

PHYSICAL, CHEMICAL AND QUALITY PROPERTIES OF AGGLOMERATES AND THEIR BEVERAGES FROM FLUIDISED BED DRYING OF CALAMANSI, PINEAPPLE AND STARFRUIT JUICE

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ABSTRACT

Calamansi, pineapple and starfruit juice can be converted into powder or agglomerate through the process of fluidised bed drying and agglomeration. One kilogramme of ground sugar was used as a carrier for the fluidised bed drying and agglomeration process. Essential minor additives i.e. anhydrous citric acid, flavour and permitted food colour were used to boost up flavour, sugar-acid balance and eye appeal of the product. Suitable process variables used were 40°C as the process temperature, 20 m/h as the volumetric airflow rate which resulted in an air velocity of 1.5 m/s, an atomisation pressure of 3 bar and a pump flow rate of 8 g/min. Fresh juice was used as a binder for the agglomeration process in the fluidized bed dryer which was sprayed at the beginning of the drying process. Moisture content and juice recovery of the fruits were determined. The colour, TTA, pH and viscosity of the juice were obtained and compared to that of the beverage. Organoleptic evaluation based on five sensory attributes of the juice was compared to the beverage. The particle size distribution of the agglomerates was determined by sieving. From the cumulative distribution plot, the median diameter for the carrier and agglomerates were determined. The colour, bulk density, moisture content and nutrient compositions of the agglomerates were analysed. Sorption isotherm of the agglomerates at the beginning of the storage period was analysed by determining the initial moisture content and water activity. Thus, the critical moisture content and the equilibrium relative humidity of the agglomerates were obtained from the graph. Microbiological quality remained the same throughout the 12 months of storage. Storage of the agglomerates for a period of 12 months at room temperature using laminated OPP/PE/AL/PP (with thickness 20µ:15µ:7µ:25µ) pouches did not change the physical, chemical and quality properties of the agglomerate.

Keywords : Agglomerate, Beverage, Chemical Properties, Juice, Physical Properties

1.0 INTRODUCTION

It is commonly known that pure juice derived from fruits is healthy. Fruit juices represent many people's favourite beverages; it offers a whole range of exciting tastes and flavours. Juices are now accepted worldwide as additives or supplements for many beverages [1]. The general perception of consumers towards these fruit beverages is the benefits to health. Moreover fruit juice beverages are marketed as fitness beverages and consumers like their 'naturalness'. They also like the taste and the convenience [2]. Variety is the predominant factor in which the fruit beverage market thrives. Exotic fruit flavours such as guava, papaya, kiwi and mango, once foreign to beverage ingredient labels, are now becoming popular in fruit beverages. Fruit beverages are increasingly being served with meals, the percentage has gone up from 5% in 1999 to 5.8% in 2000 [3]. Juice or ingredients derived from tropical fruits such as bananas, pineapple, mango and passion fruit may be used to add functionality to beverages. In addition to providing functionality to beverages and benefits such as texture and flavour, they have potential health benefits [4]. All beverages perform an essential nutritional function—that of hydration as well as giving enjoyment to the consumer [5]. Beverage creation is based on concept definition, ingredient selection, formula testing and processing which leads to quality and stable shelf life [6].

Besides fresh fruit beverages, there is an untapped market for ready-to-beverage fruit beverages. The ready-to-beverage fruit beverages available in the market are mostly processed from temperate fruits. These ready-to-beverage fruit beverages can be processed using the fluidised bed agglomerator or spray dryer by agglomeration [7]. Agglomeration is a process whereby several particles are caused to adhere to each other in random fashion, resulting in a porous, open structure aggregate of greater size than the original individual particle [8]. It is primarily a mixing-drying process in which both the powder and liquid ingredients are sprayed into a mixing chamber. The objective of the process is to obtain a homogeneous mixture with liquid evenly distributed throughout the powder [9]. There is very little information on the ready-to-beverage fruit beverages using the fluidized bed agglomeration process especially on tropical fruits. This study was undertaken to use the fluidised bed agglomeration process on calamansi, pineapple and starfruit juice to produce agglomerates as a ready-to-beverage fruit beverage when dissolved in water.

2.0 MATERIALS AND METHODS

2.1 FRUITS

Calamansi (*Citrus microcarpa*), pineapple (*Ananas comosus* (L)) variety Moris had colour index 7 and starfruit

(Averrhoa carambola (L)) variety B10 had colour index 5 [10] were purchased locally from the market and stored at ambient temperature for 24 hours before processing. Calamansi fruits were washed and crushed in the hydraulic press (Associated Instrument Manufacturer Sdn. Bhd., Kuala Lumpur) at a pressure of 100 bar. Pineapple was deskinning manually, sliced and crushed in a high output centrifugal juice extractor (Santos N°28, France). Starfruit was sliced manually and crushed in a high output centrifugal juice extractor (Santos N°28, France). The extracted single strength juice was strained using a muslin cloth to remove any trace of fibre.

