DEVELOPMENT AND QUALITY EVALUATION OF MICROENCAPSULATED BANANA PSEUDOSTEM JUICE POWDER

by

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TAVANUR - 679573, MALAPPURAM

KERALA, INDIA

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SARANYA S
(2014-18-110)

THESIS

Submitted in partial fulfilment of the

requirement for the degree of

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KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

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2016

DECLARATION

I hereby declare that this thesis entitled **"Development and quality evaluation of microencapsulated banana pseudostem juice powder"** is a *bonafide* record of research work done by me during the course of research and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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Certified that this thesis entitled **"Development and quality evaluation of microencapsulated banana pseudostem juice powder"** is a *bonafide* record of research work done independently by Ms. Saranya S under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

Tavanur | **Dr. Sudheer K. P.**
Date: | (Chairman, Advisory Board)

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We, the undersigned members of the Advisory Committee of **Ms. Saranya S (2014-18-110)** a candidate for the degree of Master of Technology in Agricultural Engineering majoring in Agricultural Processing and Food Engineering agree that the thesis entitled **"Development and quality evaluation of microencapsulated banana pseudostem juice powder"** may be submitted by **Ms. Saranya S (2014-18-110)** in partial fulfillment of the requirement for the degree.

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Saranya S

Dedicated to

Beloved parents

&

My Profession

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SYMBOLS AND ABBREVIATIONS

et al.	:	and others
%	:	per cent
&	:	and
/	:	per
<	:	less than
>	:	greater than
±	:	Plus or minus sign
°	:	degree
°B	:	Degree brix
°C	:	degree celsius
a*	:	Greenness or redness
Al	:	Aluminium
ALPE	:	Aluminium laminated polyethylene
AOAC	:	Association of analytical chemist
b*	:	Blueness or yellowness
C.V.	:	Coefficient of variation
Ca	:	Calcium
CRD	:	Completely randomized design
Cu	:	Copper
df	:	Degree of freedom
etc.	:	etcetera
F	:	F value
Fe	:	Iron
Fig.	:	Figure
g	:	gram
g/ml	:	Gram per mililiters
h	:	Hour
H_2SO_4	:	Sulphuric acid
HCL	:	Hydrochloric acid
HDPE	:	High density polyethylene
HG	:	Horse gram extract
K	:	Potassium
KCAET	:	Kelappaji College of Agricultural Engineering and Technology
kg	:	kilogram
Kg/cm^2	:	Kilogram per square centimetre
L*	:	Lightness or darkness
LBD	:	Loose bulk density
LDPE	:	Low density polyethylene
MD	:	Maltodextrin
mg	:	milli gram
Mg	:	magnesium
min	:	minute
ML	:	milk
ml	:	milliliter
Mn	:	Manganese
Na	:	Sodium
Ni	:	Nickel
No.	:	Number
P	:	Pseudostem juice
p	:	probability
pH	:	percentage of H+ ions
PP	:	Poly propylene
rpm	:	revolution per minute
s	:	second
S	:	Significant

CHAPTER I

INTRODUCTION

Banana (*Musa sp.*) commonly known by the name plantain is a large perennial herb with leaf sheaths that form trunk like pseudostem. Different parts of the plantain tree have several medicinal uses. Due to the enhanced food value and versatile medicinal value, it is one of the important low cost food crops in India. World production of banana is estimated at 48.9 million tones out of which 10.4 million tonnes, is contributed by India. Because of higher return as compared to other crops, the area under banana is increasing steadily. After harvest of the fruit, the pseudostems are cut and deserted in the fields to become organic waste because it cannot be used for the second time. The huge quantity of biomass thus produced mostly in the form of pseudostem is an absolute waste. For each ton of bananas harvested, around four tons of wastes are generated, among which 75% consists of banana plant pseudostem. About 60-65% pseudostem is produced from a whole plantain tree (NAIP, 2011). Disposal of these huge wastes creates environmental pollution and also the farmers need to spend more money for its disposal. Even though this pseudostem having high medicinal values like anti-urolithiatic activities, value- added products from banana pseudostem is mostly restricted to non food products like fiber extraction and paper products only. Also, it takes extreme amount of energy and time to be processed into biogas, pulp and paper. High perishability and its immediate browning might be the reason for its restricted application in food industry. In order to add value to banana plantation and exploitation of waste produced, the pseudostem could be processed into products (NAIP, 2011).

