Drum drying of banana pulp on the sorption isotherm and flexible packaging requirement

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ABSTRACT

Banana (musa *Sapientum var* Cavendish) pulp was obtained and drum dried with varied concentrations of prepared cornstarch, skimmed milk powder and sugar. The water activities of the resulting powders were determined and from which the packaging requirement of the free flowing combinations was determined. The dried banana pulp was found to be thermoplastic and highly hygroscopic. The thermosplasticity has been proved in model system to be mainly due to the sugars naturally present or added. Cornstarch added up to a level of 7.5% on the fresh weight of the pulp aided drying but did not reduce hygroscopicity skimmed milk powder similarity of 5.10% level improved the drying. Characteristics slightly. The dried product had moisture content of approximately 2.0% which was equivalent to (a_w)of 5.11 of 38.5^{o}C. The storage condition should be such that does not go beyond 0.15 which is equivalent to about 2.5% moisture. In this range of (a_w), Polyethylene (density 0.954) of thickness more than 5 mil or saran 517 of 1 mil thickness would be expected to keep the product in good condition at 30^{0}C for 300 days.

Key words: Banana, drum drying, thermoplasticity hygroscopicity, water activity, polyethylene, saran.

INTRODUCTION:

Banana is an important fruit consumed extensively throughout the world for its flavour and food value. It is grown extensively in the tropics where the fruit is available throughout the year. It is canned in the form of slices in syrups or dehydrated either in the form of slices, chips etc or the pulp is asceptically packed either in cans or in drums for use in sauce, ice-cream toppings, syrup manufacture, cake, doughnuts etc (Fisher, 1961). Strained pulp of banana custard is prepared commercially in canned form for use as infant food but drum drying technique has been successfully used for preparing dried banana products from banana puree (Subrahmanyan, 1959). Zdenka and Coussin (1965) produced from Cavendish banana dehydrated flakes by means of a stainless steel double-drum drier in which a tasting panel adjudged the flakes produced from banana which had been steam blanched prior to dehydration to be superior to those prepared from unblanched fruit. They further established that the optimum operating conditions for drum-drying the banana pulp were; drum distance, 1.0mm; product retention time, 51 sec; steam, 29529kg.m-^{2} (Convertion factor: 1Ib/in^2 = 703. 06kg/m^2) 421b/ in 2 or and drum surface temperature 145^{0}C. At this condition, the average composition of ripe Cavendish bananas and of the dehydrated flakes produced from them were compared thus:

Component	Ripe Banana	Dehydrated Flakes
Moisture (%)	70.4	2.6
Ash (%)	0.72	3.2
T.S.S.(%)	19.0	65.0
Acidity as citric (%)	0.34	1.6
PH	5.0	4.9
Vitamin C (mg/100g)	10.6	22.5

Siddappa and Ranganna (1961) prepared banana custard powder by drum drying. In the preparation, strained banana pulp (3.2%) was mixed with skimmed milk powder(160g) sugar, (160g) corn starch (80g) precooked; egg yolk (80g) and lemon juice (80g) with pH adjusted to 5.0. The mixture was cooked and drum dried at the following conditions:

Width of the drum………………. 194mm
Diameter of the drum…………... 153mm
Speed of rotation of drums……. 3rpm
Space between the two drums……. 0.225mm
Steam pressure in the drums……. 45699kg.m-^{2}

The dried banana product was found thermoplastic in nature as it was not easily scraped off the drums surface. The product was sticky when hot and stucked on the scrapper which distrupted the drying operation. To overcome the thermoplasticity and stickiness, Eoklin (1965), Salunkhe and Dessai (1984) suggested addition of starch and other additives, Lazar and Ramsey (1976) found that drying in stages enabled successful drum drying of low melting foods which are thermoplastic or heat-sensitive. Further, the drum dried product was hygroscopic and required moisture proof packaging. The moisture exchange between a product and its surrounding atmosphere as well as its biochemical changes can be controlled by providing adequate packaging (Sagar, 2001). Also Sagar and Neelavathi (2005) in their study of the influence of different packaging materials (200, 400 gauge LDPE, and 200 gauge HDPE) on the quality of Ready-to-eat (RTE) dehydrated carrot shreds found that HDPE 200 gauge pouch was suitable in retaining higher quality of total carotenoids and B-carotene as well as high sensory score during storage of the ready-to-eat (RTE)-carrot shreds.

