DEVELOPMENT OF SPRAY-DRIED POWDERED KAMIAS *(Averrhoa bilimbi Linn.)*

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ABSTRACT

Underutilized fruits contain phytochemical substances that have promising health effects on humans. The need to make these fruits commercially available is still on progress and research on them is of little importance. Averrhoa bilimbi or also known as kamias is an indigenous fruit that is cultivated semi-wild everywhere in South East Asia including the Philippines. Spray drying is a drying technique wherein a liquid or slurry feed is turned into a dry powder. Fruit juice powder is widely accepted for human consumption and is a good alternative to convenient and healthy food products. This study aims to develop an instant powdered Kamias fruit juice drink using spray-drying technique. Sensory evaluation, proximate, physicochemical, vitamin C and microbiological analysis were conducted. Seventy-five (75) untrained panelists evaluated the four formulations of fruit juice which are control (100% extract), kamias powder with 30% gum arabic, kamias powder with 30% maltodextrin and kamias powder with 15% maltodextrin and 15% gum arabic (mixed carriers). It was evaluated according to the five sensory attributes using 9-point hedonic scale. Kamias powdered juice with 30% maltodextrin was considered the best formulation by means of sensory evaluation. Proximate analysis has yielded 3.08-4.70% moisture, 0.31-0.84% fat, 1.13-2.52% protein, 0.14-2.85% ash and 90.83-93.72% carbohydrates content of the four formulations. Physicochemical analysis such as pH, TSS, Bulk Density and aw was also done with a result of 2.54-4.05, 84.31-95.03°B, 0.32-0.42g/ml, and 0.19-0.30, respectively. Vitamin C content of the kamias powders significantly decreased. Kamias powder with 30% Gum Arabic has retained the highest amount of Vitamin C among the three powdered samples. Microbial analysis of the best formulation resulted in negative presence of coliform count and yeast and mold while total plate count was 6x102cfu/g. The encapsulation method using maltodextrin and gum arabic as carriers showed different physical, chemical and sensorial properties. The encapsulation of core material was successful to retain considerable amounts of vitamin C.

Keywords: *Averrhoa bilimbi Linn*, Powdered Juice, Spray-drying, Gum Arabic, Maltodextrin

INTRODUCTION

Tropical fruits are widely grown in countries such as the Philippines. Native tropical fruit species are very important for the economic welfare of small farmers in Asia. Most of these species have multi-purpose use for food, shelter, timber, fuel, medicine and other uses (Bhag M. *et al*., 2016). Tropical fruits and their diverse uses contribute considerably to food and nutritional security, income generation, poverty reduction and ecosystem and environmental sustainability (Bhag M. *et a*l., 2016). The uses of fruits for commercial purposes are widely acceptable for human consumption while noncommercial tropical fruits are still underutilized. These fruits are potentially rich in polyphenolic compounds, caratenoids, anthocyanins, fatty acids, minerals, and amino acids but research on their development is still yet to be explored. The need to make these fruits more popular and commonly available is of great importance to the society (Hong-Eng *et al*., 2010).

It is well established that the tropical fruits contribute significantly towards improvement of human nutrition and health. These are rich sources of vitamins and minerals and possess high dietary energy (Bhag M. *et al*., 2016). Some tropical fruits including pineapple, lemon, guava, grapefruit, kamias and many more have shown excellent sources of Vitamin C or also known as ascorbic acid. Indigenous fruit trees are important in a way contribute to the health life, food safety, and economic problems especially in the developing countries (Cheikhyoussef & Embashu. 2013).

These indigenous fruit trees play an important role preventing chronic diseases since these are a rich source of micro nutrients such as Vitamins A and Vitamin C, minerals, adding macro nutrients such as carbohydrates, proteins, fats, and fiber as well (Okullo. *et al*., 2014). Though indigenous fruit trees are important in the human diet, little attention has been given in improving and developing it in researches (Cheikhyoussef & Embashu. 2013).

Averrhoa bilimbi (Bilimbi), or locally known as Kamias belonging to the family of *Oxalidaceae*, reaches 16 to 33 ft (5-10 m) in height, leaves are 12 to 24 in (30-60 cm, fruit is 1.5 to 4 in (4-10 cm) long and small, fragrant, 5-petalled flowers, yellowish-green or purplish marked with dark-purple. The fruit is crisp when unripe, turns from bright-green to yellowish-green, ivory or nearly white when ripe and falls to the ground. The outer skin is glossy, very thin, soft and tender, and the flesh green, jelly-like, juicy and extremely acid. The *bilimbi* tree is cultivated semi-wild everywhere in the Philippines and is produced in small scales and is usually grown in backyards. It is very common in Thailand, Malaysia and Singapore and frequent in gardens across the plains of India. Flavonoids, saponins, and triterpenoid are contained in its fruit extracts and its chemical constituents are amino acids, citric acid, chrysanthemin, phenolics, potassium, sugars and vitamin A (Roy *et al.,* 2013). Other than the health benefits mentioned, *Bilimbi* is a wealth source of vitamin C (Roy *et al*., 2013). Other uses of kamias fruit include food flavoring, as a souring agent for local dishes, or they may be eaten raw (Masilungan & Absulio, 2012). Fruits are also used in the production of vinegar, wine, and pickles and in the preparation of Hindu dishes; mature fruits can also be processes into jams and jellies (De Lima *et a*l., 2001).