2.2 MINOR ADDITIVES AND BINDER

2.2.1 CALAMANSI

Minor additives were added at very low dosage because they are essential elements that add definition in terms of color and character through flavour and acid-sugar balance in a beverage. For the calamansi agglomerate, the minor additives used in this study were 1% (10g) calamansi flavour (Bayer Malaysia Sdn. Bhd.), based on 1 kg of sugar, a solution weight of 1 g taken from 1% stock solution of tartrazine (Boustead Engineering Sdn. Bhd.), and 0.1 g taken from 1% stock solution of brilliant blue (Boustead Engineering Sdn. Bhd.) were adequate for the product (Table 1). The minor additives were added to 40 g of fresh calamansi juice to be sprayed at the beginning of the fluidised bed drying and agglomeration process. Three percent of anhydrous citric acid (Shin Heng Chemicals Sdn. Bhd., Malaysia) based on 1 kg of sugar (30 g) was mixed thoroughly with the carrier. It was found that this amount of citric acid produced a suitable sugar-acid level for this product.

2.2.2 PINEAPPLE

Similarly for the pineapple agglomerate, 1% (10 g) pineapple flavour (Bayer Malaysia Sdn. Bhd) and food color (1 g of sunset yellow and 2 g of tartrazine) were added to 40 g of fresh pineapple juice to be used as a binder for the agglomeration process in the fluidised bed dryer. Three percent of anhydrous citric acid (Shin Heng Chemicals Sdn. Bhd., Malaysia) based on 1 kg of sugar (30 g) was mixed thoroughly with the carrier. The binder was sprayed onto the carrier in the fluidized bed dryer at the beginning of the drying process to ensure all the minor additives were evenly distributed on the carrier. This was immediately followed by spraying of fresh pineapple juice.

2.2.3 STARFRUIT

For the starfruit agglomerate, the minor additives used were 1% (10g) starfruit flavour (Bayer Malaysia Sdn. Bhd.) based on 1 kg of sugar, solution weight of 2 g (from 1% stock solution) of tartrazine (Boustead Engineering Sdn. Bhd., Malaysia) and 3% anhydrous citric acid (Shin Heng Chemicals Sdn. Bhd., Malaysia) based on 1 kg of sugar was mixed thoroughly with the carrier. The starfruit flavour and food color which were used as a binder were added to 40 g of fresh starfruit juice for the agglomeration process in the fluidized bed dryer. The binder was sprayed onto the carrier in the fluidized bed dryer at the beginning of the drying process to ensure all the minor additives were evenly distributed on the carrier. This was immediately followed by spraying of fresh starfruit juice.

Table 1: Composition of minor additives added to juice as a binder

Composition	Calamansi	Pineapple	Starfruit
Citric acid (g)	30	30	30
Flavour (g)	10	10	10
Sunset yellow (g)	-	2	-
Tartrazine (g)	1	1	2
Brilliant blue (g)	0.1	-	-
Juice (g)	40	40	40

2.3 CARRIER

Granulated sugar was purchased from a local market. The sugar was ground using the disk mill (Safe World Enterprise, Model SWE-UM 50-SS, Shah Alam). Particle size distribution of the ground sugar was evaluated using ASTM mesh no. 20, 30, 40, 45, 50 and 60 on a Rotap device (Endecott Test Sieve Shaker, England) for 5 min. One kilogram of this ground sugar with a mean particle size of 425 micron was used as a carrier in the fluidized bed dryer and agglomerator.

2.4 EQUIPMENT AND INSTRUMENTATION

The fluidized bed dryer and agglomerator (Glatt model GPCG1, Germany) has a vertical column as the drying chamber and a product container which is cylindrical or slightly conical and has a 200 mm mesh at its base. The product container is placed in the machine during operation and heated air is drawn through the mesh to fluidise the carrier. A pneumatic sprayer with a nozzle is fixed at the upper position of the vertical column. The capacity of the equipment is 1-1.5 kg bed load. Inlet temperature of the fluidizing air, product temperature in the drying chamber and exhaust temperature were displayed on the LED control panel. The product and filter differential pressures, airflow rate, atomisation pressure were displayed on the control panel. These variables were recorded and printed on paper at 60 second intervals.

