Exploring Oven-drying Technique in Producing Pineapple Powder

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Abstract - *Pineapple puree and juice of 11 to 12 °Brix were used to obtain pineapple powder using oven-drying technique. Addition of maltodextrin in treatments 2 and 4 yielded good quality powder, however addition of sugar and maltodextrin in treatments 1 and 3 resulted to sticky product which was processed to pineapple leather. Treatment 2 composed of pineapple puree and maltodextrin resulted to significantly higher powder recovery compared with treatment 4 which composed of pineapple juice and maltodextrin. The solubility of pineapple powder improved as maltodextrin concentration is increased from 40.00 % to 60.00 %.Addition of maltodextrin also reduced stickiness of the final product. An instant pineapple powder of 5.47 and 5.33 % moisture content could be produced by oven-drying.This level of moisture content will prohibit bacterial growth in the pineapple powder but may have mold or yeast growth with increase storage period at environments with high humidity. Molds were observed on the 17th day at 89.00 % relative humidity as exhibited by the moisture sorption isotherm data. This suggests that appropriate packaging with moisture barrier is recommended for pineapple powder. This study showedthat by using appropriate ratio of juice, puree, and maltodextrin and appropriate oven drying conditions, a good oven-dried pineapple powder could be obtained.*

Keywords: *oven-drying, pineapple powder, maltodextrin, sorption isotherm*

INTRODUCTION

Pineapple (*Ananascomosus*) is a tropical fruit which may be enjoyed whole and fresh, juiced or canned. The country's pineapple production in the first quarter of 2017 was estimated at 613.53 thousand metric tons. Northern Mindanao remained the highest producer followed by SOCCSKSARGEN and Bicol Region[1].

The bountiful pineapple harvest that flood the market during its peak season during the months of April and June[2]keeps the food industry in developing new products from pineapple. The benefits of constantly developing a product are the elevation of the fresh pineapple demand which translates to increase in revenue and promotes employment and consequently reducing the pineapple loss caused by the microorganisms, chemical and enzymatic reactions during the peak of harvesting season[3].

To maximize the full potentials of pineapple, exploring innovations of pineapple products can be done. Pineapple powder is an interesting product because it is more economical over their liquid counterparts because the weight and packaging are reduced, convenient to handle and transport, and have longer shelf life [4]. Pineapple powder can be consumed as an instant juice powder or a flavoring agent. Gabas[3] claimed that dried fruit powder,when reconstituted with water resembles to the original fruit juice. Fruit powders are

Ensuring food safety and quality, improved process and preservation of food are the main goals of the food industry [5]. Considering the perishable nature of pineapple, it is necessary to preserve them through drying method. At present, there is a growing interest in the use of conventional drying techniques [6; 7]. Common methods of drying processes include solar drying, air drying, spray drying, and freeze drying[6].Solar and air drying perhaps are the oldest method of drying with a disadvantage of dependence on weather condition and prone to insect infestation, dust, and dirt contamination[8]. Suzihaque[9], Cano-Chauca[10], and Jittanit[11] prepared banana milk, mango,and pineapple powder by spray drying technique, respectively. Spray drying involves atomization of the liquid feed and instantaneous drying of milk or fruit juice components [6]. Vinod[12] investigated the effect of freeze drying on the jack fruit powder. In freeze drying, moisture is removed as a result of sublimation of water, without a phase change from solid to liquid [12]. The setbacks with spray and freeze drying are they are not cost effective and not energy efficient, though they produce good quality fruit powders [6]. Therefore, the need arises to develop a suitable low-cost technology for making fruit powders. Due to the limited research about oven-dryingjuice and puree to the best of the researcher's knowledge, this study was carried out. Oven-drying or convective drying applies hot air to remove water from the food substances. Application of oven-drying in combination with osmotic dehydration was studied on fruits leathers such as Indian mango [13],apple-blackcurrant [14], and pineapple [15]. Preservation of fruits juices to powder gained attention in recent years to increase the shelf life and easy handling of juices. The objectives of this study are two-fold; (1) to study the potential of producing the oven-dried pineapple powders from fruit juice and puree and (2) to determine the pysico-chemical attributes of the oven dried pineapple powders.

METHODS

Raw Materials

Fresh, mature, and fully ripe 'Smooth Cayenne' pineapples were purchased from local market. Pineapples with average weight were chosen for this study. The maltodextrin and white sugar were also purchased from the local market.