High moisture content due to the water activity of fruits is one of the major reasons for its quality loss. Drying of fruits that will remove the moisture content and decrease the water activity is necessary to maintain its quality (Krishnan, 2008). Disadvantages of using dehydration technologies such as freeze drying are prolonged processing time, high energy costs, high product hygroscopicity and undesirable physical changes such as collapse.

Among the drying techniques, spray drying is commonly applied to produce the fruit juice into powder form (Phisut, 2012). Spray drying is the transformation of a liquid or slurry feed to a dry powder (Goula & Adamopoulos, 2010). This process is done by atomizing the fluid into a drying chamber, where there is hot-air steam and liquid droplets passed through it (Sabhadinde, 2014).

It is said that phenolic compounds constitute one of the most abundant and extensively distributed group of substances in the plant kingdom; foods and fruit juices may have a very complex phenolic composition (Ashraf *et al*., 2011). Natural pigment found in fruit juices has some added value for its color and functional properties. Juices had shorter shelf life and proper storage is costly. Nevertheless, powdered juices are able to maintain the fruits phytochemicals properties for longer period and helps in reducing handling and storage cost (Chik *et al*., 2011).

Various studies have been proposed to improve and increase the production of fruit juice powder such as the study of addition of drying aids (maltodextrins, glucose, soybean protein, sodium chloride, and skim milk powder), new techniques for spray drying (Goula & Adamopoulos, 2010), use of different carrier agents for powder, storage stability, and conservation of its physicochemical properties (Navas et al. 2011), physical and functional properties of spray dried food (Franceschinis et al. 2014), microencapsulation (Guardiola, 2011), factors that influence properties of the product like inlet temperature, air dry flow rate, feed flow rate, atomizer speed, type and concentration of carrier agent (Phisut, 2012), effect of maltodextrin as a carrier agent at different concentrations at different drying temperatures on the physical and drying properties of the spray-dried fruit (Shishir et al. 2015) and spray drying of different kinds of vegetables and fruits.

Kamias known for its potential local uses needs to be developed also for commercial purposes since no information about kamias powders exist in literatures. The need to utilize this tropical fruit for production of shelf stable products may be achieved by spray-drying process. Kamias has nutritional properties and is a high source of Vitamin C. Therefore, drying operations must be carefully investigated to maintain these nutritional properties. Vitamin C retention in different temperature and after dried must be investigated to determine the effect of temperature in reduction of Vitamin C (Krishnan, 2008).

There is a great demand of fruit juices in treatment of various illnesses such as arthritis, heart diseases and muscle aches and drug addiction (Malaviya & Mishra, 2011). People who consume more fruit juices are associated to gain more essential nutrients such as Vitamins C, magnesium, folate, potassium, and vitamin B-6, and better diet quality compared to those who do not consume fruit juices (O'Neil *et al*., 2012). The objective of the study is to develop an instant powdered Kamias fruit juice drink using spray-drying technique. They are popular and economically important and will help provide nutrition growth. Many people as of today consume fruit juices on a daily basis and as a way to receive the fruits nutrients (Serpen, 2012). The development of kamias as a powdered fruit juice will help promote its health benefits since it's a potential source of Vitamin C and considerable amounts of flavonoids and polyphenols.

Theoretical Background

Averrhoa bilimbi Linn. (Kamias) belongs to the family of *Oxalidiaceae*. It is commonly known as kamias in the Philippines, cucumber tree in America, bimbling plum in Creole, and blinblin or carambolier bilimbi in France (Ramjan Ali *et al*. 2013). *A. bilimbi* is an attractive and a long-standing tree that grows 5-10m in height and 3-6cm long in leaf (Agena *et al*., 2012 in Orwa et al., 2009). Kamias is a tropical tree that grows best in complete exposure to sunlight rather than in shady or semi-shady areas (Agena *et al*., 2012 in Orwa *et al*., 2009). The kamias tree grows 18-64 flowers that form on the trunk and older branches. The waxy, pale green fruit is slightly lobed, grows to about 4 inches long and up to an inch wide, with seeds that are about one and a half inch long. The sour fruit changes from green to light yellow when ripe and matures 50-60 days after flowering (Love & Paull, 2011).

Sources

Though this fruit is widely cultivated in the tropical region, the origins of this fruit is not yet clear but Correa (1926) reported that the plant is native to India, from where it was brought to Brazil centuries ago. *A. bilimbi* tree is cultivated in the states of Brazil including Rio de Janeiro, Amazonas, Para and Santa, but the distribution of its fruits is limited (De Lima *et al*., 2001). Kamias is closely related to *Averrhoa carambola* or starfruit that originated in Southeast Asia and is claimed as a native to Malaysia and the Indonesian Moluccas (Love & Paull, 2011). Indonesia, Malaysia, Philippines, India, and Sri Lanka produce this tree on a small scale and is usually a backyard tree. Kamias tree is also common in other Southeast and South Asian countries and is now found worldwide (Love & Paull, 2011).