2.5 PROCESS PARAMETERS

The process parameters were determined after several trials. They were found to produce reproducible results. The spraying process was carried out by an atomised sprayer consisting of a nozzle of 1.0 mm diameter. The bed load used was 1 kg of carrier. The inlet temperature used was 70°C and the process temperature was 40°C in the drying chamber. The fluidizing airflow rate used was 20 m/h which resulted in an air velocity of 1.5 m/s. The atomization pressure at the spray nozzle was 3 bars. The flow rate of the peristaltic pump used was 8 g/min. The total drying and agglomeration duration was 3 hour. The amount of juice sprayed during the drying and agglomeration process was 1 kg.

2.6 FLUIDIZED BED DRYING AND AGGLOMERATION PROCESS

The process variables of the fluidized bed dryer and agglomerator were set before loading. Preheating of the drying chamber was carried out for 15 minutes on empty load until equilibrium had been attained which was indicated by stable inlet, product and drying temperatures. One kg of ground sugar with mean particle size of 425 micron was used as the carrier and loaded into the product container. After loading, heating was continued for another 15 minutes to ensure the carrier was

thoroughly heated to 40 °C. The shaking device was activated at 10 second interval for a duration of 5 seconds to prevent product from sticking to the filters.

When the operating conditions were stable which were shown by constant product temperature, spraying of the binder (to which minor additives were added) commenced at the beginning of the agglomeration process to ensure uniform blending of the ingredients. This was immediately followed by spraying of fresh juice. The spraying of fresh juice continued for 3 hours until the product was well agglomerated and fluidised. After spraying was terminated, drying process continued for another 30 minutes to ensure the agglomerate was thoroughly dried. At the end of the process, the product was unloaded from the product container and was cooled for 2 h at room temperature before product analysis were carried out (Figure 1).

2.7 PACKAGING AND STORAGE STUDIES

The product was packed in unprinted bags of laminated OPP/PE/AL/PP (with thickness 20µ:15µ:7µ: 25µ) with dimensions 10 cm x 13 cm containing 50 g each and heat-sealed. Prior to storage, 20 bags were randomly taken of which nine bags were for physico-chemical properties and nutrient analysis, five bags for sorption isotherm, four bags for organoleptic evaluation and two bags for microbiological evaluations at zero month storage. The remainder of the packs was stored at ambient temperature for one year. At the fourth, eighth and twelfth month of storage, eight bags were randomly taken of which two bags were for physico-chemical properties, four bags for organoleptic evaluation and two bags for microbiological evaluations.

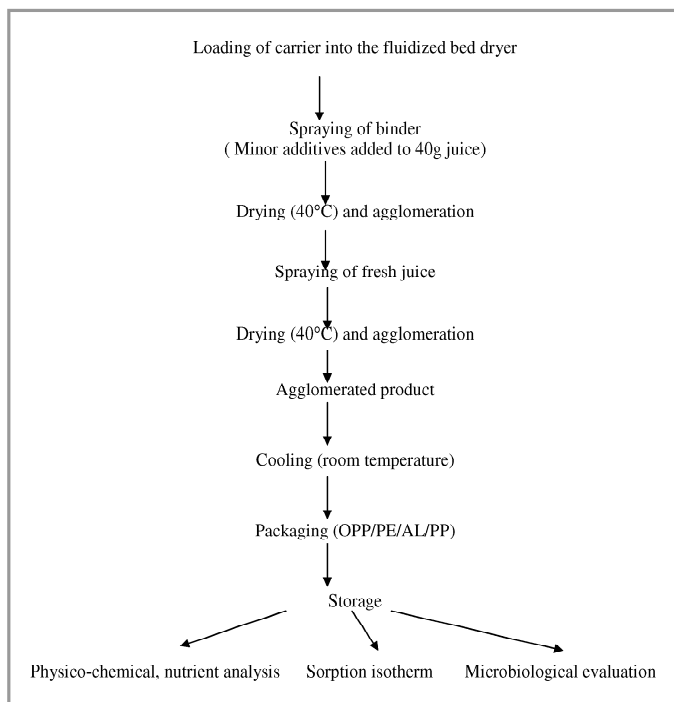


Figure 1: Fluidized bed drying, packaging and storage studies of agglomerate

2.8 PHYSICAL-CHEMICAL PROPERTIES OF FRUITS AND THEIR JUICES

Triplicate readings of the moisture content (wet basis) of the macerated fruit were determined by using the AOAC

Official Methods [11]. The juice recovery was determined from triplicate samples obtained at different batches of processing by calculating the percentage of the weight of extracted juice from the weight of the fruit. The juice pH was determined using the WTW pH meter (Werkstätten, Germany). Total soluble solid (TSS) of the juice was determined using the refractometer (Atago NI, range 0-32%, Japan). The juice viscosity was determined using the viscotester (Haake – Type VTO1, Germany) using spindle no. 4 at ambient temperature. Total titrable acidity (TTA) of the juice was determined by titrating a known weight of juice to pH 8.1 with 0.1N NaOH and the results expressed as a percentage of oxalic acid [11]. Triplicate readings of the juice colour were determined for L*, a*, b* values.