Also since a sorption isotherm depicts the equilibrium relationship between moisture content and water activity at a specific temperature, data on these are used in the following ways:

i. Determinationof its hygroscopicity;
ii. Definition of moisture and equilibrium relative humidity conditions under which product deterioration can occur i.e. the critical moisture content and equilibrium moisture content values.
iii. Establishing safe moisture limit, using the BET and GAB theories (Iglesias and Chirife 1976; Bizot, 1993; Diosad *et al* 1996; and Hallstrom *et al* 1996) of monomolecular absorption and
iv. Determination of package characteristic required to assure product protection during the projected shelf life (Kumar, 2000).

Jideani *et al.* (1995) used these theories in the determination of the moisture adsorption isotherms of preserved “*Fura*”.

The present study relates to the drum drying of banana pulp, with the view to determining the effect of removal of sugar and additions of various concentrations of starch, sugar and skimmed milk powder on drum drying of banana pulp and the water activity of the dried product in relation to its flexible packaging requirements.

MATERIALS AND METHODS:

Model system: A pre-mix consisting of cornstarch, sucrose glucose and skimmed milk powder was prepared. The corn starch was cooked to gelatinization with the required quantity of milk powder and drum dried with or without added sucrose, glucose and skimmed milk powder at concentrations given in Table I. This is in line with the suggestion of Siddappa and Ranganna (1961) The drying conditions were:

Steam pressure…………………… 29259 kg. M^{-2}

Drum speed ………………………..4rpm

Gap between drums,…………… 0.254mm

Determination of the constituent responsible for the dried product:

Approximately 5.0kg batch of peeled banana was blended in 10 litres of 95% ethanol in laboratory blender for 2 mins. and strained using a muslin cloth. The residue was mixed with 200 ppm $S0_2$ and made up to 2.88kg with water, again blended and divided into 5 lots as follows:

(a) 550g. of the pulp was mixed with water, again made up to 1kg. with water and drum dried.

(b) The pulp (550g) was mixed with 160g.of sucrose and made up to 1kg. with water and drum dried.

(c) Same as in (b) except that glucose was used in place of sucrose.

(d) Same as in (b) except that 80g. of glucose and 80g. of sucrose were used instead of 160g. of sucrose.

(e) The pulp (550g) was mixed with 75g. of corn starch powder which has been precooked in minimum quantity of water and made up to 1kg. with water.

The prepared lots were blended in the laboratory blender for 2 mins. before drying. The drying conditions were the same as before except that steam pressure was maintained at 45699kg.m^{-2}

Studies on drum drying of banana pulp.

Ripe bananas of 10kg wt. (Cavendish variety) were peeled and blended in a blender with 200ppm SO_2 for 2 mins. This mixture was dispensed with precooked corn starch, sugar and skimmed milk powder at concentrations shown in Table 2. The mixture was again blended and drum dried under the conditions stated earlier, except that the steam pressure was maintained at 35153kg.m^{-2}. The hot dried samples were collected aseptically in tins having tight fitting lids allowed to cool hand crushed filled into polythene bags and stored in the desiccators.

Determination of water activity (a_w).

To study the effects of various treatments on the water activity (a_w), the dried samples were stored at different relative humidites (RH).

The equilibrium relative humidity (ERH) relationships were determined by winks weight equilibrium method of Ranganna (1977) in which saturated solutions of different salts having definite RH were used to obtain a_w in the range of 0.11 – 0.791 at 28.5^{0}C. Sulphuric acid was used to get water activity of less than 0.001. The hand crushed samples were powdered using a dry blender. Two grams of each respective sample were weighed into tared petri dishes, spread uniformly and exposed to a_w ranging from less than 0.001 – 0.791 in desiccators maintained at 38. 5 + 0.1^{0}C in an incubator. The a_w was calculated at equilibrium by making use of a vacuum oven at 70^{0}C for 10hrs and the amount of moisture lost or gained at different RH equilibration.

Determination of bulk density

The compact bulk density was found by the method of Lazar *et al.* (1956) by taking the powder in a graduated measuring cylinder, repeatedly tapping the cylinder until there was no change in the volume and recording the weight as well as the volume. Weight divided by the volume gives the compact bulk density.