Uses and Benefits

Parts of the tree are used ethno medically for the in the treatment of children's cough in syrup of flowers, stomach ache in fruits and as a cooling drink in juice of preserved fruits (Ramjan Ali *et al*., 2013). Certain parts of this plant has shown traditional medicinal effect such as the leaves for treating itches, swellings of mumps and rheumatism, and on skin eruption, its flowers effective against coughs and thrush, and the fruit itself for curing coughs, beri-beri and biliousness (Kumar *et al*., 2013). In addition to that, it is also used as a cure for fever, inflammation, rectal bleeding and internal hemmorrhoids (Agena *et al*., 2012). Kamias fruit also contains high acidity and high oxalic acid content which can remove stains on clothes and metal blades and as a hand wash (Masilungan & Absulio, 2012). In the study of Ramjan-Ali *et al.* (2013), hypoglycemic and hypolipidemic properties in Type I diabetic rats were exhibited by the ethanolic leaf extract of *A. bilimbi* and its semi-purified fractions when administered both intraperitoneally (Tan *et al*., 1996) and orally (Pushparaj *et al*., 2000; Pushaparaj *et al.,* 2001). In the study of Anitha *et al.* (2010), pharmacognosy of kamias was shown. It is medicinally used as an antibacterial (Das *et al*., 2011; Karon *et al*., 2011; Zakaria *et al*., 2007) and as an antifungal agent (Nazmul *et al*., 2010). Agena *et al*. (2012) concluded that phytochemical compounds such as apigenin, luteolin and phenolics found in the leaves of kamias can be used for the prevention of the adverse effects of UV radiation on the skin due to their photoabsorptive property. Miean & Mohamed (2001) stated in their study that the antibacterial activity of kamias could also be associated with the presence of the same bioactive compounds like flavonoids, apigenin, and luteolin (Zakaria *et al*., 2007). Previous phytochemical investigations showed that chloroform extracts from of *A. bilimbi's* leaf and fruit possess antibacterial activity against the Grampositive *S. aureus, S. epidermis, B. cereus, K. rhizophila, C. diphteriae* and Gramnegative *S. typhi, C. fuendii, A. hydrophila,* and *P. vulgaris* (Jais *et al*., 2009). Fruits of *bilimbi* are believed to be a possible source of bioethylene as they were seen to be softening fast when injured, which could mean that they produce a high level of ethylene which is the most effective ripening agent (Masilungan & Absulio, 2012).

Nutritional Content (Philippine FCT, 1997)

Table 1. Vitamin Composition of Kamias Fruit (vitamins per 100g)

Riboflavin	0.030 mg
Vitamin B1 (thiamine)	0.010 mg
Niacin	0.30 mg
Ascorbic Acid	10 mg
Carotene	0.035 mg
Vitamin A	0.036 mg

Table 2. Mineral Composition of Kamias Fruit (minerals per 100g)

Phosphorus	11.1 mg
Calcium	8 mg
Iron	0.4 mg

MATERIALS AND METHOD

Materials

Twenty kilograms of fresh Kamias fruit and one kilogram of sugar was obtained from a farm in Balintawak, Quezon City. Kamias fruit were authenticated at the National Museum, Manila City.

The following reagents and laboratory apparatus were used in different analysis of the product: 0.1N HCl, Concentrated sulphuric acid (H_2SO_4), Sodium hydroxide (NaOH) solution 40% w/w, Potassium sulphate (K_2SO_4) and Copper sulphate ($CuSO_4$), Boric acid (H_3BO_3), distilled water, Methyl red, crucible, oven, muffle furnace, blowpipe, filter paper, petroleum ether, extraction tube, soxhlet apparatus, glass dish, solution of sulphuric acid (0.128M) 7.1ml, solution of potassium hydroxide (0.223M), acetone as foam suppresser. Equipments used were electric juicer (Dowell RP4310), digital balance (Ohaus, Digital Scale, USA), blender (Hanabishi, MB450141, Philippines).

Method

Kamias Extraction

Fresh green Kamias fruits were sorted, washed using tap water and then trimmed. Trimmed kamias fruits were ground using an electric juicer. Using cheesecloth, the ground kamias was filtered to eliminate the seeds and pulp (Rodriguez-Hernandez *et. al*., 2005). The juice was transferred in a microwavable container and was kept at 4°C.

Encapsulation of the core material

For the preparation of the core material, 25 grams of Kamias extract and 58 grams of distilled water were mixed together to come up with 30% concentration. Encapsulating material was done by also mixing 25 grams of the encapsulating material and 58 grams of distilled water (Logan, 2014). The encapsulating material solution and the core solution was mixed together homogenously using blender. After mixing, the homogenous mixture was transferred in ziplock and kept at 4°C for further processing (Logan 2014).

Spray Drying of the Encapsulated Kamias Extract

The spray drying process was performed in a Forturo spray dryer lab plant located in Sucat, Paranaque City. The spray dryer has a 1.5-mm diameter nozzle and main spray chamber of 500 mm, 215 mm. The microencapsulated extracts were fed into the main chamber through a peristaltic pump, with drying air flow rate of 73 m^3 h^{-1} and compressor air pressure of 0.06 MPa. The feed flow rate used was 15 g min^{-1}, and the inlet & outlet air temperatures were 180-240°C and 90-98 °C. These latter conditions were selected in a previous work, based on an experimental design (Tonon *et al.,* 2008).