2.9 PHYSICO-CHEMICAL PROPERTIES AND NUTRIENT ANALYSIS OF AGGLOMERATE

The agglomerate was sieved through ASTM mesh no. 20, 30, 40, 45, 50 and 60 on a Rotap device to determine the particle size distribution. Three colour readings of the starfruit agglomerate was determined for L*, a*, b* values. Triplicate readings of the moisture content (wet basis) of the agglomerate were determined by using the AOAC Official Methods. Triplicate readings of bulk density of the agglomerate were determined [12]. This was measured as the weight of the agglomerate per unit volume of the graduated cylinder, which contained the agglomerate. Nutrient analysis of the agglomerate was carried out by using the AOAC Official Methods. The nutrient analysis carried out were protein, fat, ash, crude fibre, total sugars, energy, dietary fibre, calcium, iron, sodium, potassium, vitamin C and A.

2.10 SORPTION ISOTHERM

Sorption isotherm of the product at the beginning of the storage period was analysed according to the method of Labuza [13]. It is the relationship between the moisture content of a product and the relative humidity at which it is in equilibrium at the temperature [14]. A known weight of the product was placed in a desiccator, which was exposed to different saturated salt solutions of known relative humidity. The initial moisture content of the product was determined according to the AOAC Official Methods and the initial water activity value was determined by, $a_w = \frac{\%ERH}{100}$, where a_w = water activity and

ERH = equilibrium relative humidity.

The moisture content of the product at different relative humidity was determined and physical changes of the product were observed. Sorption isotherm curve was obtained by plotting the moisture content on the Y axis versus equilibrium relative humidity on the X axis. Each sample was indicated by a point on the plot and a smooth curve was generated through the data.

2.11 PHYSICAL-CHEMICAL PROPERTIES AND ORGANOLEPTIC EVALUATION OF BEVERAGE

The beverage was obtained by dispersing 100 g of agglomerate in 1 L of water at 5 to 15°C and stirring for about 1 minute [15]. L*, a*, b* values, TTA, pH, TSS and viscosity in triplicate readings were determined from the beverage. Organoleptic evaluation of the beverage compared to the fresh

juice was carried out. Twenty experienced panelists were asked to rate the flavour, sweetness, sourness, colour and overall acceptability using a 9-point hedonic scale where 1 = dislike extremely and 9 = like extremely.

2.12 MICROBIOLOGICAL EVALUATION

Plate count of total viable count (TVC), yeast and mould (Y&M) and coliform count was done on all samples in triplicates using pour plate method of ICMSF [16]. Plate count agar (Oxoid, Hampshire England), malt extract agar (Oxoid) and MacConkey broth (Oxoid) media were used to enumerate TVC, Y and M and coliform accordingly. A 10 gram of each sample replicate were weighed and then homogenised in a quarter strength Ringer buffer solution (Oxoid, Hampshire England) using laboratory blender (Stomacher 400, Seward England). Homogenate were then diluted decimally following which one mL of the selected diluted homogenate were pipetted into an empty petridish and then appropriate molten agar were then poured and mixed. For coliform count a most probable number (MPN) method was used. The Y and M plates were incubated at 32°C for 72 hours while the TVC plates and MPN tubes were incubated at 37°C for 48 hours. Viable counts of TVC and Y&M were determined by counting the number of colonies formed and reported as colony forming units per gram (cfu/g).

2.13 SAMPLING

Twelve batches of calamansi, pineapple and starfruit processing (from raw fruits until product and beverage analyses) were carried out over a period of 12 months. Out of these 12 batches, 3 batches were randomly selected for the purpose of this paper. The results presented in this paper are the average values of 3 batches.

3.0 RESULTS AND DISCUSSION

3.1 PHYSICO-CHEMICAL PROPERTIES OF JUICE AND BEVERAGE

Moisture content of the fruits was relatively high ranging from 83.80% to 90.12% (Table 2).

Juice recovery was moderately low for calamansi at 35.80%, higher for pineapple at 43.82% and relatively high for starfruit at 65.07% since no skin was removed which is consistent with the results shown by Shaw et al. [17].