RESULTS AND DISCUSSION

The results are as shown in Tables 1,2,3 and Fig. 1. Raw Ripe banana flesh minus skin is said to contain 59% edible matter, 70.7% water 3.4% unavailable carbohydrate, 16.2% sugar as monosaccharides 3.0% starch as glucose, 0.18% total nitrogen and 10.0% ascorbic acid (Pearson, 1976). Bourdouil (1929 and 1931) and Stratton and Loesecke (1930) have shown that ripening is accompanied by an increase in the moisture content and in the reducing sugar of the pulp, a decrease in its total solids and starch.

The additional water in the pulp is derived partly from the oxidized carbohydrate during the process of intense respiratory activity, which goes on during ripening and partly from the water which migrates from the peel and the stalk to the pulp. The process of ripening is characterized chiefly by the conversion of starch in the unripe fruit to sugars in the ripe fruit (Poland *et al* 1938). Unripe fruits of plaintain and banana contain from 21% to 32% starch, in-significant quantities of sucrose and invert sugar. This amount of starch in the fully ripe fruits may fall to a level below 2%.

Conversely, the sugar content rises from 2% in the green to approximately 20% in the fully ripe fruit (Oyenuga 1968). These effects are demonstrated in the studies in model system using corn starch, sugars, skimmed milk powder and water in Table I. where it can be observed that pure corn starch alone produced white powdery flakes in the double drum drier used at the settings. The introduction of sugars into the corn starch produced grayish sticky/ molten flakes and the addition of skimmed milk powder (SMP) to the mixture of starch and sugars produced brownish sticky flakes. The grayish and brownish coloration are explained by the levels of ionic nitrogen present in the products. It was also observed that sucrose being made of glucose and fructose produced less sticky flakes than glucose, alone which indicates that glucose is more thermoplastic than sucrose.

Previous workers siddappa and Ranganna (1961) have studied drum drying of banana pulp using starch, sucrose, protein etc. So therefore in the model system cornstarch, sugar, glucose and skimmed milk powder were used. In the model system 10% of gelatinished corn starch dries in the form of a thin white powdery flakes at 3,1638kg. m-^{2} (Table I). Added sucrose (at level 20%) renders it sticky while glucose (20% level) hinders complete drying. The resulting product was a grayish sticky molten mass. Glucose and sucrose (at 10% level each) yielding a sticky product. Increase or decrease in the concentration of added sucrose or glucose and addition of skimmed milk powder (at 10% level) did not improve the quality of the product but turned brownish. These results show that starch aids drying while sucrose and glucose impair the drying characteristics of starch rather than improving. The dried products becoming sticky or molten when sucrose or glucose is added respectively indicated that they are responsible for renderings the dried product thermoplastic especially with glucose. Extraction of the banana pulp with alcohol renders it free of all alcohol soluble which consist mostly of sugars, organic acids, amino acids etc.

The residual pulp reconstituted in water, on drum drying, yielded a non-flaky, non-sticky powdery material which was easily scrapped off by the doctor's blade. When either sucrose or glucose was added to the alcohol-extracted pulp, the resulting material did not dry satisfactorily and the dried product was sticky but not so when starch was added showing thereby, that the sugars were mainly responsible for thermosplasticity of the dried product.

The composition of banana changes during ripening. Unless the fruit is fully ripe, it contains starch and when fully ripe, only sugars but not starch. Oyenuga (1968) found that peeled ripe banana (edible portion) contains 30.54% dry matter, 4.16% crude protein which contains 3.72% true protein, 0.50% either extract, 0.06% crude fibre, 4.54 total ash which contains 4.34% silica free ash and 90.74%

nitrogen free extractives. The banana pulp from ripe fruit dried in the form of continuous elastic sheet, which did not break when hot, became crisp on cooling and powdered easily. The dried flakes as well as the powder were highly hygroscopic and sticky. Hence, as the dried product comes out of the drier, it must be immediately transferred to an airtight container. The concentration of cornstarch used in the present study varied from 2.5 to 12.5% on the fresh weight basis of the pulp. With increasing concentration of starch up to 7.5%, the dried product came in the form of continuous sheets and was less sticky. At 10-12.5% starch concentration, the product became brittle and was discontinuous but was, however, less sticky (Table 2).

