



Foam–Mat Dehydration Effect on the Physical Properties, Micronutrient Contents and Sensory Characteristics of Pineapple and Cashew Apple Juice Powder

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Pineapple and cashew juices were subjected to foam–mat drying to investigate effect on the physical, nutrient and sensory properties of the juice powder. Improved pineapple and Brazilian cashew varieties, soybean and fresh eggs as raw materials were obtained from Anyigba, Nigeria. The fruits were separately prepared into pulpy juice (30 – 35% solids). While soybean and egg were prepared into soy protein isolate and liquid egg albumin respectively as foam agents for each juice at 2 concentration levels (1.0% and 2.0% of pulpy juice). The mixture of juice and foam agent in each case was whipped in food mixer for 10mins, as well as control sample. Stablefoam obtained was dried (60°C) in tray dryer, milled into powder (375 µ size), packaged (HDPE) and kept at ambient not longer than 2 weeks for physical, nutrient and sensory evaluation and statistical data analysis using standard methods. Foam-mat dried pineapple and cashew powder with added soy protein showed higher hydration capacity (2.0–7.4 mL/g powder) than similar samples containing egg albumin, regardless of the concentration (1–2%), while control samples had highest

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hydration values (7.4–8.5 mL/g powder). Bulk density (0.30–0.45 g/mL) decreased as foam agent level increased. Pineapple powder has lower reconstitution ratio (powder: water being 1:4) than cashew powder (1:5) which was not affected by the foam agent. Cashew juice powder had lower wettability values (39–40s) than pineapple (44–59s) and therefore cashew powder is more wettable at ambient temperature, $28\pm 2^{\circ}\text{C}$. Similarly, pH values of reconstituted cashew juice (4.4–4.7) were lower than those of pineapple (4.9–5.1). Ascorbic acid contents of 209–230 and 87–112 mg/100 g powder of cashew and pineapple respectively were obtained. The beta carotene contents of 0.19–0.34 and 0.05–0.06 mg/100 g powder for cashew and pineapple respectively were obtained which did not experience any loss. Reconstituted cashew juice powder with added soy protein and control had mean colour scores 5.7 – 6.6. Also, reconstituted pineapple powder samples with egg albumin (2.0%), soy protein (1.0%) and control had similar colour; with mean scores 6.2–7.0, while powder with no foam agent was significantly different ($p<0.05$). The taste and flavour of foam–mat dried cashew juice (2.0% soy protein) and control were similar, pineapple (2.0% egg white, 1% soy protein) and the control had similar high mean flavour and taste scores (6.2–7.0) and other samples are significantly different ($p<0.05$). Both cashew powder (2% soy protein) and pineapple (2.0% egg albumin) were adjudged most desirable.

Keywords: Foam–mat drying; cashew and pineapple; foam–agent; juice powder; physical and sensory attributes.

1. INTRODUCTION

Foam–mat dehydration is one of the emerging drying techniques suitable for food preservation. It involves drying of liquid or semi liquid food concentrate in the form of stabilized foam, prepared by the addition of foam agents and/or stabilizer in small quantity, followed by whipping in a continuous mixer to stiff foam. The stable foam is dried in heated air at relatively low temperature under atmospheric pressure [1,2] This drying technique has been variously used to produce free flowing powder of different food and related products such as liquid milk [3], mango puree [4], banana [2], apple [5]. It has also been reported that several foam agents suitable for different products have been used, such as egg white, protein isolates, carboxyl methyl cellulose, glyceryl monostearate (GMS), monoglyceryl palmitate (MGP), methyl cellulose and mixtures [4,6]. Researchers have also reported that great difficulties facing ordinary hot air drying, spray, drum, freeze drying techniques (such as flavour loss, colour degradation and high operating cost) have been overcome by using foam – mat drying option. It has several advantages over other forms of drying [1]. According to [4]. The natural flavour and colour of mango have been retained in foam – mat dried mango powder. Also, vitamin C contents of citrus have been retained in foam – mat dried citrus juice powder. In this work soy protein isolate and liquid egg albumin as natural foam agents, able to foam stable foam, retain flavour, colour, aid reconstitution, readily available and cheap have been used to produce both pineapple and cashew juice powder and the

effect on physical/chemical properties and sensory attributes of powder investigator.

