Abstracts of the Ph. D. Thesis Submitted

PACKAGING AND STORAGE STUDIES ON FRESH GUAVA FRUIT AND OSMOTIC-AIR DEHYDRATED POWDER OF GUAVA (Psidium guajava L.)

Name of Student	Major Advisor
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India is one of the largest producers of the guava fruit (Psidium guajava L.) in the world. Guava is an important fruit crop of India and called the "Apple of the Tropics". Improved packaging technology and storage reduces post harvest losses and increases the shelf life of fresh guava fruit and processed products of the fruit. It also reduces the glut in the market and farmers fetch remunerative price during harvesting season in the domestic market.

Freshly harvested and fully matured guava fruit (Lucknow-49) were procured from a farm of Vanthli Taluka, Junagadh District. The guava fruit were immediately precooled at 10 0C for 1 h to remove field heat and graded on the basis of weight and damaged fruit were sorted out. After washing, the fruit were pretreated with 500 ppm benomyl for 5 minutes and dried under shade. Two fruit were placed in a 150 x 225 mm size of LDPE bag with 80-100 mm headspace for packaging. The fruit were treated with active MAP with three levels of gas concentrations i.e., 3 % O2 + 5 % CO2, 6 % O2 + 5 % CO2 and 9 % O2 + 5 % CO2 and packed in two levels of thickness of LDPE bags i.e., 25 µ and 50 µ. The samples were stored at two levels of temperature of 5 ± 1 0C with 90-95 % Rh and 10 ± 1 0C with 85-90 % Rh.

The physical, biochemical, sensory characteristics of the guava fruit and gas concentration in head space within package were recorded at an interval of 7 days during storage. It was concluded that the shelf life of guava fruit can be increased up to 42 days by packaging in 50 µ LDPE bags at 9 % O2 + 5 % CO2 gas concentration and stored at 10 0C without much change in physical, biochemical and sensory characteristics. The cost of packaging of guava fruit and net profit per kg were estimated to be ₹ 5.11 and ₹ 10.89, respectively.

The uniformly ripened with reasonably hard guava fruit of 60 to 65 mm diameter was selected for osmotic dehydration. The selected fruit were washed with clean water, peeled, cut into two halves, cored and sliced in 10 mm thickness. The slices were pretreated with 0.1 % KMS and 0.1 % citric acid solution for about 5 minutes and immersed in three different sucrose solution concentrations i.e., 50, 60 and 70 0Brix with sample to solution ratio 1:5 (w/w). The samples were kept at room temperature (25 ±7 0C) and 50 0C for 6 h and 12 h immersion time without any agitation. After completion of immersion time, the guava slices were removed from the solution, drained and rinsed with clean water to remove the syrup adhered to the

surface. The osmotic-dehydrated guava slices were dried in a single layer in a tray dryer at 60 ± 2 0C drying temperature and 2.5 m/s air velocity. Dried guava slices were ground and sieved by 300 mesh sieve to obtain powder.

The observations of various characteristics viz., solid gain, water loss, water loss to solid gain ratio, weight loss and moisture content of guava slices were recorded during osmotic dehydration. The drying characteristics of guava slices were observed during tray drying. The observations of various physical, biochemical and sensory characteristics of guava powder were evaluated after osmotic-air dehydration. The initial moisture content of guava slices reduced from 455.86 % (d.b.) to 41.08 %-195.25 % (d.b.) after osmotic dehydration and after osmotic-air dehydration, it reduced from 41.08 %-195.25 % (d.b.) to 4.25 %-4.94 % (d.b.). The highest water loss to solid gain ratio and rehydration ratio of guava slices was found to be 5.28 and 2.93 for 60 0Brix sucrose solution, 6 h immersion time and 50 0C process temperatures during osmosis and tray drying, respectively. The maximum water solubility index, water absorption index and ascorbic acid of guava powder was observed to be 86.68 %, 516.63 % and 146.17 mg/100 g for 60 0Brix sugar solution, 6 h immersion time and 50 0C process temperature.

It may be concluded that 60 0Brix sucrose solution, 6 h immersion time and 50 0C process temperature showed best quality in terms of drying, physico-chemical and sensory characteristics of guava powder.

The best quality powder was packed in 50 µ flexible packages viz., LDPE, HDPE, PP, aluminium laminated polyethylene (ALPE) pouch of 105 x 140 mm size with nitrogen gas keeping 40-50 mm headspace and also in glass bottle. The powder in 50 µ LDPE bag without sealing was considered as control. The dehydrated powder was stored for a period of 8 months at room temperature (14.3-37.4 0C and 16.3-86.4 % Rh). The physical, biochemical, microbial and sensory characteristics of guava powder were determined at an interval of 2 months up to 8 months during storage.