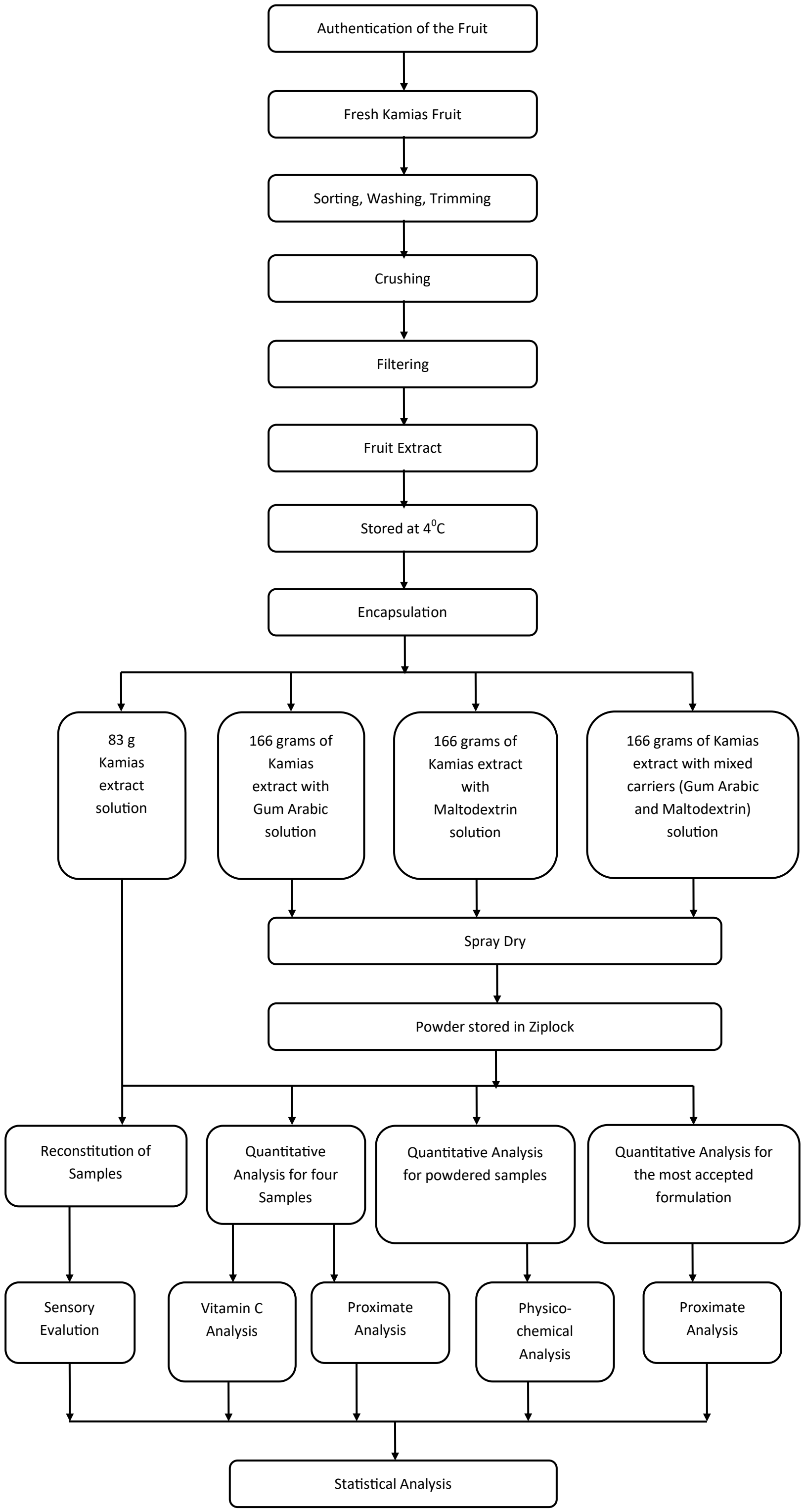

Figure 1: Process Flow Chart in Processing Kamias Fruit Powder

Table 3. Proportions of Kamias Extract and Carrier

Formulations	Components (%)	
	Kamias extract	Carrier
Control	100%	0%
Treatment 1	70%	30% Gum Arabic
Treatment 2	70%	30% Maltodextrin
Treatment 3	70%	15% Maltodextrin + 15% Gum Arabic

Sensory Analysis

Seventy five untrained panelists aged between 15-40 years were selected to take part in the sensory analysis. The panel evaluated the sensory attributes such as color, aroma, flavor, mouthfeel and overall acceptability (Mahendran 2010). The reconstituted sample is a mixture of 25 grams of encapsulated Kamias powder and 50 grams of table sugar added with 1 Liter of water as suggested by commercial powdered juice drink. These samples were carried out using the four different formulations with the same amount of sugar then stir together until it is completely dissolved (Mahendran, 2010). Four samples of Kamias beverage were tested using a 9 point-hedonic scale to determine which of the samples was the most accepted. The sensory analysis was conducted inside the food laboratory where seventy-five untrained panelists specifically students, teachers, and employees from Colegio de San Juan de Letran were gathered. Sensory attributes includes appearance, aroma, taste, mouthfeel and overall acceptability.

