4788	3.2412	2.83	2.89
	Total	6	2.9327	.18050	.07369	2.7432	3.1221	2.76	3.19
C18:1tr	purple	2	0.0500	.00000	.00000	.0500	.0500	.05	.05
Ans	Yellow	2	0.0705	.00071	.00050	.0641	.0769	.07	.07
	sweet calabash	2	0.0500	.00000	.00000	.0500	.0500	.05	.05
	Total	6	0.0568	.01059	.00432	.0457	.0679	.05	.07
C18:1C	purple	2	14.5900	.16971	.12000	13.0653	16.1147	14.47	14.71
is	Yellow	2	16.4050	.20506	.14500	14.5626	18.2474	16.26	16.55
	sweet calabash	2	15.6500	.19799	.14000	13.8711	17.4289	15.51	15.79
	Total	6	15.5483	.82889	.33839	14.6785	16.4182	14.47	16.55
C18:2	purple	2	72.1800	.86267	.61000	64.4292	79.9308	71.57	72.79
	Yellow	2	67.5680	.84570	.59800	59.9697	75.1663	66.97	68.17
	sweet calabsh	2	71.3850	.84146	.59500	63.8248	78.9452	70.79	71.98
	Total	6	70.3777	2.30140	.93954	67.9625	72.7928	66.97	72.79
C20:0	purple	2	0.2650	-.09192	.06500	-.5609	1.0909	.20	.33
	Yellow	2	0.3000	.00000	.00000	.3000	.3000	.30	.30
	sweet calabsh	2	0.2300	.00000	.00000	.2300	.2300	.23	.23
	Total	6	0.2650	.05167	.02110	.2108	.3192	.20	.33
C20:1	purple	2	0.0850	-.07778	.05500	-.6138	.7838	.03	.14
	Yellow	2	0.1710	.00141	.00100	.1583	.1837	.17	.17
	sweet calabsh	2	0.1300	.01414	.01000	.0029	.2571	.12	.14
	Total	6	0.1287	.05226	.02133	.0738	.1835	.03	.17
C20:3	purple	2	0.0500	.00000	.00000	.0500	.0500	.05	.05
	Yellow	2	0.1600	.00000	.00000	.1600	.1600	.16	.16
	sweet calabsh	2	0.1700	.01414	.01000	.0429	.2971	.16	.18
	Total	6	0.1267	.05989	.02445	.0638	.1895	.05	.18
C21:0	purple	2	0.3100	.00000	.00000	.3100	.3100	.31	.31
	Yellow	2	0.3830	.00424	.00300	.3449	.4211	.38	.39
	sweet calabsh	2	0.3750	.00707	.00500	.3115	.4385	.37	.38
	Total	6	0.3560	.03600	.01470	.3182	.3938	.31	.39

C22:0	purple	2	0.1100	.00000	.00000	.1100	.1100	.11	.11
	Yellow	2	0.1205	.00071	.00050	.1141	.1269	.12	.12
	sweet calabsh	2	0.0800	.00000	.00000	.0800	.0800	.08	.08
	Total	6	0.1035	.01880	.00768	.0838	.1232	.08	.12
C22:2	purple	2	0.1500	.01414	.01000	.0229	.2771	.14	.16
	Yellow	2	0.0805	.00071	.00050	.0741	.0869	.08	.08
	sweet calabsh	2	0.0500	.00000	.00000	.0500	.0500	.05	.05
	Total	6	0.0935	.04628	.01889	.0449	.1421	.05	.16