The highest water solubility index, water absorption index, ascorbic acid, total sugar and sensory score was found to be 85.28 %, 508.69 %, 114.99 mg/100 g, 53.60 % and 7.90, respectively in ALPE pouch with nitrogen gas followed by HDPE bag with nitrogen gas at the end of 8 months of storage. The minimum moisture content, reducing sugar, titratable acidity, non- enzymatic browning and total plate count of guava powder was found to be 4.80 %, 33.78 %, 0.96 %, 0.095 OD and 365 cfu/g, respectively in ALPE pouch with nitrogen gas followed by HDPE bag with nitrogen gas at the end of 8 months of storage period. Yeast and mould, E. coli and salmonella were found absent in all packaging materials except control.

The osmotic-air dehydrated guava powder can be stored up to 8 months in nitrogen gas filled ALPE pouch without much change in physical, biochemical, microbial and sensory characteristics. The cost of preparation as well as packaging

of guava powder and net profit per kg of guava powder was estimated to be ₹ 292.30 and ₹ 216.70, respectively.

Standardization of drying and extraction techniques for production of lycopene from tomato processing waste (pomace)

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Tomato (Lycopersicon esculentum) is a fruit used mainly as a vegetable both in fresh as well as in processed forms. Lycopene is an important carotenoid in tomatoes is responsible for the red colour in tomatoes. The antioxidant capability of lycopene has led to promising results in decreasing the risk of some illnesses and cancers.

Tomato peels can be a viable source of lycopene, as the per unit mass of tomato peels contain about five times more lycopene than the whole tomato pulp. As the primary component of tomato pomace, the tomato peel has the potential for higher amounts of lycopene than tomatoes themselves. Based on the interesting chemical composition of tomato by-products and fractions, propose their use in human nutrition as functional food. Tomato processing waste (pomace) having peel, pulp and some amount of seed has a high moisture content that makes it susceptible to microbial proliferation and spoilage. Therefore, skin can be preserved by drying and then used for lycopene extraction.

Supercritical fluid extraction (SFE) has emerged as a highly promising environmentally benign technology for selectively recovering thermally labile bioactive ingredients from natural sources. The nutraceutical produced by SFE using carbon dioxide (CO_2) at near-ambient temperatures are preferred by consumers due to their superior quality and higher bioactivity without the problems of residual solvent and microbial contamination. It yields tailor-made extracts of superior organoleptic profile and shelf life, with high potency of active ingredients. Further, due to the relatively low temperature of operation, the extracts are very close to those found in nature both in smell and taste.

In this study, the effects of different dryer (tray, vacuum and fluidized bed) and temperature (50, 60, 70, 80 and 90 °C) on lycopene retention in dried pomace were evaluated. The dried pomace developed by standardized drying techniques was used for optimization of processing parameter (temperature, pressure, dynamic time) of SFE and particle size on the basis of lycopene extract yield and purity of lycopene. Purity of lycopene was determined using HPLC. The optimized extract was studied for its shelf life for two months at different storage conditions.

The highest lycopene content in whole tomato as well as pulp was found in cv. Heem Shikhar (3.09 and 3.05 mg/100 g). Also, the highest lycopene content in peel was found in cv. Heem Shikhar (8.67 mg/100 g). Pulp: peel: seed ratio found in Heem Shikhar variety was 90.96: 6.68: 2.35. The moisture content of tomato pomace produced from Heem Shikhar variety was found 84.71 %, protein 7.13 %, fat 0.31, fiber 2.65 %, ash 0.7 % and carbohydrates by difference was found to be 4.51 %. The seed to pulp and peel ratio in dry pomace was found to be 34:66.

The pomace dried at 50 ºC temperature in fluidized bed dryer had significantly maximum lycopene content (24.34 mg/100 g) retention which was followed by tray and vacuum dryer.

Optimum value of lycopene extract (4.93 g/100 g) and purity of lycopene (81.319 %) was found at 60 °C temperature, 375 bar pressure, 120 min dynamic time of SFE conditions and keeping particle size of dried pomace of 0.6 mm. Lycopene extract stored at a temperature of 30 °C showed gradual decrease in purity of lycopene content after 7 days to till 60 days. Changes in purity of lycopene stored at -4 °C were less prominent till 60 days.