2. MATERIALS AND METHODS

2.1 Sources of Materials

Ripe pineapple, PA (improved variety) and cashew apple, CA (medium Brazilian Jumbo variety) fruits were obtained from Anyigba and CRIN, Ocheja Station respectively. Soyabean (for soy protein isolate) and eggs (for liquid albumin) as foam agents were also obtained from Anyigba.

2.2 Sample Preparation

Pulpy fruit juice preparation: Both pineapple and cashew apple pulpy juices were separately prepared (30 – 35% total solids) and pasteurized according to method described [5,7].

2.3 Foam Agent Preparation

Egg white (albumin) was obtained from fresh whole egg and prepared for use as foam agent according to method described [8]. Soyabean was processed into soymilk using standard method [9] and then acidified to pH 3.5 by citric acid (5.0% solution) to coagulate soy protein which was removed by filtration and used as foam agent.

2.4 Foaming of Sample by Whipping and Drying Operation

Each prepared foam agent (egg white and soy protein isolate) was applied to each juice sample at 2 levels (as 1.0% and 2.0% of pulpy juice), the individual mixture in a mixer (Kenwood, Model BL 3) was whipped (1000 rpm) for 10 minutes and also control samples were similarly whipped (32-35°C). The foam void in each case was spread thinly (1 – 2 mm thickness) on a tray polished with antisticking agent (modified dextrin) and dried in a laboratory tray dryer (Bench Series Model) with fan at 60°C to a constant mass and scrapped. then incorporated with anticaking agent (calcium triphosphate as 0.1% of scrapped mass), dry milled (375 micron particle size) and packaged in heat sealed HDPE (0.22 mm gauge) bag, kept not longer than 4 weeks before use (for physical, chemical and sensory evaluation).

3. PHYSICAL PROPERTY ANALYSIS

3.1 Hydration (Water Absorption) Capacity

The method described [10] was used. 1 gram powder weighed into a conical graduated centrifuge tube, 10mL distilled water added, mixed, centrifuged at 5,000 rpm for 30 min. Then allowed to stand for 30 min. Free water volume was recorded, weights of tube before mixing with water and after decanting were recorded.

Volume of water absorbed (mL) = Wt of water absorbed (g) = Wt of tube after decanting (g) – initial Wt before mixing with water (where Wt is weight).

Water absorption capacity is expressed as mL water/g powder. Three separate measurements were made for each powder and average determined.

3.2 Bulk Density Determination

Juice powder bulk density was determined according to method described [2]. It is the ratio of unit mass (g) of powder to the volume (mL) it occupies, expressed as g/mL.

3.3 Reconstitution Ratio Determination

The method described according to [2,11] was used. 1.0 g powder sample was collected in a crucible and water added in ratios (1:1; 1:2; 1:3;

1:4; 1:5; 1:6; 1:7; 1:8) gradually to make the mixture have the same consistency with that of fresh pulpy juice by observation. The appropriate ratio of powder: water to make resemble original fresh juice is the reconstitution ratio and therefore recorded for each sample. Three measurements were made and the average value taken.

3.4 Wettability Determination

AOAC method [12] described was used to determine wettability of juice powder samples. 1 gram juice powder was weighed into 25 mL graduated cylinder with diameter 1.0 cm. Hand palm was placed over the open end and then inverted, and clamped at a 10.0 cm height from the surface of a 600 mL beaker containing 500 mL distilled water. The finger was removed and sample allowed to drop. The time taken (s) for the sample to become wet was taken and recorded as wettability, 3 determinations for each sample were made and average value recorded.

3.5 pH Determination

The method described [2] was used to determine the pH values of foam – mat dried juice powder samples reconstituted into indirect juice. 20 mL indirect juice from each powder was used (uniscopes pH meter, model pHs-3B, England). pH electrode was washed with distilled water, allowed to stabilize, then values taken thrice.