Table 2: Mean values+ of moisture content and juice recovery of fruits

Characteristics	Calamansi	Pineapple	Starfruit
Moisture content (%)	83.80	88.36	90.12
Juice recovery (%)	35.80	43.82	65.07

+ Average of three batches

Extracted juice from calamansi is too sour to be consumed as a straight beverage. From preliminary trials, diluting fresh calamansi juice with 50% w/w water and 10% w/w sugar produced the most acceptable diluted juice as a straight beverage [7]. The colour of the diluted juice was greenish yellow colour values of $L^* = 23.1$, $a^* = -1.1$, $b^* = 20.9$, the TTA was low; the pH was low, a moderately high value of TSS and a non-viscous fluid (Table 3). The reconstitution of calamansi agglomerate in either cold or warm water is known as dissolution, dispersion or solubility. From preliminary sensory evaluation trials, a dissolution rate of 100g of agglomerate in 1L of water at 5°C produced acceptable flavour, sweetness, sourness

and colour of the calamansi beverage. Compared to the diluted juice, the colour of the calamansi beverage was light greenish yellow, the TTA was significantly different from the diluted juice, the pH was significantly different from the diluted juice, and the TSS and viscosity were not significantly different from each other.

Table 3: Mean values+ of colour, TTA, pH, TSS and viscosity of diluted calamansi juice and beverage

Characteristics	Diluted juice	Beverage
Colour (L^* , a^* , b^*)	23.1, -1.1, 20.9	87.3, -3.3, 18.5
Total titratable acidity (%)	1.5a	0.6b
pH	2.9a	3.1b
Total soluble solids	11.4a	12.8a
Viscosity at 30°C (cP)	3.5a	2.7a

Mean values with different letters in each row are significantly different ($p < 0.05$) based on t-test

+Average of three batches

The pineapple juice was light yellow with colour values of $L^* = 44.44$, $a^* = 1.14$, $b^* = 25.43$ (Table 4). The TTA level was low at 0.47% which is typical of this variety [18]. The pH was low at 3.75, it had moderately low TSS at 9.5 and the juice can be considered as a non-viscous fluid at 2.55 cP. The colour of the pineapple beverage was light yellow with values of $L^* = 64.62$, $a^* = 0.53$, $b^* = 25.90$ which was similar to the pineapple juice. The TTA of the pineapple beverage and pineapple juice was 0.40 and 0.47 respectively was not significantly different from each other. The pH of the pineapple beverage was 2.88 which were significantly different from the pineapple juice at 3.75. The TSS of the pineapple beverage and pineapple juice was 9.0 and 9.5 respectively was not significantly different from each other. The viscosity of the pineapple beverage and pineapple juice was not significantly different from each other at 2.77 cP and 2.55 cP respectively. The pineapple beverage had values that were close to the values of the juice therefore had acceptable characteristics of a fruit beverage.

Table 4: Mean values+ of colour, TTA, pH, TSS and viscosity of pineapple juice and beverage

Characteristics	Diluted juice	Beverage
Colour (L^* , a^* , b^*)	44.44, 1.14, 25.43	64.62, 0.53, 25.90
Total titratable acidity (%)	0.47a	0.40a
pH	3.75b	2.88a
Total soluble solids	9.5a	9.0a
Viscosity at 30 °C (cP)	2.55a	2.77a

Mean values with different letters in each row are significantly different ($p < 0.05$) based on t-test

+Average of three batches

The starfruit juice was dark yellowish orange with colour values $L^* = 6.31$, $a^* = -0.22$, $b^* = 8.76$ (Table 5). The TTA level was low at 0.25%, the pH value was 3.52, it had moderately low TSS at 8.0 and the juice can be considered as a non-viscous fluid at 3.0 cP. The colour of the starfruit beverage was light yellowish orange with colour values of $L^* = 77.30$, $a^* = -6.60$, $b^* = 23.14$. The TTA of the starfruit beverage was not significantly different from the juice at 0.21% and 0.25% respectively. The TSS of the juice and beverage was not significantly different from each other. The TSS of the beverage was 9.0 which was slightly higher than the TSS of the starfruit juice which was at 8.0. The viscosity of the beverage was not significantly different from the juice.

Table 5: Mean values+ of colour, TTA, pH, TSS and viscosity of starfruit juice and beverage

Characteristics	Diluted juice	Beverage
Colour (L*, a*, b*)	6.31, -0.22, 8.76	77.30, -6.60, 23.14
Total titratable acidity (%)	0.25a	0.21a
pH	3.52a	2.99b
Total soluble solids	8.0a	9.0a
Viscosity at 30 °C (cP)	3.0a	2.8a

+ Average from three batches of processing
Mean values with different letters in each row are significantly different ($p < 0.05$) based on t-test

3.2 ORGANOLEPTIC EVALUATION OF BEVERAGE

Results of organoleptic evaluation (Table 6) of the calamansi beverage showed that there was no significant difference in the colour of the beverage and the diluted juice. However, the flavour, sweetness, sourness and overall acceptability differed significantly with higher scores given to the beverage. This could be due to the reason that the diluted juice prepared from fresh fruits had a slight bitter after-taste which was not found in the beverage. As for the pineapple beverage, there was no significant difference in the colour, flavour, sweetness, sourness and overall acceptability of the beverage and the juice. However, all the attributes had higher scores given to the juice except for the overall acceptability which was given the same score for both the beverage and juice. For the starfruit beverage, there was no significant difference in the colour, flavour, sourness and overall acceptability of the beverage and the juice. However, the sweetness of the beverage was significantly different from the juice.