Proximate Analysis

Moisture Determination (AOAC 934.01)

Moisture was determined by oven drying method. Using 1.5 g of well-mixed sample, it was accurately weighed in clean, dried crucible (W_1). The crucible was placed in an oven at 100-105°C for 6-12 h until a constant weight was achieved. Then the crucible was placed in a desiccator for 30 min to cool (Gul & Safdar, 2009) and weighed again (W_2).

Ash (AOAC 942.05)

For the determination of ash, clean empty crucible was placed in a muffle furnace at 600°C for an hour, cooled in desiccator and then weight of empty crucible was noted (W_1). One gram of 1 sample was taken in crucible (W_2). The sample was ignited over a burner with the help of blowpipe, until it is charred. Then the crucible was placed in muffle furnace at 550°C for 2-4 h. The appearances of gray white ash indicate complete oxidation of all organic matter in the sample. After ashing, furnace was switch off (Gul & Safdar, 2009).

Crude Protein (AOAC 984.13)

Protein in the sample was determined by Kjeldahl method. The sample was digested by heating with concentrated sulphuric acid (H_2SO_4) in the presence of digestion mixture. The mixture was made alkaline. Ammonium sulphate formed released ammonia that was collected in 2% boric acid solution and titrated against standard HCl. Total protein was calculated by multiplying the amount of nitrogen with appropriate factor (6.25) and the amount of protein was calculated (Gul & Safdar, 2009).

Crude Fats (AOAC 954.02)

Solvent extraction method for fat determination was implied. It consists of extracting the dry sample with some organic solvent. Since all the fat materials e.g. fats, phospholipids, sterols, fatty acids, carotenoids, pigments and chlorophyll are extracted together, the results are therefore frequently referred to as crude fat. Crude fat was be determined by ether extraction method using soxhlet apparatus. Approximately 1 g of moisture free sample was wrapped in filter paper, placed in a fat free thimble and introduced in the extraction tube. A clean, dry and pre-weighed receiving beaker was filled with petroleum ether and fitted into the apparatus. Water and heater were turned on to start extraction. After 4-6 siphoning, ether was allowed to evaporate and the beaker was disconnected before the last siphoning. Extract was transferred into a clean glass dish with ether washing and solvent was evaporated on a water bath.

Carbohydrates

Carbohydrates were determined by mathematical calculation. It was calculated by subtracting the sum of percentages of proximate component from 100%. It represents soluble carbohydrates, other digestible and easily utilizable non-nitrogenous substances in the powder (Gul & Safdar, 2009).

Physico-Chemical Analysis

Water Activity *(A_w)*

Kamias powder of 0.5 grams was determined using a water activity meter (AQUALAB series 3TE, Device Co., Germany) at 25°C.

Total Soluble Solids *(TSS)*

Total soluble solids were determined using a RFM Refractometer equipped with a percentage sugar scale and expressed as °Brix. Weigh and dissolve 10 grams of sample in 100ml water then put a small quantity of the test solution on the fixed prism of the refractometer.

pH (AOAC 973.41)

The pH of the juice was determined with a glass electrode attached to a Thermo Orion pH-meter.

Bulk Density

Bulk density of the samples was determined gravimetric method. 10 grams of powder was put into a 100 ml graduated cylinder and the cylinder slightly tapped to a constant volume.

Vitamin C Analysis (AOAC 19^{TH} Ed. 2012)

Vitamin C was analyzed by weighing approximately 0.10 g of the powder to a tenth of a milligram and transfers it quantitatively into a 125-mL Erlenmeyer flask. Dissolve the powder in 15 mL of distilled water. Using a 10-mL pipet, transfer 30 mL of standard KIO_3 solution into the sample solution above and then add approximately 1 g of solid KI, 10 mL 0.2 M H_2SO_4, and 0.1 g of $NaHCO_3$ to the flask. Then titrate the excess I_3 - in the sample with the standardized $Na_2S_2O_3$ solution. After the red-brown solution changes to a faint, pale yellow color, add about 10 drops of starch solution. Stirring constantly, continue titrating slowly until the blue color disappears.

Microbial Analysis

Microbial examinations of the most preferred powder were performed to assess Total Plate Count, Coliform count and Yeast and Mold Count. Pour Plate technique and Serial Dilution were method used to count the bacteria. Pour plate technique was done by transferring 0.1 mL (100 mL) of diluted bacteria from each tube into an empty Petri dish. Once the diluted bacteria samples have been added to the Petri dishes, pour a melted Nutrient Agar into each Petri dish. Gently swirl the Nutrient Agar and diluted bacteria samples together, and let the Petri plate solidify. While serial dilution was performed using 1 mL of the bacterial sample added to 9 mL distilled water, and it is mixed together (creating a 10-1 dilution). Then, 1 mL from that mixture is added to 9 mL distilled water, and it is mixed together (a 10-2 dilution) (Fankhauser, 2000).