3.6 Micronutrient Content Analysis

3.6.1 Vitamin C (as Ascorbic acid) content determination

Vitamin C content was determined as described [12]. 2 gram juice powder was weighed and mixed in 100 mL distilled water. Mixture was filtered and clear solution obtained. 2.5 mL acetone (as stabilizer) was added, and 10 mL of the clear solution was pipetted in triplicates into conical flasks. It was titrated against indophenol dye solution (2, 6 – dichlorophenol indophenol) to a faint pink colour which persisted for 15 seconds; titre value (v) was recorded.

$$\text{Vitamin C content (mg/100mL)} = 20 (v) (c)$$

Where

v = volume of indophenol used (mL)
C = Dilution constant.

3.6.2 Beta carotene (Vitamin A precursor) content determination

The method described [12] was used to determine beta carotene content. 5 gram juice powder was extracted with 40mL hexane: 60mL ethanol mixture, then mixture transferred to a separating funnel and swung vigorously after adding 20mL of 20% sodium chloride solution. The mixture was allowed to settle, then lower layer was run off. The top layer of hexane containing the carotenoids was collected, diluted and the optical density measured using spectronic 20 at 440 nm wavelength. 3 determinations were made for each sample and mean value calculated.

3.6.3 Total titratable acidity determination

It was carried out according to [12] method which involved the experimental samples. 10 gram powder was blended using 90 mL distilled water and filtered. 20 mL filtrate with 2 drops phenolphthalein indicator was titrated with 0.1M NaOH. Average of 3 titre values determined and recorded as V (mL). 1 mL 0.1 M NaOH is equivalent to 0.007005 g citric acid. Dilution factor is 10.

$$\begin{aligned} \text{Acidity (as citric)} &= V \times 0.0075005 \times 10 \text{ g} \\ &\quad \text{citric/10 g powder} \\ &= V \times 7.005 \text{ mg/100g powder} \end{aligned}$$

3.6.4 Moisture content determination

Moisture content of samples were determined using oven drying method as described [10]. Oven dried evaporating dish was weighed, added 5g powder, transferred to hot air electric oven (Model J02707, Michel, England) set at 105°C for 3 hrs, cooled in desiccators for 1 hr and weighed.

$$\begin{aligned} \% \text{ Moisture content (dry weight basis)} \\ &= \frac{\text{Loss in sample weight as moisture (g)} \times 100}{\text{Original sample weight (g)} - \text{Loss in weight (g)}} \end{aligned}$$

Triplicate values were obtained for each sample.

3.7 Sensory Evaluation and Data Analysis

The juice powder samples (coded) were reconstituted at the ambient temperature (28±2°C), powder: water ratio being 1:4 and 1:5 for pineapple and cashew respectively, the control sample (fresh direct juice) also included. They were presented separately for sensory quality evaluation (colour, taste, flavour,

consistency) and acceptability to 10 untrained panelists who are familiar with the juices, using a 7 – point hedonic scale rating. Sensory scores were subjected to statistical analysis, using ANOVA and Tukey's LSD method of mean separation [13, 14]

4. RESULTS AND DISCUSSION

Effect of dehydration on the physical properties (hydration capacity, bulk density, reconstitution ratio, wettability) of foam – mat dried pineapple and cashew apple juice powder.

Table 1 shows the hydration or water absorption capacity; bulk density, reconstitution ratio, wettability and pH values of reconstituted product of pineapple and cashew juice powder samples.

The hydration capacity (HC) of pineapple (PA) and cashew (CA) powder samples ranged from 6.9 – 8.2 and 7.0 – 7.4 mL/g powder respectively. It was found that control samples had highest HC values for both pineapple and cashew. While samples incorporated with soy protein as foam agent (1% and 2%) were higher than those samples with egg white foam agent in both pineapple and cashew powder. The concentration of foam agent (1% and 2%), whether soy protein or egg white did not obviously affect hydration capacity. Occluded air pockets in foam – mat dried powder might be responsible for reduced hydration capacity than non foamed powder with little or no air pockets. Similar lower H.C. of foam – mat dried banana powder using GMS than non foamed banana has also been reported [2] and concentration of not greater than 4% foam agent was not found to affect hydration capacity.