DEVELOPMENT AND STORAGE OF WHEY BASED BANANA BEVERAGE

Name of Student	Major Advisor
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Banana is the second largest produced fruit after citrus contributing about 16 per cent of the world's total fruit production. India is one of the largest producers of banana in the world, contributing more than 27 per cent of the global banana production. In India, the major banana producing states are Maharashtra, Tamil Nadu and Gujarat. The productivity of banana in Gujarat (61.5 t/ha) is remarkably higher than the national standard (34.4 t/ha). Also, the area under banana crop is increased by 25.76 per cent while the production increased by 51.27 per cent during the last five years in Gujarat. Rising area, production and productivity of banana in Gujarat as well as in India is becoming a matter of concern for the development of new value added products from the ripe banana to avoid its losses after ripening.

Whey is one of the highly nutritious byproduct from dairy industry containing valuable nutrients. A huge quantity of whey is being drained out annually from the dairy industries poses a serious threat to environmental safety. Hence, the conversion of whey into beverages is one of the most attractive avenues for its utilization for human consumption. The beverages prepared using whey has off-flavour. Mentha arvensis (M. arvensis) extract is commonly used as a natural flavouring agent in most of the whey-based fruit beverages. It is, therefore, felt

appropriate to use the M. arvensis instead of other flavouring agents like vanilla, chocolates, etc. in the development of natural beverage for fetching the higher market demand.

The banana (cv. 'Grand Naine') fruits of good quality and well matured, ready for ripening were procured from the local market. The physical and biochemical properties of the selected fruits were determined using the standard analytical methods.

The process of heating the ripe banana slices is an important process parameter in the production of banana juice. Hence, the heating temperature and time duration was standardized for obtaining optimum juice yield having higher total soluble solids with the characteristic banana odour and taste in the prepared banana juice. Three levels of temperature (40, 70 and 100ºC) and three levels of time duration (30, 45 and 60 minutes) were selected for heating the banana slices to obtain the banana juice of desired quality. The physicochemical properties and organoleptic qualities of the prepared banana juice were determined using the standard equipments and methods. From the combined evaluation of physicochemical properties and organoleptic characteristics of the banana juice prepared during the various treatment combinations, it may be concluded that the ripe banana slices should be heated at 100ºC temperature for 45 minutes in hot water bath to obtain the banana juice having higher yield, TSS content and superior organoleptic quality. After standardizing the heating parameters, the banana juice was produced at optimum processing conditions for utilizing in the beverage preparation.

Similarly, the milk whey was prepared from the standardized Taaza brand milk having 3.1% fat & 7.9% SNF and marketed by Mother Dairy, Junagadh, Gujarat. The procedure adopted for the production of whey was followed as described by De (1991). The physicochemical characteristics of prepared milk whey viz., protein, fat, total solids, pH and acidity were measured using digital milk analyzer.

The M. arvensis extract was prepared from its plant material obtained from the local vegetable market following the standard procedures. The different proportions of banana juice i.e. 5, 10 and 15 ml, M. arvensis extract i.e. 1, 3 and 5 ml and the ground sugar powder was added at equal rate of 8 g in each sample. The rest of the amount of milk whey was added to the mixture for making 100 ml beverage for optimizing their proportions to develop an acceptable whey banana beverage. On the basis of the physicochemical properties and sensory attributes of the banana beverage prepared using various proportions of banana juice and M. arvensis extract, it was established that the beverage prepared with 15 ml banana juice and 3 ml M. arvensis extract indicated better physicochemical properties and superior organoleptic quality.

An acceptable whey banana beverage, obtained at the optimized proportions of banana juice, M. arvensis extract and milk whey, were packed in airtight transparent and amber coloured glass bottles and stored under the refrigerated conditions (7+1°C) to evaluate its shelf life. The physicochemical and organoleptic characteristics of the stored beverages were evaluated at 7 days interval for 42 days of storage period. From the physicochemical properties and microbial analysis, it was concluded that the prepared beverage packed in transparent glass bottle can be stored safely up to 35 days at the refrigerated condition. However, it was felt advisable to consider the safe storage period of 28 days for its safely consumption.

Hence, from the study conducted, it may be concluded that the prepared whey banana beverage should be packed in transparent glass bottle and store at refrigerated conditions (7 + 1 ºC) safely up to 28 days. Further, it may also be concluded that, looking to the nutritious virtues, cost of production and cost-benefit ratio, the developed whey banana beverage could be recommended for the large scale production at industrial level.