Table 6: Average scores+ for colour, flavour, sweetness, sourness and overall acceptability of beverage and juice

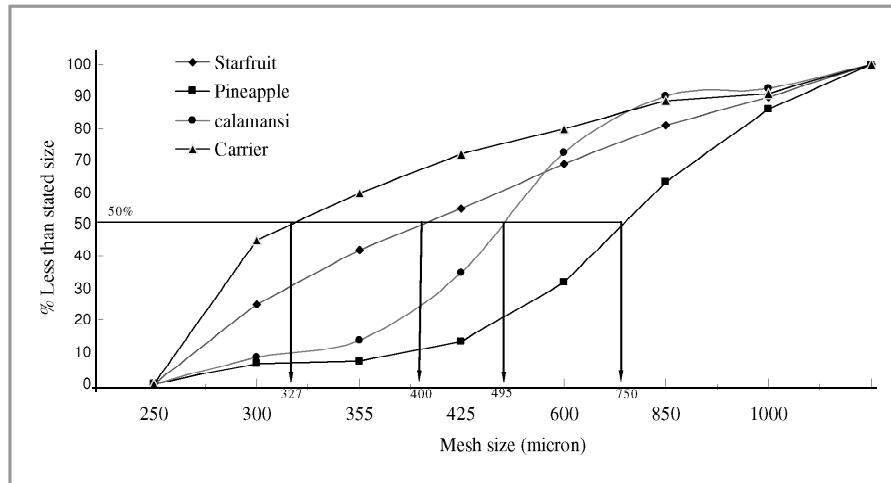
	Beverage/Juice	Colour	Flavour	Sweetness	Sourness	Overall acceptability
Calamansi	Beverage	6.4a	6.3a	6.2a	6.3a	6.3a
	Diluted juice	5.8a	4.8b	4.5b	4.4b	4.4b
Pineapple	Beverage	6.7a	6.3a	6.3a	6.2a	6.3a
	Juice	6.9a	6.5a	6.5a	6.3a	6.3a
Starfruit	Beverage	6.45a	5.45a	6.20a	5.60a	5.75a
	Juice	5.90a	5.95a	5.10b	5.65a	5.35a

Mean values with different letters in each column for each fruit juice type are significantly different ($p < 0.05$) based on t-test
+Using a 9-point hedonic scale where 1 = dislike extremely and 9 = like extremely

3.3 PARTICLE SIZE DISTRIBUTION OF CARRIER AND AGGLOMERATES

The purpose of particle size distribution is to determine the percentage frequency of distribution of particle sizes. The overall particle size distribution of the agglomerates and the carrier can be depicted clearly in the cumulative distribution plot (Figure 2) which shows how much material lies above or below a particular size [19]. The plots show that for a particular mesh size, the carrier has more percentage passed as compared to the agglomerates. The median diameter is the diameter for which 50% of the particles measured are less than the stated size [20].

In this figure, the median diameter for the carrier is 327 μm and the median diameter for the starfruit agglomerate is 400 μm , the calamansi agglomerate is 495 μm and the pineapple agglomerate is 750 μm indicating that the median diameter of the agglomerates is bigger than the carrier. This occurrence happened as a result of agglomeration, whereby several particles are caused to adhere to each other in random fashion, resulting in a porous, open structure aggregate of greater size than the original individual particle [8]. Therefore it considerably increased the surface area of this product to produce the desired porous structure. When this product is reconstituted through wetting of the agglomerate the fluid penetrates into the hollow

**Figure 2: Cumulative distribution plot of agglomerates and carrier**

interior space as a result of capillary absorption, dissolving the hollow bridges so that the individual particles come apart and are distributed in the fluid [21].

3.4 PHYSICO-CHEMICAL PROPERTIES OF AGGLOMERATES

The colour of the agglomerated calamansi powder was $L^* = 91.8$, $a^* = -7.1$, $b^* = 20.1$ (Table 7) indicating that it was pale greenish yellow which is the perceived colour of the calamansi skin. The colour of the pineapple and starfruit agglomerate was light yellow with color values $L^* = 90.57$, $a^* = -0.51$, $b^* = 25.93$ and $L^* = 92.93$, $a^* = -6.31$, $b^* = 23.95$ respectively.