Irrespective of the concentration of starch used, addition of 5% of sugar on fresh weight basis of the pulp did not affect the drying characteristics of the product, but the resulting product was sticky. Addition of 5-10% of skimmed milk powder to the above system did not affect the drying characteristics but reduced the stickiness.

Hence, banana pulp could be drum dried using a minimum of 5% starch but not more than 7.5% and with or without added sugar (5%) and skimmed milk powder (5.0%). From the model systems, it is obvious that replacing sucrose with glucose makes the product more sticky. Starch and to some extent skimmed milk powder reduced the thermoplasticity of the product.

Water Activity ($a_{w):}$ Aw and moisture sorption isotherm have significances with regard to storage characteristics and in determining the nature of the packaging material required (Bizot 1993; Hallstrom *et al* 1996). The moisture isotherms are shown in Fig. I. These show the variations in ERH with changes in the water content of the samples at 38.5^0 C. The curves exhibit sigmoid pattern as observed by Kumar (1994) and there is a steep increase in the equilibrium moisture content beyond the a_w of 0.3. The initial moisture content of the product varied from 1.8 – 2.6% the average being 2.06% (Table 3). In the determination of aw, it was observed that the banana puree drum dried either with or without added starch (2.5% - 12.55), sugar (5.0%), and skimmed milk powder (5-10%) were free flowing at aw of 0.20 and became sticky at aw of 0.32. Hence, for these drum-dried products, the danger point is at aw of 0.20 and the critical point is about 0.05aw less than the danger point, i.e. around 0.15. The equilibrium moisture content at the aw from Fig. I is found to range from 2.1 to 3.0% (average being2.5%). This result is comparable with the findings of Hutchinson and Offen (1984) on white beans.

Based on the water activity data (Table 3) the following data were taken to determined the nature of packaging material required for packing drum – dried banana powder which will have a shelf life of 300 days at 30^0C.

Unit size of packaging required………………… ………………. 100g
Storage relative humidity…………………..…………………….. 57%R.H.
Initial moisture content of the product…………..………….. 2%
Maximum permissible moisture limit……….. ………………. 2.5%
Bulk density of the product[a]…………… ……………………….. 0.87g/ml
Surface area of Pouch required for product[b] ………………………… $150cm^2$
Permissible uptake of moisture by weight…………………… - 0.5%
Therefore, 100g of product can pick up 5.0g moisture
1.g mole (18.0g) of water vapour occupies at NTP……… 22.4litres
Therefore 0.5g of water occupies at NTP 62222 m/s
The ERH at 2% moisture is 14.25 and at 2.5% moisture, 16.0%[d.]
Average for these is 15.0% hence, average vapour pressure differential (D) between the inside and the outside of the wrapper during the storage may be assumed to be equivalent to (75-15) = 60% i.e. 60% of the saturation vapour pressure at 30^0C.

The saturation vapour pressure at 30^0C is 31.79mm. Therefore, D = 60% of 3.179cm = 1.9074cm. The permeability of the film (gas or water vapour transmission) is defined as quantity of gas or vapour passing through a piece of film of 1 unit area in unit time with unit differential across the faces. It may be calculated using the expression.

$$P = \frac{q}{At\,(P^1 - P^2)} = \frac{622.22}{150 \times (300 \times 24 \times 60 \times 60) \times 1.91}$$

Where P = water vapour or gas transmission of the film in cc/cm2/sec/cm of Hg.
q = quantity of water vapour or gas in cc
t = time of storage in sec
P^1 = water vapour pressure outside the package
P^2 = water vapour pressure inside the package
$P^1 – P^2$ = water vapour differential between outside and inside of the wrapper during the period of storage of the package expressed in cm of Hg.
Hence P = 8.3785 X 10^{-8} cc/cm^2/ sec/ cm of Hg.

Table 9-5 in Manual of Analysis of Fruits and Vegetables products (Ranganna, 1977) shows that saran of 1mil thickness or polyethylene (HDPE 0.954) of more than 3 mil probably 5 mil would give the required protection.