Bulk density of pineapple and cashew juice powder ranged from 0.34 – 0.42 and 0.30 – 0.45 g/mL respectively. It follows similar trend as H.C, non – foamed powder with higher values (0.42 – 0.45 g/mL), and it slightly decreased as concentration of foam agent increased from 1 to 2% in both powders. Low bulk density value is an indication that foam – mat dried pineapple and cashew with 2% foam agent incorporated would occupy more volume (to become lighter) than sample with 1% foam agent whether soy protein or egg white which also becomes lighter particle than sample without any foam agent and regarded as denser particles. The presence of air spaces/pockets in the powder particles is equally responsible for low bulk density values.

Table 1. Some physical properties of foam – mat dried pineapple and cashew juice powder

Physical property		Samples				
		NFJ	EWJ 1.0%	SPJ 1.0%	EWJ 2.0%	SPJ 2.0%
Capacity (mL/g)	PA	8.2±0.1	7.2±0.2	7.8±0.0	6.9±0.1	8.0±0.2
	CA	7.4±0.04	7.0±0.02	7.1±0.03	7.0±0.02	7.1±0.01
Bulk Density (g/mL)	PA	0.42±0.1	0.37±0.3	0.38±0.3	0.34±0.3	0.35±0.3
	CA	0.45±0.03	0.40±0.01	0.40±0.01	0.30±0.02	0.43±0.01
Reconst. ratio (powder: water)	PA	1:4	1:4	1:4	1:4	1:4
	CA	1:5	1:5	1:5	1:5	1:5
Wettability(s)	PA	59±0.25	53±0.10	55±0.30	44±0.04	48±0.20
	CA	44±0.02	40±0.0	40±0.00	39.0±0.01	40.0±0.0
pH Value	PA	4.6±0.02	4.9±0.01	5.0±0.03	4.9±0.04	4.9±0.2
	CA	4.4±0.10	4.6±0.03	4.5±0.01	4.6±0.02	4.7±0.01

Values represent average of 3 determinations (\pm SD)

Sample	Codes
NFJ	– Non foamed juice powder
EWJ (1.0%)	– Egg white foamed juice powder (1.0%)
SPJ (1.0%)	– Soy protein foamed juice powder (1.0%)
EWJ (2.0%)	– Egg white foamed juice powder (2.0%)
SPJ (2.0%)	– Soy protein foamed juice powder (2.0%)
PA	– Pineapple
CA	– Cashew apple

Reconstitution properties expressed as ratio of powder: water, showed ratios of 1:4 and 1:5 (powder: water) for foam – mat dried pineapple and cashew juice powder respectively at the ambient temperature. Pineapple powder has lower reconstitution ratio, than cashew inspite the same moisture content of powder, because pineapple needed to be reconstituted into pulpy juice (viscous liquid) and cashew powder into free flowing juice (not viscous at all) to resemble the initial consistency of juice dehydrated into foam – mat dried powder. Both foam agents used (egg albumin and soy protein) and concentration were not found to affect reconstitution ratio of the fruit powders.

The pH values of reconstituted foam – mat dried pineapple juice (4.9 – 5.1) was slightly higher than the reconstituted sample without any foam agent (4.6). The foam – mat dried cashew juice pH was also higher (4.5 – 4.7) than the non foamed sample (4.4). Increase in pH of foam – mat dried product is due to addition of foam agents that have high pH values close to 7 (neutrality). Apparently, change in pH did not seem to affect taste of reconstituted powder as sensory evaluation revealed. Slight increase in pH of foam – mat dried mango reconstituted into juice (pH 5.5) was reported in the work carried out [4].

4.1 Wettability

Wettability value of pineapple powder ranged from 44 to 59s which was found to reduce as the concentration of both foam agents increased from 1% to 2%. Low value shows high wettability, while wettability of cashew juice powder ranged from 39 to 44s lower than the value for pineapple and which seemed not to be affected by foam agent concentration.

Low wettability values indicate greater porosity, and wettability of powder. Therefore foam – mat cashew juice powder with lower values than pineapple are more wettable. Similarly foam – mat dried pineapple powder with higher concentration of foam agent are more porous and wettable.

4.2 Retention of Vitamin C and Beta Carotene Contents in Foam – Mat Dried Fruit Juice Powder

The ascorbic acid, beta carotene, moisture and acid contents of experimental samples of foam – mat dried pineapple and cashew juice powder are shown in Table 2.