Data Interpretation and Calculation

All experiments were conducted in triplicate and the data of sensory evaluation were analyzed statistically using ANOVA and Duncan's multiple range test (DMRT) at the significance level of $p < 0.05$. All the data were presented as the mean scores (Santhalakshmy *et al.,* 2015).

RESULTS

Sensory Analysis

Kamias juices were prepared from the spray-dried fruit powders of Kamias. Reconstitution of powders was done by adding water and equal amount of sugar to the powder. These powdered juices were compared with fresh Kamias extract based on the appearance of color, taste, aroma, mouthfeel and general acceptability that are presented in Figure 4

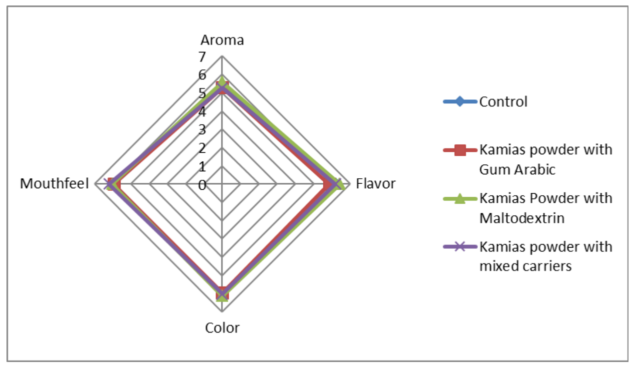

Figure 4: Summary of Sensory Attributes

Table 4: Sensory Evaluation of Kamias beverage

SENSORY ATTRIBUTES	Treatment 1 (100% Kamias Extract)	Treatment 2 (70% Kamias Extract : 30% Gum Arabic)	Treatment 3 (70% Kamias Extract : 30% Maltodextrin)	Treatment 4 (70% Kamias Extract : 15% GA : 15% Maltodextrin)
Color	6.09[a]	5.96[a]	6.13[a]	6.01[a]
Taste	6.2[a]	5.85[a]	6.41[a]	6.19[a]
Aroma	5.37[a]	5.27[a]	5.57[a]	5.25[a]
Mouthfeel	5.96[a]	5.93[a]	6.03[a]	6.19[a]
General Acceptability	6.13[a]	5.88[a]	6.39[a]	6.36[a]

Table 5: Proximate Analysis of the Samples

SENSORY ATTRIBUTES	Treatment 1 (100% Kamias Extract)	Treatment 2 (70% Kamias Extract : 30% Gum Arabic)	Treatment 3 (70% Kamias Extract : 30% Maltodextrin)	Treatment 4 (70% Kamias Extract : 15% GA : 15% Maltodextrin)
Moisture Content (%)	96.52	4.70	3.08	3.74
Crude Fat (%)	0.84	0.31	0.67	0.53
Crude Protein (%)	2.01	1.13	2.24	2.52
Ash (%)	0.14	2.85	0.29	2.38
Carbohydrates (%)	0.49	91.71	93.72	90.83

Table 6: Physicochemical Analysis of the Powdered Samples

PARAMETERS	Treatment 2 (70% Kamias Extract : 30% Gum Arabic)	Treatment 3 (70% Kamias Extract : 30% Maltodextrin)	Treatment 4 (70% Kamias Extract : 15% GA : 15% Maltodextrin)
pH @10% Aq. Sol.	4.05	2.54	3.90
Bulk Density g/mL	0.32	0.41	0.42
Water Activity	0.30	0.19	0.20
Total Soluble Solids (°Brix)	84.31	89.98	95.03
pH @10% Aq. Sol.	4.05	2.54	3.90

Table 7: Vitamin C Analysis of the Powdered Samples

	Vitamin C content (mg/100g)
Treatment 1 (100% Kamias Extract)	8.70
Treatment 2 (70% Kamias Powder : 30% Gum Arabic)	2.32[a]
Treatment 3 (70% Kamias Powder : 30% Maltodextrin)	2.26[a]
Treatment 4 (70% Kamias Powder : 15% GA & 15% Maltodextrin)	2.22[a]

Table 8: Microbiological Test of the Most Accepted Formulation

Foods Micro Test	Result	Standard
Coliform Count (cfu/g)	(-)	10
Total Plate Count (cfu/g)	6×10^2 cfu/g	1×10^3 cfu/g
Yeast and Mold Count	(-)	(-)
Foods Micro Test	Result	Standard

* CFU – Colony forming unit

DISCUSSION

Sensory Analysis

The results of sensory evaluation are shown in Table 4. Sensory evaluation showed that the Control and the powdered samples produced were not significantly different (p>0.05) in terms of all the sensory attributes tested. Based on the results of the sensory attributes of the four formulations, treatment 3, kamias extract with maltodextrin showed the best formulation in terms of color, flavor, aroma, mouth feel and general acceptability. Maltodextrin is a polysaccharide or hydrolyzed starch which is carbohydrate in nature that makes it commonly used as a wall material (Gharsallaoui *et al.,* 2007). With a wide range of starch depolymerization (DE) <20, maltodextrin have a heterogeneous composition of the mixture of sugars which exhibits the properties of emulsifiers, fillers, stabilizers, gluing or raising agents and they prolong freshness, reduce sweetness, enhance taste and smell, and delay the process of crystallization (Ruiz & Campos, 2016). In the study of Jittanit *et al*. (2011), tamarind powder with maltodextrin produced by drum-drying resulted with preferred sensory data for appearance, color and overall likeness. Gum Arabic sensory scores did not showed a significant difference with maltodextrin carrier even though it showed the highest scores for all the sensory attributes. This is due to the ability of gum Arabic to create a good emulsion for spray-drying and its ability to act as an emulsifier (Vega & Roos, 2006). Gum Arabic is used to encapsulate extracts, essential oils, antioxidants, colors, vitamins, and fatty acids (Ruiz & Campos, 2016).