DESIGN AND DEVELOPMENT OF GEL EXPULSION MACHINE FOR ALOE VERA LEAVES

Name of Student	**Major Advisor**
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Aloe vera gel is the commercial name given to the fiber free mucilaginous exudate extracted from the hydroparenchyma of the succulent leaves of Aloe vera (Aloe barbadensis Miller). Aloe vera gel is used in medicine, cosmetics and nutrition purposes. The hand filleting and whole leaf processing are the methods, generally used for the extraction of Aloe vera gel. The expanding Aloe industry urgently needs to develop appropriate machine to maintain its biological activity and hygienic conditions. An effort has been made to design and develop the Aloe vera gel expulsion machine.

An Aloe vera gel expulsion machine based on the principle of splitting leaf to reduce crushing force and expulse the inner gel by passing split leaf between two rotating roller. The whole gel expulsion machine is divided into following two components: (a) Splitting unit and (b) Gel expulsion unit. The performance of the developed gel expulsion machine was evaluated at seven speeds of the machine i.e. 45, 60, 75, 90, 105, 120 and 135 rpm of expulsion roller and three leaf thicknesses i.e. less than 25 mm, 25 – 30 mm and greater than 30 mm in terms of gel recovery, expulsion efficiency, output capacity and percentage of residual gel in leaf. The expulsed gel through the developed machine was evaluated for quality parameters like viscosity, optical density and refractive index.

The average length width and thickness of Aloe vera leaf are 495.20, 86.38 and 28.32 mm respectively with apparent volume 323.90 cc, whereas the average leaf weight, crude gel weight and pulp recovery was found to be 0.409 kg, 0.213 kg and 51.92 % respectively. The maximum gel recovery 39.14 % was found of at the speed of 75 rpm and 30 mm leaf thickness. The minimum residual gel percentage i.e. 4.41 % was found at speed of 75 rpm and less than 25 mm leaf thickness. The highest gel expulsion efficiency 84.05 % was found at speed 90 rpm and 25 –30 mm leaf thickness. The maximum output capacity was found 116.19 kg/h at speed 135 rpm and leaf thickness ranging from 25 to 30 mm.

It was concluded that for getting maximum gel recovery, minimum residual gel percentage, highest expulsion efficiency and output capacity, the expulsion of Aloe vera leaves should be carried out at 75 rpm roller speed and 25 – 30 mm thickness of leaves. The average values of viscosity, refractive index and optical density of the expulsed gel were found to be 0.621 Stokes, 1.3364 and 0.239 respectively. The mean values of pH, TSS, fiber content, total sugar and reducing sugar were found to be 6.298, 1.174 0Brix, 1.1158 (Pulp) and 0.194 (gel), 1.9528 %, and 0.0258 % for mechanical gel expulsion. The cost of gel expulsion for Aloe vera leaves by the developed machine was estimated to be Rs. 667.5/tonne as compared to Rs. 2000 per tonne by the manual method.

STUDIES ON OSMO-FREEZE DRYING OF SAPOTA (*Achras sapota L.*)

Name of Student	**Major Advisor**
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Sapota (Achras sapota L.), which is commonly known as “Chikoo” in India, is a highly perishable fruit found in almost all the tropical parts of the country. Once sapota fruit ripens, it needs to be consumed within a couple of days due to its perishable nature. A possible alternative solution to this problem is to prepare best quality sapota powder by modern advance technique of osmo-freeze drying to get the combined benefits of these two valuable processes. Osmotic dehydration prior to freeze drying will retains the colour, flavour, aroma, texture and taste in the final product. Subsequent freeze drying will give the dried product of excellent quality, stability and reconstitution characteristics when placed in water. The packaging of sapota powder by best comprehensive method to permit long term storage without

any quality or microbial deterioration.

The uniformly matured and reasonably hard sapota fruits (cv. Kallipati) were cleaned, peeled and sliced manually at 4 mm thickness. Osmotic dehydration of 4 mm sapota slices was carried out at different osmotic variables, viz., osmotic solution concentration (600 and 700 Brix,), immersion time (5 and 10 h), process temperature (300, 400 and 500 C) and sample to solution ratio (1:5). The observations of different osmotic characteristics viz., solid gain (SG), water loss (WL), water loss to solid gain ratio (WL/SG), weight loss and moisture content of sapota slices during osmotic dehydration were recorded. Also, the biochemical characteristics viz., titratable acidity, total sugar and ascorbic acid of osmotically dehydrated sapota slices were also determined.

The initial moisture content of 73.54 to 74.80 % (wb) of the fresh sapota slices was reduced to 48.80 to 61.13 % (wb) after osmotic dehydration. The highest values of water loss to solid gain ratio (6.02 %), titratable acidity (0.15 %) and ascorbic acid content (22.52 mg/100 g) as well as reasonably lower gain of sugar (22.40 %) during osmotic dehydration of sapota slices were obtained in treatment having 60 0Brix osmotic solution + 5 h immersion time + 50 0C temperature. It could be concluded that the treatment having 60 0Brix osmotic solution + 5 h immersion time + 50 0C temperature was found to be the best on the basis of osmotic and biochemical characteristics of osmosed sapota slices among all the treatments.