The moisture content of the calamansi and pineapple agglomerate was 3.2 % and 3.1% respectively which falls under the category of milk powder which has moisture content of 2–4% [22]. The moisture content of the starfruit agglomerate was 1.64%. This value is lower than the value that Heiss [14] reported for safe storage where the moisture content of 2% is required for fruit juice powder such as pineapple and grapefruit juice powder.

The bulk density of the calamansi, pineapple and starfruit agglomerate was 0.6 g/mL, 0.67 g/mL and 0.63 g/mL respectively, well within the acceptable range of food powders which have densities in the range of 0.3–0.8 g/mL [22].

Table 7: Mean values+ of colour, moisture content and bulk density of agglomerates

Characteristics	Calamansi	Pineapple	Starfruit
Colour (L*, a*, b*)	91.8, -7.1, 20.1	90.57, -0.51, 25.93	92.93, -6.31, 23.95
Moisture content (%)	3.2	3.1	1.64
Bulk density (g/mL)	0.60	0.67	0.63

+ Average from three batches of processing

3.5 NUTRIENT ANALYSIS OF AGGLOMERATES

The nutrient analysis of the calamansi, pineapple and starfruit agglomerates (Table 8) showed that most of the compositions were relatively low except for the total sugars, total carbohydrate and energy value. This was reasonable because sugar was used as a carrier. Potassium, calcium and vitamin C contents were present in relatively high amount in the three agglomerates.

Table 8: Mean values+ of nutrient analysis of agglomerates

Chemical analysis	Composition in 100 g		
	Calamansi	Pineapple	Starfruit
Protein (N x 6.25) (g)	0.2	0.3	0.8
Fat (g)	1.0	1.3	0.1
Ash (g)	0.2	0.2	0.1
Crude Fibre (g)	0.9	0.2	0.6
Total Sugars (g)	94.5	93.5	93.7
Total Carbohydrate (g)	92.1	95.5	96.6
Dietary Fibre (g)	0.0	0.0	0.0
Energy (Kcal)	378	395	391
Calcium (mg)	6.9	4.0	1.0
Iron (mg)	0.6	0.8	0.6
Sodium (mg)	1	1.7	1.0
Potassium (mg)	64	70	59
Vitamin C (mg)	4.6	5.3	3.9
Vitamin A (mg)	0.7	3.0	6.0

+ Average of two analysis

3.6 SORPTION ISOTHERM OF AGGLOMERATES

The initial moisture content of the calamansi agglomerate was 3.21% and the water activity was 0.47. The critical moisture content of the calamansi agglomerate was 6.6% and the equilibrium relative humidity was 62% (Figure 3). At this point, the colour of the product changed slightly, the top layer of the product was still powdery but the bottom layer clumped slightly. For the pineapple agglomerate, the initial moisture

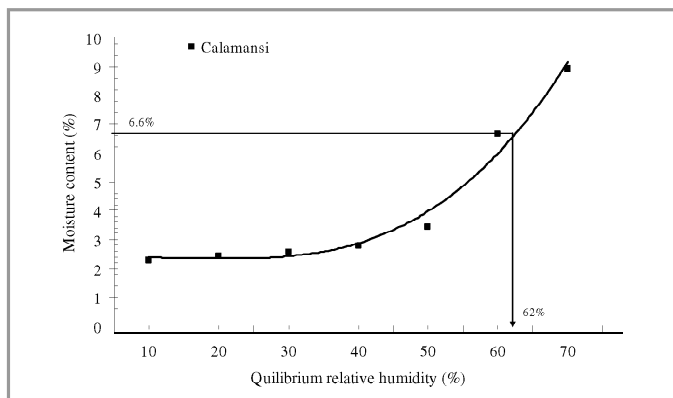


Figure 3: Sorption isotherm of calamansi agglomerate

content was 1.9 % and the water activity was 0.32. The critical moisture content of the pineapple agglomerate was 3.8 % and the equilibrium relative humidity was 60.5% (Figure 4). The product was damp and clumping occurred. The initial moisture content of the starfruit agglomerate was 2.52% and the water activity was 0.33. The critical moisture content of the starfruit agglomerate was 6.0% and the equilibrium relative humidity was 58.5% (Figure 5). Slight clumping occurred in this product.