Proximate Analysis

The results of the proximate analysis showed that the moisture content of the extract contained 96.52% greater than 4.70% in Kamias with Gum Arabic, 3.08% moisture in kamias with maltodextrin but lesser when compared to 3.74% moisture of kamias powder with mixed carriers. In a study about Pineapple and Tamarind pulp and powders (Taufiq, 2015), moisture content of the pineapple pulp showed a very high value because of the high water content of the fruit, however the powder contained low moisture content.

Carbohydrate content of Kamias powder with maltodextrin was higher when compared with Kamias powder with Gum Arabic and Kamias powder with mixed carriers with values of 93.72%, 91.71% and 90.83%, respectively. Nevertheless, the carbohydrate content of the product was significantly high compared to the study reported by (Kouassi, *et al.*, 2013). Gum Arabic and Maltodextrin are carbohydrates in nature since they are both polysaccharides (Wilson, 2007). High content of carbohydrates signifies that the product can be a good source of energy to the body (Waziri, 2015).

The fat content of extract is 0.84% greater than the 0.31% fat content of Kamias powder with Gum Arabic, meanwhile the kamias powder with maltodextrin has 0.67% crude fat greater than kamias powder with mixed carriers with a value of 0.53% crude fat. Crude fat usually decreases after a sample has undergone a process like heating.

The extract contained 2.01% crude protein greater than 1.13% crude protein of Kamias powder with gum Arabic, 0.67% crude protein of kamias with maltodextrin is greater than 0.53% crude protein of kamias with mixed carriers. While the ash of kamias with gum Arabic contained 2.85% greater than the ash of the extract with 0.14% yet kamias powder with maltodextrin has 0.29% ash less than 2.38% ash of kamias powder with mixed carriers. In a study conducted by Grabowski (2007), the addition of encapsulating material increased the amount of soluble solids in the samples which in turn lowered the fiber, protein, and ash content of the powdered samples.

Physico-Chemical Analysis

The pH was analyzed using glass pH electrode at 10% aquaeous solution. The pH of Kamias powder with gum Arabic was high with a value of 4.05 compared to 2.54 and 3.90 pH values of Kamias powder with Maltodextrin and Kamias powder with mixed carriers, correspondingly. Since the pH of the Kamias powdered samples are below 4.6, it is considered as acid food which means more hydrogen ion is present in the product same with the study of (Bigueja, 2016).

According to Taufiq (2015), Water activity *(Aw)* is defined as the activity of free water in the food system which is responsible for any biochemical reactions. The result showed that kamias powder with gum arabic, kamias powder with maltodextrin and kamias powder with mixed carriers contained 0.30, 0.19 and 0.20, respectively. Based on the results, all the A_w values of the three powdered samples were lower than 0.6 which means the powders are considered to be microbiologically stable (Navas, 2011).

The bulk density of the Kamias powders ranged from 0.32g/ml to 0.42g/ml. In a study about Spray-dried soymilk (Ishiwu, 2014), it is proven that the inlet temperature greatly affects the of bulk density of the powder. The bulk density increases as the inlet temperature also increases. The result of bulk density of the samples is closely related to the reported bulk density of milk powders having less than 0.4g/ml (Neff & Morris, 2008 & Udensi & Okaka, 2000).

The method of refractometry was used in determining the total soluble solids of the samples. Products were diluted at 2% solution. The results showed that Kamias powder with mixed carriers obtained 95.03°B higher than 89.98°B of Kamias powder with Maltodextrin and 84.31°B of Kamias powder with gum Arabic.

Vitamin C Content

As a result of high temperatures and oxidation, the vitamin c content of the spray dried kamias powder was significantly decreased. In this analysis, titrimetry method was used to analyse the vitamin C present in the four formulations namely control (kamias liquid extract) and the three kamias powders with carriers of maltodextrin, gum arabic, and mixed. The vitamin C content in the control showed the highest amount of vitamin C with 8.70mg/100g.The control sample, which is the kamias liquid extract, was not subjected to spray drying for the purpose of comparing the initial vitamin C content present in the kamias liquid extract before processing it to thermal conditions. It can be shown in table no. 6 that kamias powder with gum Arabic showed the highest vitamin retention with 2.32mg/100g following kamias powder with maltodextrin of 2.26mg/100g. Lastly, kamias powder with mixed carriers showed the lowest vitamin C content with 2.22mg/100g.