Osmotically dehydrated sapota slices were freeze dried at -20 and -40 0C temperature at a constant vacuum pressure of 1 torr using freeze dryer. Also, the tray drying of sapota slices was carried out at 60 0C air temperature and 1.25 m/s air velocity as a control treatment.

The highest freeze drying time of 42 h was required to reduce the initial moisture content of 152.65 % (db) to 3 to 4 % (db) in treatment having 60 0Brix osmotic solution + 5 h immersion time + 50 0C process temperature - 40 0C freeze drying temperature, whereas lowest of 26 h was required to reduce initial moisture content of 104.62 % (db) and 96.85% (db) to 3 to 4 % (db) in treatments having 70 0Brix osmotic solution + 10 h immersion time + 40 0C process temperature - 40 0C freeze drying temperature and 70 0Brix osmotic solution + 10 h immersion time + 50 0C process temperature - 40 0C freeze drying temperature, respectively. The treatments with -20 0C freeze drying temperature required more freeze drying time (4 to 6 hour) as compared to treatments with -40 0C freeze drying temperature to reduce the almost similar initial moisture content of osmotically dehydrated sapota slices to 3 to 4 % (db).

Overall quality evaluation of osmo-freeze dried sapota powder revealed that the highest values of rehydration ratio (4.56), water solubility index (89.15 %), water absorption index (701.82 %), titratable acidity (0.26 %), ascorbic acid content (54.66 mg/100 g), overall acceptability (8.33) as well as lowest non-enzymatic browning (0.040 OD) were obtained in treatment having 60 0Brix osmotic solution + 5 h immersion time + 50 0C process temperature - 40 0C freeze drying temperature.

However, the recovery of powder (24.86 %) and total sugar content (61.15 %) were comparatively lower in the said treatment that might be attributed to lower solid gain during osmotic dehydration.

It could be concluded that treatment having 60 0Brix osmotic solution + 5 h immersion time + 50 0C process temperature - 40 0C freeze drying temperature, was found to be the best among all the treatments on the basis of physical, biochemical and sensory characteristics of osmo-freeze dried sapota powder.

The packaging of the best quality osmo-freeze dried sapota powder obtained by treatment D6 (S1I1T3F2) was carried out in different packaging materials viz., low density polyethylene (LDPE), high density polyethylene (HDPE), poly propylene (PP) and laminated aluminium foil (LAF) pouches at 300 and 700 mm Hg vacuum pressure and stored at room temperature (15.4 - 38.2 0C and 16.3 - 82.4 % Rh). The quality evaluation of osmo-freeze dried sapota powder was carried out during 10 months storage period on the basis of its physical, biochemical, microbial and sensory evaluation.

The highest retention of physical characteristics viz., moisture content (5.05 % (wb)), water solubility index (86.13 %) and water absorption index (687.39 %), as well as biochemical characteristics viz., titratable acidity (0.32 %), total sugar (55.33 %), ascorbic acid (53.54 mg/100 g) and non-enzymatic browning (0.225 OD) was obtained in treatment having laminated aluminium foil pouches with 700 mm Hg vacuum level, at the end of 10 months of storage period among all the treatments. While, the lowest total plate counts of 7.68 cfu/g as well as absence of E.coli, yeast and mould, salmonella as well as highest sensory score of 7.27 in terms of colour, flavour, taste, odour and overall acceptability was obtained in the said treatment.

Based on the storage studies of osmo-freeze dried sapota powder, it may be concluded that treatment having laminated aluminium foil pouches with 700 mm Hg vacuum level, was found to be the best among all the treatments on the basis of physical, biochemical, microbial and sensory characteristics of osmo-freeze dried sapota powder due its impervious nature as compared to other packaging materials.

Finally, optimizing the process of all the three different experiments of this investigation, it may be concluded that the best quality osmo-freeze dried sapota powder was obtained by osmotic dehydration of 4 mm thick sapota slices at 60 0Brix osmotic solution concentration, 5 h immersion time, 50 0C process temperature and 1:5 sample to solution ratio followed by freeze drying at –400 C freeze drying temperature and 1 torr constant vacuum pressure. The best quality powder obtained by these optimized variables could be efficiently stored in laminated aluminium foil pouches (LAFP) with 700 mm Hg vacuum level for more than 10 months without much change in physical, biochemical, microbial and sensory characteristics.