Preparations of pineapple puree and juice mixtures

Fresh pineapples were washed thoroughly to remove adhering dirt, then peeled off and cut into cubes. The cubes were homogenized using laboratory electrical blender. Four portions of the puree were set aside.The following preparations were done on the formulation of oven dried pineapple powder:

Treatment 1:(PSM) **-** this formulation was made usingpineapple puree, sugar, and maltodextrin with 60:20:20 ratio. Pineapple puree was heated at 80°C with constant stirring. Then, sugar and maltodextrin were added.

Treatment 2:(PM) -this formulation consisted of 60% pineapple puree and 40 % maltodextrin. Pineapple puree was heated at 80°C with constant stirring. Then, maltodextrin was added.

Treatment 3: (JSM) -this formulation was made using pineapple juice, sugar, and maltodextrin with 90:30:30 ratio. Pineapple puree was filtered to extract the juice. Then, the juice was heated at 80°C for five (5) minutes with constant stirring. Sugar and maltodextrin were added.

Treatment 4:(JM) -this formulation consisted of pineapple juice and maltodextrin with 90:60 ratio. The juice was heated at 80 °C for five (5) minutes with constant stirring. Then, maltodextrin was added.

Oven-Drying

Each treatmentwas poured in trays with plastic sheet. It was loaded and dried in the drier until sample become crisp. The temperature of the oven was set at 55 °C for 24 hours.

Quality Determination

The soluble solid content and pH of the pineapple puree, juice and mixtures produced in Treatments 1, 2, 3 and 4 were measured by digital refractometer and pH meter respectively.

Physical Analysis of the Oven-dried Powder

Moisture content

The moisture content was determined based on AOAC method[16]. In brief, each samples of pineapple powder (2g each) were weighed and then dried in an oven at 135 °C for 2 hours. The samples were taken out from the oven, cooled in a desiccator and weighed.

Calculation

$$\text{Moisture (\%)} = \frac{(W1-W2)}{W1} \times 100$$

where: W1 = weigh (g) of sample before drying

W2 = weight (g) of sample after drying

Moisture sorption isotherm

Table 1. Determination of the moisture sorption isotherm (Weight equilibrium method).

RH, %	Saturated salt solution
11	Lithium chloride
23	Potassium acetate
32	Magnesium chloride
42	Potassium carbonate
52	Magnesium nitrate
62	Cobalt (II) chloride
75	Sodium chloride
79	Ammonium sulphate
89	Barium chloride

Two hundred (200 ml) of saturated solutions of each salt was carefully placed in separate jars and closed tightly. The jars were allowed to stand for 24 to 48 hours to equilibrate. Dry crucibles were loaded in moisture sorption isotherm (MSI) jars (Table1). Set-up was equilibrated for one (1) week. Moisture content of each sample was determined before loading in MSI jars. This data was used in calculating equilibrium moisture content. About 2 grams of oven-dried pineapple powder were placed in a tared crucible. These were exposed to different relative humidity inside the glass jars. Loss or gain in weight of the samples was periodically determined until equilibration was attained. The moisture content at this point is the equilibrium moisture content (EMC), which was determined using a relative humidity (RH, %) in the glass jars where samples were stored was plotted.A smooth curve know as sorption isotherm of the pineapple powder was drawn between EMC and RH.

Statistical Analysis

Data were statistically examined by analysis of variance and the means were separated by Least Significant Difference (LSD) test. Analysis was done using R v.3.2.4 (2016) statistical package. Microsoft Excel (2016) was used to draw the moisture sorption isotherm.

RESULTS AND DISCUSSION

Quality of Raw Material

The measurement of soluble solid content and pH of the fresh pineapple puree and juices revealed that their soluble solid contents ranged from 11.00to12.00°Brix. The average pH of the fresh pineapple puree and juices in this study was 4.60. Listed in Table 2 are the soluble content and pH of the different formulations in making pineapple powder. Treatments 1 and 3 havea higher total soluble solid compared to treatment 2 and 4.

Table 2. The total soluble solid content and pH of the mixtures produced in Treatments 1, 2, 3, and 4.

Treatment	Parameter		Appearance
	pH	TSS, °Brix	
1. PSM	4.60	47.00	Sticky, light yellow
2. PM	4.60	12.00	Powdery, light yellow
3.JSM	4.50	44.00	Sticky, light yellow
4.JM	4.50	12.00	Powdery, light yellow

Pineapple Powder Appearance

The results show that addition of 20% sugar and 20% maltodextrin in pineapple puree and juice in treatments 1 and 3 respectively resulted to sticky products (Table 2). Thermo-plasticity and hygroscopicity at high temperatures and humiditiesof fruit juices with high sugar content like pineapple is also a big challenge even in spray drying technique [17]. These characteristics are attributed to low molecular weight of major solids in fruit juices such as fructose, glucose, and sucrose and organic acids such as citric, malic, and tartaric acid[18]. When spray dried, the low glass transition temperature (Tg), high hygroscopy, low melting point, and high water solubility of these solids resulted to sticky product[19].