Spray drying technique involves air pressure and high drying temperatures that can reduced vitamin c content while processing. According to Ruiz *et al*. (2009), vitamin c retention in spray dried passion fruit juice increased when the temperature was lowered and pressure was raised, reaching its maximum value at 180ºC and 0.2 MPa and the retention was higher at 10:5 % (w/v) concentration of the lactose-maltodextrin. Ruiz et al. (2009) also added that moisture content; oxygen, pH, and light all have a reducing effect in vitamin c retention but temperature far by the most influential factor that degrades ascorbic acid during drying. Rodriguez-Hernández *et al*., (2005) reported that at low temperatures, spray-dried powder of cactus pear retained higher amounts of vitamin c. While in the study of Tan *et al*. (2015), spray drying was used to encapsulate aqueous bitter melon extract however more than 80% of the saponins were not recovered after the process. High drying temperatures of 150-220°C used in spray drying was the cause of high loss of the saponins.

In a comparative study of microencapsulation efficiency conducted by Krishnan *et al.* (2005), microcapsules of cardamom oleoresin was evaluated using scanning electron microscopy. Results showed that using gum Arabic as wall material were nearly spherical providing greater protection for oleoresin microencapsulation, whereas the microcapsules using maltodextrin was broken. Mosquera et al. (2012) studied freeze-dried strawberry powder and found that gum arabic as a more effective wall material than maltodextrin. Due to higher apparent viscosity of gum Arabic, water emulsions convey a positive effect on microencapsulation efficiency (Silva *et al*., 2012). Another microencapsulation efficiency study conducted by Al-Ismail *et* *al.* (2015), results indicated that resistance of gum arabic to severe temperature during spray drying produced microcapsules with the highest ME with 99.6% while as whey protein isolate as wall material showed the lowest ME with 72%. Silva *et al*. (2012) also added that gum arabic presented higher vitamin C and phenolic compounds in spray dried camu camu powder than the powder acquired with maltodextrin, suggesting that gum Arabic was more effective in protecting bioactive compounds. Moreover, Nurhadi *et al*. (2012) studied the addition of gum Arabic and maltodextrin to vacuum and spray dried honey powders. Honey powders with gum Arabic had lower destruction effect than honey powders with maltodextrin for both types of drier.

Microbiological Analysis

Presence of microbes in processed and unprocessed food leads to food borne disease that can have an adverse effect in human health and trigger death. Unhygienic conditions, improper handling of equipment and poor cleaning conditions are just some of the factors wherein bacteria and microorganism may multiply and grow (Bigueja, 2016). Thus safety assessment of foods is prominent to meet quality standards. Based on the results given, there was no presence of coliform count of the kamias powdered juice with maltodextrin. This means that the amount of coliform passed the standard which is 10cfu/g. The total plate count of kamias powdered juice with maltodextrin was found to have 600cfu/g. This amount of total plate count is also within the allowable limit which is 1,000cfu/g.

Yeast and mold are acidophiles or acid loving microorganism that has a greater chance of survival in foods that have low ph conditions (Bigueja, C. 2016). Stability of foods is threatened with moisture content available in food ingredients. It is more likely for microorganisms to inflict damage on foods with high water content especially for molds to quickly spread and multiply (Saha et al., 2016). Kamias powdered juice is an acid food drink found to have low water activity. Thus if not properly stored, yeast and mold can outgrow bacteria and cause spoilage. Negative results showed for the yeast and mold count in kamias powdered juice. Therefore, kamias powdered juice is safe for consumption.

CONCLUSION

In conclusion to the present study, the researchers were able to develop an instant powdered kamias fruit juice extract through the process of spray drying and microencapsulation technique. Spray drying technique causes the biological active compounds such as vitamin C to reduce its content due to high temperatures used. The encapsulation method using maltodextrin and gum arabic as carriers showed different physical, chemical and sensorial properties based on the different analysis used. Kamias extract with gum arabic carrier showed better results to retain vitamin C due to its good emulsifying property rather than maltodextrin. The researchers were successful to conduct sensory evaluation to determine the most acceptable formulation. Using one way ANOVA, kamias extract with maltodextrin was the best formulation and was tested for microbial analysis. The result of the microbial analysis of the kamias powdered juice with maltodextrin was found safe for consumption. Microbial Proximate analysis and physicochemical analysis of the four formulations showed minimal difference. Even though the vitamin C content of the three formulations significantly decreased due to high temperature, the encapsulation of the extract were successful to retain considerable amounts of vitamin C.

RECOMMENDATION

The researchers recommend using other different processing techniques such as freeze drying that uses minimal temperature to assess vitamin C retention. The researchers also recommend testing the morphology of the kamias powder by scanning electron microscopy to understand the interparticle forces that influence the performance of powders. Furthermore, different formulations of maltodextrin and gum arabic should also be taken into consideration to test if the content of vitamin C would increase or decrease. The researchers also recommend using maltodextrin and gum arabic in different types of product. In addition, operating conditions such as the hot air outlet and inlet temperature of the spray drying method should be monitored to check if there is a change in the physical, chemical, and sensorial properties besides reducing its yield. Lastly the researchers would also recommend to specify the participant's demographies such as age bracket, gender and frequency of juice consumption and also to specify fruit sample inclusion criteria such as color, texture, size, and maturity.

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