Notes:

a. The value represents average of the bulk densities of the sample.

b. This is calculated from the bulk density thus: 1g of dry sample occupies 1m1.

$$100g \quad \frac{100}{0.87m1} = 115m1$$

Unit surface area of package = (3" $115)^2$ = $23.62cm^2$
for 6 surfaces 23.62X 6 = 141. 72 cm^2
Allowing room for possible expansion or space for I.P.D. of packaging material required is taken as $150cm^{2.}$

c. 2% moisture refers to average equilibrium content which is read on the sorption isotherms and the corresponding equilibrium humidity found.

d. 2.5% moisture refers to average equilibrium moisture at critical point 15% R.H; the corresponding equilibrium humidity read at this EMC from the sorption isotherms.

CONCLUSION

Drum dried banana pulp is thermoplastic and highly hygroscopic in nature. Making use of the pulp devoid of alcohol soluble solids and by studies in model systems, the thermoplasticity has been shown to be mainly due to the sugars naturally present or added. Cornstarch added up to a level of 7.5% on the fresh weight of the pulp aided drying but did not reduce hygroscopicity. Skimmed milk powder similarly at 5-10% level improved the drying characteristics slightly.

The dried product had moisture content of approximately 2.0%, which was equivalent to aw 0.11 at 38.5^{0}C. The storage conditions should be such that the aw does not go beyond 0.15 which is equivalent to about 2.5% moisture. Making use of the data from the aw calculations involved in finding the suitable packaging material are given. Polyethylene (density 0.954) of thickness more than 5 mi1 or Saran 517 of 1mil thickness may be expected to keep the product in good condition at 30^{0}C for 300 days. Use of in-package desiccant would further improve the shelf life of the product.

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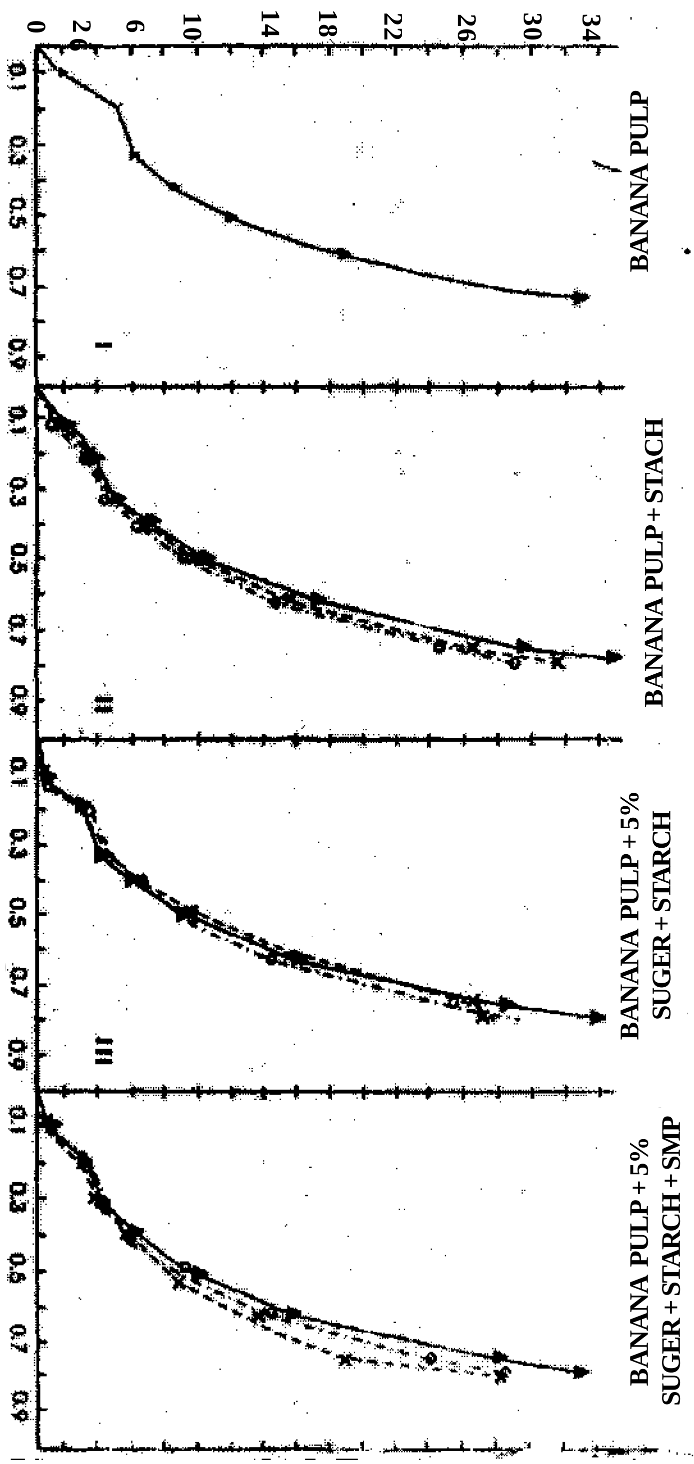
BANANA PULP
BANANA PULP+STACH
BANANA PULP+5%
SUGER+STARCH
BANANA PULP+5%
SUGER+STARCH+SMP
I
II
III
0
2
6
10
14
18
22
26
30
34
0.1
0.3
0.5
0.7
0.9