Adding some adjuncts such as maltodextrin and Arabic gum overcomes the thermoplasticity and hygroscopicity problems occurring in drying the fruit juice with high sugar content.[10]. But in this experiment, the sugar and maltodexrin combination did not work. Hence, drying of treatments 1 and 3 were discontinued and were re-processed to pineapple fruit leather instead. On the other hand, in treatment 2 (pineapple puree + maltodextrin) and 4 (pineapple juice + maltodextrin), the appearance of the pineapple powder product was light yellow and powdery with high intensity of pineapple aroma.

Physical Properties of Powdered Pineapple

Table 3. The moisture contents, powder recovery, and solubility of oven-dried pineapple powders

Treatment	Parameters		
	Moisture Content (%)	Powder Recovery (%)	Solubility (minute)
T2: 60 % Pineapple puree + 40 % maltodextrin	5.47 ^{a}	75.33 ^{a}	6.67 ^{a}
T4: 90% Pineapple juice + 60 % maltodextrin	5.33 ^{b}	64.00 ^{b}	4.67 ^{b}

^{ab}*Means with the same letter are not significantly different at 5 % probability level.*

The results (Table 3) show that the moisture contents of the powders were 5.47 and 5.33% for T2 and T4, respectively. This is in agreement with the reported value of Jittanit[11] in the range of 4.0-5.8% for spray dried pineapple. Moisture content represents the water composition in a food system. However, the moisture content reported in this study was higher than those reported for guava, pineapple, and star fruit with final moisture content ranged from 1.91 to 2.21 % [20] but this may be due to the initial pineapple quality and processing methods. Treatment 4 with higher maltodextrin concentration resulted in lower moisture content of oven-dried pineapple, probably due to a decrease in pineapple solids in the mixture and increase amount of free water evaporation. A similar effect was observed in spray drying of pineapple blended with maltodextrin[20]. Treatment 2 provided significantly higher powder recovery of 75.33% compared to treatment 4. The fibers present in puree and higher moisture content in treatment 2 probably adds weight to the recovered powder. The oven-dried pineapple produced could be reconstituted with water. Results show that an increase of maltodextrin concentration significantly improved solubility. The solubility of pineapple powder was 6.67 min when 40% maltodextrin was added to pineapple puree whereas adding 60% maltodextrin decreased the solubility time to 4.67 min. In spray drying technique, maltodextrin is added to pulp in order facilitate production of non-hygroscopic and fine flowing powder [21]. Based from the results, addition of maltodextrin to pineapple juice and puree caused changes in the microstructure of the powder, in effect influencing the functional characteristics of the pineapple powder. Maltodextrin was used as a carrier in this study in making oven-dried pineapple as it is the most utilized substance in spray drying juices due to its solubility in water. However, due to the change in structure of the powder, it influences the functional solubility. Results (Table 3) suggested that the properties of the powdered pineapple particles change as a function of maltodextrin concentration; the higher concentrations lead to increased solubility of the powder in water.

Moisture Sorption Isotherms of Pineapple Powder

Aouaini[22] defined the food sorption isotherm as the thermodynamic relationship between the equilibrium of the moisture content and water activity of a food product at constant temperature and pressure. Understanding the data derived from the sorption isotherms are highly valuable in designing and optimizing of drying equipment, designing of packages and predicting product quality, stability, and shelf-life during storage[22].Numerous preservation techniques to inhibit chemical reactions and reduce available water for microbial growth have been reported in literature[22]-[24].

Based on the experimental computed values, the EMC of all the samples generally increase as the relative humidity also increased (Table 4). The increase in EMC of the samples is brought about by the vapor pressure deficit (VPD) which decreases as relative humidity forms an atmosphere near saturation and enhances the capability of the material to absorb more moisture from the surrounding atmosphere. Thus, equilibrium moisture content increases with increasing relative humidity at the same temperature [25],[26].

Table 4. Equilibrium moisture content (EMC) of oven-dried pineapple powder at different relative humidities.