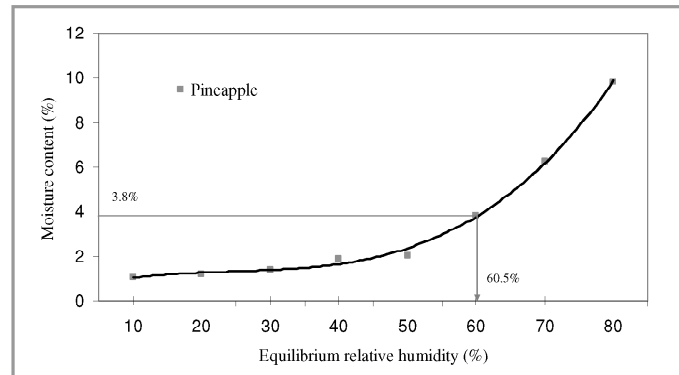


Figure 4: Sorption isotherm of pineapple agglomerate

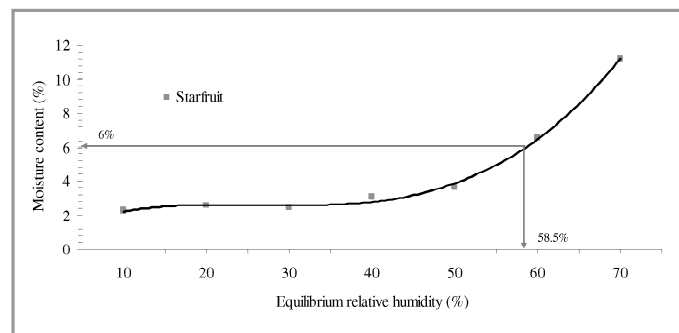


Figure 5: Sorption isotherm of starfruit agglomerate

3.7 MICROBIOLOGICAL QUALITY

Microbiological quality of the agglomerates remained in the same range and showed the same trend throughout the twelfth months of storage period as can be seen in Table 9. The aw value of the three agglomerates increased from 0.25 at zero month to 0.45 at the end of the storage period indicating a slight moisture ingress which was not detrimental. Aw is a value which indicates the free available water in the agglomerate that will allow microorganisms to grow. Even though the aw increased during storage, 0.45 was considered very low to allow for any growth to take place. Therefore, the product was considered very stable from microbial spoilage throughout the twelfth months of storage. This indicated that laminated OPP/PE/AL/PP (with thickness 20µ:15µ:7µ:25µ) was suitable to be used for the storage of the agglomerates for a period of 12 months at room temperature.

4.0 CONCLUSION

Calamansi, pineapple and starfruit agglomerate produced by fluidized bed drying and agglomeration process using ground sugar as a carrier produced a ready-to-beverage fruit beverage with acceptable properties. Suitable process variables were used during fluidized bed drying and agglomeration. The juice played a major role as a wetting

Table 9: Microbiological studies* of agglomerates stored for twelfth months

<i>Calamansi</i>	<i>Zero month</i>	<i>Fourth month</i>	<i>Eighth month</i>	<i>Twelfth month</i>
Total viable count (cfu/g)	3.0 x 10 ²	4.7 x 10 ²	3.5 x 10 ²	3.0 x 10 ²
Yeast & mould (cfu/g)	2.1 x 10 ²	<1.0 x 10	<1.0 x 10	<1.0 x 10
Coliform (MPN/g)	0	0	0	0
Water activity value (a _w)	0.25	0.47	0.46	0.45
<i>Pineapple</i>	<i>Zero month</i>	<i>Fourth month</i>	<i>Eighth month</i>	<i>Twelfth month</i>
Total viable count (cfu/g)	1.05 x 10 ³	7.5 x 10 ²	3.5 x 10 ²	4.0 x 10 ²
Yeast & mould (cfu/g)	2.1 x 10 ²	<1.0 x 10	<1.0 x 10	<1.0 x 10
Coliform (MPN/g)	0	0	0	0
Water activity value (a _w)	0.26	0.42	0.44	0.44
<i>Starfruit</i>	<i>Zero month</i>	<i>Fourth month</i>	<i>Eighth month</i>	<i>Twelfth month</i>
Total viable count (cfu/g)	3.7 x 10 ²	1.4 x 10 ²	6.5 x 10	3.0 x 10
Yeast & mould (cfu/g)	2.0 x 10 ²	3.0 x 10	1.0 x 10	1.0 x 10
Coliform (MPN/g)	0	0	0	0
Water activity value (a _w)	0.25	0.41	0.43	0.45

*Average of two analysis

agent for successful agglomeration which produced a range of suitable particle size distribution for rapid solubility. The physical and chemical properties of the beverage depended upon several chemical attributes of the product, namely color, flavour, TTA, pH and TSS which were contributed by the juice as well as the essential minor additives. Storage of the agglomerates for a period of 12 months at room temperature using laminated OPP/PE/AL/PP (with thickness 20µ:15µ:7µ:25µ) pouches did not change the physical, chemical and quality properties of the agglomerate.

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