Table 1: Studies In model-system using corn starch, sugar, skimmed milk powder (SMP) and water.

S/NO	Starch g	Glucose g	Sucrose g	SMP g	Water g	Total weight g	Drying characteristics.
1	100	-	-	-	9001000	White	powdery flakes.
2	100	200	-	-	7001000	Grayish	Molten Flakes.
3	100	-	200	-	7001000	Grayish	Sticky Flakes.
4	100	100	100	-	7001000	Grayish	sticky Flakes.
5	100	200	-	100	600	1000	BrownishMore Sticky Flakes.
6	100	-	200	100	600	1000	Brownish More Sticky. Flakes.
7	100	100	100	100	600	1000	Brownish More Sticky. Flakes.
8	125	-	200	100	575	1000	Brownish Less Sticky. Flakes.
9.	150	-	200	100	550	1000	Brownish Less Sticky Flakes.
10	175	-	200	100	525	1000	Brownish Less Sticky Flakes.

Table 2: Studies on drum drying of Banana Pulp.

S/ NO	Banana pulp weight used (g)	Starch[a] %	Sugar[a] %	SMP[a]	Drying characteristics.
1.	400	-	-	-	Continuous Sticky Flakes.
2.	400	2.5	-	-	Continuous Less Sticky Flakes.
3.	400	5.0	-	-	Continuous Less Sticky Flakes.
4.	400	7.5	-	-	Continuous Less sticky Flackes.
5.	400	10.0	-	-	Non-Continuous, non-sticky flakes.
6.	400	2.5	5.0	-	Continuous Gummy Flakes.
7.	400	5.0	5.0	-	Continuous Less Gummy flakes.
8.	400	7.5	5.0	-	Continuous Less Gummy flakes.
9.	400	10.0	5.0	-	Continuous Less Gummy Flakes.
10.	400	2.5	5.0	5.0	Continuous Less Sticky Flakes.
11.	400	5.0	5.0	5.0	Continuous Less Sticky Flakes.
12.	400	7.5	5.0	10.0	Continuous less Sticky Flakes.
13.	400	10.0	5.0	10.0	Continuous Less sticky Flakes.
14.	400	10.0	20.0	10.0	Continuous Molten Flakes.
15.	400	12.5	20.0	10.0	Continuous gummy Flakes.

a. Percentage calculated on fresh weight of banana Pulp.

Table 3: Data on water activity (a_w)

Sample composition

S/ No	**Banana pulp**	**Starch %**	**Sugar %**	**SMP[a] %**	**a_w at equilibrium**	**E.M.C. of dry solid g /100g.**
1.	+	-	-	-	0.135	2.3
2.	+	5	-	-	0.125	2.4
3.	+	7.5	-	-	0.113	1.6
4.	+	10.0	-	-	0.130	1.9
5.	+	5	5	-	0.135	1.6
6.	+	7.5	5	-	0.151	2.2
7.	+	10.0	5	-	0.134	1.8
8.	+	5	5	5	0.142	2.0
9.	+	7.5	5	10	0.168	2.6
10.	+	10.0	5	10	0.135	2.2

a. *Percentage calculated on fresh weight of pulp*

b. *By graphical interpolation the Equilibrium Relative Humidity was found and this converted to water activity a_w at equilibrium thus: % RH/100*

c. *Using the a_w at equilibrium data the corresponding moisture content g/100g of bone dry solids was read f*