RH, %	**EMC, %**	
	Treatment	
	PM (2)	**JM (4)**
11	2.44	2.38
23	4.91	4.54
32	5.83	5.31
42	8.17	7.65
52	8.21	11.20
62	11.92	12.20
75	18.30	17.51
79	21.49	39.24
89	35.60	36.07

Table 5 indicates the physical appearance of the oven-dried pineapple powder and the number of days it took to equilibrate the samples in the glass jars with varying relative humidities. Changes in physical state of the powders were observed at different relative humidities. Both treatments (2 and 4) have light yellow colored powder from 11% down to 75% RH. Browning and growth of molds were observed at 79% and 89% RH respectively.

Caking of the samples was observed in both treatments at the 17th day from 23 % to 89% RH. Mathlouthi [27] defined caking as the lumping of food powders due to spontaneous agglomeration phenomenon as a result of liquid bridges formation. It happens in surfaces containing amorphous products due to surface plasticization induced by water sorption.

Table 5.Number of days for the oven-dried pineapple powder to reach equilibrium moisture content (EMC) and their physical appearance at different relative humidities.

RH, %	Treatment			
	PM (2)		JM (4)	
	Days	Appearance	Days	Appearance
11	10	light yellow and powdery	10	light yellow and powdery
23	17	light yellow and powdery	17	light yellow and powdery
32	17	light yellow and caking	17	light yellow and caking
42	17	light yellow and caking	17	light yellow and caking
52	17	light yellow and caking	17	light yellow and caking
62	17	light yellow and caking	17	light yellow and caking
75	17	light yellow and caking	17	light yellow and caking
79	17	light yellow with browning and caking	17	light yellow with browning and caking
89	17	moldy and caking	17	moldy and caking

Caking frequently occurs in water soluble powders which are exposed to high relative humidity. The succeeding moisture evaporation causes recrystallization, agglomeration and the deposition of solid bridges between particles[27]. Furthermore, storage of pineapple powder in an environment with high humidity can absorb moisture to a level that supports the growth of molds[28]. This is supported by the high moisture content obtained from the storage of pineapple powder for 17 days in 89 % relative humidity.

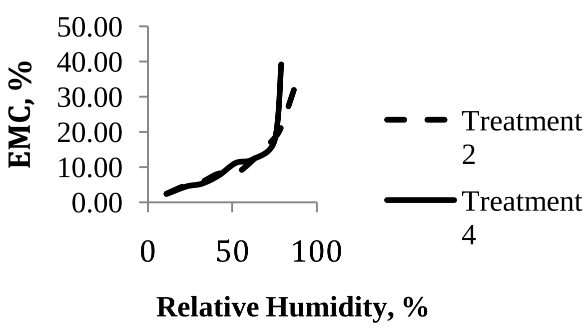

Figure 1. Moisture sorption isotherm of different formulations in making oven-dried pineapple.

Figure 1 illustrates the equilibrium moisture content of the two formulations of oven-dried pineapple powder where EMC was plotted against different relative humidities. The curve obtained in this study for both treatments 2 and 4 exhibited Type 2 sigmoidal sorption isotherm. Three major factors, including colligative solution effects, capillary effects, and surface interaction, occur over the whole moisture range in biological systems and yield the characteristic sigmoidal sorption isotherm [29; 30]. This observation may be attributed to the high carbohydrate content of oven-dried pineapple[28].Similar type 2 sigmoidal isotherm was observed in tomato pulp[31], rapeseed[32], and cassava flour [33].

CONCLUSION AND RECOMMENDATION

Oven-drying pineapple puree and juice with maltodextrin as adjunct has been studied successfully. However, addition of sugar to treatments 1 and 3 were not feasible as it resulted to sticky product. The value obtained for moisture content for treatment 2 and 4 implies that the oven-dried products will not allow bacterial growth but may have mold or yeast growth with increase storage period at high humidities. This hypothesis holds true as supported by the result of moisture sorption isotherm where molds were observed on the 17th day at 89 % relative humidity. In terms of solubility of pineapple powder, increasing maltodextrin concentration from 40.00 % to 60.00 % increases powder solubility.The quality of oven-dried pineapple is dependent on the operating parameters. Thus, it is important to discern the factors affecting the product properties such as amount of maltodextrin and oven temperature, to obtain pineapple powder with better sensory and nutritional characteristics and better process yield.

Based on the findings, shelf life studies considering packaging and storage conditions are recommended for better transport and economic benefits. Further, sensory evaluation should be conducted to know if it's acceptable to the consumers.

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