The ascorbic acid content of pineapple juice powder ranged from 87 – 112 mg/100g sample which increased with concentration of both foam agents (egg white and soy protein isolate). Juice

powder sample without foam agent had the lowest ascorbic value. About 80 – 87% of the initial ascorbic acid content (112 mg/100L) in pineapple was retained in foam – mat dried powder, while 65% was retained in un-foamed juice powder.

Cashew juice powder ascorbic acid content was found to range from 209 to 230 mg/100 g, which also showed similar increase with foam agent concentration as pineapple juice powder. While between 92 and 95.8% of the original ascorbic acid content was retained in foam – mat dried cashew juice powder. Both egg white and soy protein seemed to have equal tendency to enhance ascorbic acid retention. Prevention of ascorbic acid loss by the foam agents suggests that they might have some antioxidant property as well.

Similar prevention of vitamin C loss in foam – mat dried tomato powder by using GMS has been reported [1].

The beta carotene content of foam – mat pineapple juice powder ranged from 0.050 to 0.06mg/100g powder which did not seem to experience loss and not affected by neither foam agent, concentration nor drying process. The values for cashew juice powder ranged from 0.19 to 0.34 mg/100g powder showing greater carotene content more than pineapple.

However, beta carotene content decreased (slightly) with increased concentration of both egg white and soy protein foam agents leading to retention of between 56 and 62% the non foamed cashew juice powder had greater content of β -carotene retained (0.31mg/100g, equivalent to 91.2% retention) showing that neither egg white nor soy protein can help retain β -carotene in foam – mat dried cashew juice powder. This also suggests that beta carotene is probably chelated by formation of complexes with the foam – agent which was not found to affect its reconstitution.

4.3 Acid Content of Foam – Mat Dried Juice Powder

Acidity of pineapple – powder expressed as citric acid ranged from 5.4 – 16.0 mg/100g powder) which was found to reduce with increased concentration of both egg white and soy protein foam agents. This is an indication that the foam agents contain basic components that can cause partial neutralization reaction in foam void during drying. Similar reduction in citric acid content of cashew juice powder occurred, as foam agent concentration increased (value ranged from 9.1 – 9.6 mg/100g powder). Variation of acid level is also reflected in the pH values of the juice powder samples.

Table 2. Moisture, vitamin and acid contents of foam – mat dried pineapple and cashew juice powder

Analytical Parameter		Samples					
		FRJ	NFJ	EWJ 1%	SPJ 1%	EWJ (20%)	SPJ (20%)
Moisture (%db)	PA	71±0.6	131±0.01	13.0±0.01	13.0±0.02	13.0±0.03	13.0±0.00
	CA	88±0.5	15.0±0.0	12.5±0.02	13.0±0.01	13.0±0.00	13.1±0.03
Ascorbic acid (mg/100 g)	PA	112.2±0.6	6.87.0±0.4	91.0±0.3	91.0±0.3	92.4±0.4	91.2±0.3
	CA	230.0±0.3	198.1±0.5	209.1±0.4	209.0±0.3	220.0±0.6	218.1±0.5
Beta carotene (mg/100 g)	PA	0.018±0.01	0.052±0.00	0.061±	0.054±0.00	0.060±0.01	0.050±0.00
	CA	0.34±0.01	0.31±0.02	0.22±0.05	0.25±0.05	0.21±0.02	0.19±0.05
Acid content as citric (mg/100 g)	PA	13.3±0.1	12.4±0.3	16.1±0.03	16.4±0.01	5.4±0.02	8.6±0.01
	CA	9.6±0.00	9.7±0.01	9.5±0.01	9.6±0.05	9.1±0.00	9.3±0.05

Values represent average of 3 determinations (\pm SEM)

Sampl	Codes
PA	Pineapple
CA	Cashew apple
FRJ	Fresh juice
NFJ	Non foamed juice powder
EWJ (1.0%)	Egg white foamed juice powder
SPJ (1.0%)	Soy protein foamed juice powder
EWJ (2.0%)	Egg white foamed juice powder
SPJ (2.0%)	Soy protein foamed juice powder.

4.4 Effect of Dehydration on Sensory Attributes of Reconstituted Foam – Mat Dried Juice Powder

Table 3 shows the mean sensory scores of reconstituted juice powders

The colour (pale yellow) of reconstituted cashew juice samples SPJ (1.0% and 2.0%) and control (DRJ, CA) were similar with the mean scores of 5.2 – 6.6 range, while cashew samples EWJ (1.0% and 2.0%) and NFJ (without foam agent) were also similar, and found to be significantly different ($P \leq 0.05$) from the control. On the other hand, the golden yellow colour of reconstituted pineapple samples EWJ (1.0% and 2.0%), SPJ (1.0% and 2.0%) and control (DRT, PA) were similar with the mean scores of 6.2 – 7.0 range, while pineapple sample NFJ (without foam agent) with mean score 5.5 was significantly different ($P \leq 0.05$).

This is an indication that soy protein foam agent is suitable to retain colour of both cashew and pineapple reconstituted juice, while egg white is only suitable to retain pineapple juice colour and not cashew juice.

Cashew sample SPJ (2.0%) and control (DRJ cashew) have similar taste with mean scores of 6.3 – 6.9, also cashew samples NFJ, EWJ (2%)

and SPJ (1%) was significantly different ($P \leq 0.05$) but not rejected pineapple samples. EWJ (2%), NFJ (foamed) and DRJ (control) had similar most acceptable taste with mean scores sample of 6.0 – 6.8. Also, taste of pineapple samples EWJ (1%), SPJ (1% and 2%) were similarly acceptable with mean scores 5.7 – 5.9 range. The flavour and consistency of the cashew samples followed similar pattern as the taste. Pineapple sample EWJ (2.0%) and DRJ (control) had similar high mean flavour scores (6.2 – 7.0) and consistency scores (6.0 – 6.6), while samples NFJ, and SPJ (2.0%) had the least mean flavour and consistency scores (5.6 and 5.0 – 5.3 respectively). Loss of colour and flavour was greatest in samples without foam agent due to heat damage effect, and most flavour found retained in samples incorporated with foam agents, especially egg albumin and soy protein isolate at 2.0% and 1.0% concentrations respectively.

However, sensory tests revealed cashew sample SPJ (2.0%) and pineapple samples, EWJ (2.0%) and SPJ (1.0%) as most desirable. Hence, egg white and soy protein isolate are found suitable as foam agents for dehydrating cashew apple and pineapple juices into powder, which have to be applied at different concentrations.

Table 3. Shows the mean sensory scores of reconstituted cashew apple and pineapple juice powders

Sensory Attribute	Samples						
		NFJ	EWJ 1.0%	SPJ 1.0%	EWJ 2.0%	SPJ 2.0%	DRJ
Colour	CA	4.4 ^b	4.0 ^b	5.2a	46.0 ^b	5.8 ^a	6.6 ^a
Colour	PA	5.5 ^b	6.4 ^a	6.2a	6.5 ^a	6.2 ^a	7.0 ^a
Taste	CA	5.5 ^d	4.8 ^{dc}	5.3d	5.0 ^d	6.3 ^c	6.9 ^c
	PA	6.0 ^b	5.7 ^c	5.9c	6.4 ^b	5.7 ^c	6.8 ^b
Flavour	CA	5.4 ^f	4.6 ^{ef}	5.0f	5.0 ^f	6.3 ^e	6.7 ^e
	PA	5.6 ^e	5.9 ^d	5.9d	6.2 ^d	5.6 ^e	7.0d
Consistency	CA	6.1 ^g	4.6 ^h	5.0h	5.0 ^h	6.3 ^g	6.7 ^g
	PA	5.3.0 ^f	4.8 ^e	5.8e	6.0 ^e	5.0 ^f	6.6 ^e

Values represent means of 10 determinations, Means in a row with the same superscripts are not significantly different ($P \leq 0.05$)

Sample	Codes
NFJ	Non foamed juice powder
EWJ	Egg white foamed juice powder
SPJ	Soy protein foamed juice powder
DRT	Direct juice from fresh cashew apple and pineapple fruits (control).

5. CONCLUSION

It is technically feasible to produce quality foam-mat dried cashew apple juice powder using soy protein isolate as foam agent. While both egg white and soy protein isolate foam agents are found equally suitable for producing pineapple juice powder with desirable attributes.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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