The selection of proper processing technique plays a significant role in better utilization of raw materials. The major problem faced during pseudostem processing is its browning (Priya *et al.,* 2014) and preservation of its nutritional value along with prolonged shelf life. Thermal processing is found to be the best method to inactivate enzyme activity and further browning of pseudostem. Among thermal processing technique, steam blanching technique is best applicable for pseudostem processing. Steam blanching of pseudostem arrest enzyme activity and further browning. Innovative technology like microencapsulation can improve the retention time of the nutrient in pseudostem. It offers protection of sensitive food components against nutritional loss and also to preserve flavors by coating tiny droplets with a suitable wall material. Key function of microencapsulation is the controlled release of sustenance fixings at correct time at ideal spot. Spray drying is the most widely recognized and monetarily feasible procedure to deliver microencapsulated nourishment materials economically. Compared to other micro encapsulation techniques, it is promptly accessible and production expenses are lower than most other methods. The process has usually demonstrated financial viability as well as productivities. During this drying process, the evaporation of solvent, that is most frequently water, is quick and the entrapment of the interest compound occurs quasi-instantaneously. Microencapsulation by spray drying process should preferably be considered as a workmanship than a science in view of the numerous variables to streamline and the many sided quality of the heat and mass exchange wonders that happen during the microcapsule development (Gharsallaoui *et al.,* 2007).

Development of a process technology for pseudostem powder from the blanched pseudostem juice itself will reduce browning, storage and handling problems and make its use in convenient households. The development of thermal processing, micro encapsulation technologies like blanching and spray drying respectively, facilitates the exploitation of pseudostem, the waste created after harvest of banana. This will add value to the banana plantation and provide an additional income to farmers. Microencapsulating the healthy banana pseudostem juice with suitable wall material can be suggested as a healthy ready to drink mix.

Consumer’s concerns about diet and health have changed a lot. Nowadays people are moving towards healthy life style with diet including nutrient rich fortified foods. Incorporating additional ingredients like horse gram extract and milk during microencapsulation of pseudostem will improve the nutritional and medicinal value of final product.

Horse gram (*Macrotyloma uniflorum Lam.*) is one of the lesser known legumes also known as Kulthi (Mishra and Pathan, 2011). Horse gram is an underutilized legume, famous for its medicinal uses like treatment of asthma, bronchitis, tumor urinary discharge and treatment of kidney stones etc (Ghani, 2003). It also cures menstrual disorder, leucorrhoea, indigestion and breathing problems.

Milk's primary offering point is calcium, and milk-drinking is touted for building solid bones in children and avoiding osteoporosis in more adults. Youngsters require a lot of milk to manufacture bones and teeth, and will supplies vital fat and proteins and will also provides nourishment for grown-ups with crucial vitamins and minerals (Henriksen, 2009).

Blending pseudostem juice with horse gram extract and milk will enrich the resulting blend with vitamins, proteins and minerals. Adding suitable natural flavorings like ginger extract and cardamom will give better sensory qualities to the product and boost the consumer acceptance.

Considering the above cited facts, a study was undertaken to develop a process protocol for banana pseudostem powder with the following objectives**:**

1) Development of process protocol for microencapsulated banana pseudostem juice powder

2) Standardisation of spray drying parameters for the development of banana pseudostem juice powder

3) Quality analysis and storage studies of banana pseudostem juice powder

CHAPTER II

REVIEW OF LITERATURE

In present investigation, an attempt has been made to develop microencapsulated banana pseudostem juice powder by spray drying followed by its quality analysis and shelf life studies. This chapter deals with a brief account of literature, which has direct and indirect bearing on particular objectives of the investigation.

2.1 Banana pseudostem

Pseudostem is a part of plantain which is an under utilised vegetative component disposed, most often as a waste. Its massive accumulation leads to unhygienic surroundings and pollution. However, its curative properties are high. Few researchers have explored its medicinal properties and approached to utilise it (Ravi *et al.,* 2011).

2.1.1 Medicinal uses

Kailash and Varalakshmi (1993) uncovered an investigation on anti-urolithiatic action of banana stem juice and its effect in albino rats. The study revealed that alcoholic extricate produced from banana stem juice lessened oxalate, calcium and phosphate in rat's urine. Furthermore, it increased urine volume thereby diminishing the tendency to crystallize.

Feriotti and Igutti (2008) quantified pseudostem sap proximate composition *viz.* total solid- 0.308%, protein- 0.0141%, lipid- 0.005%, total sugar - 0.191%, ash -0.104% and mineral composition of sap (*viz*. Sodium- 88mg/l, Potassium - 874 mg/l, Calcium - 130 mg/l, Magnesium - 116 mg/l). Investigations were also performed to estimate the pesticides connected with banana plantations to check its deposits in debasing sap. It was confirmed that out of the thirty-four pesticides examined, none exceeded the cutoff limit expressed by Brazilian direction.

Prasobh and Revikumar (2011) carried out Ultra Violet analysis (UV), chemical test and *in vitro* studies to find the presence of potassium nitrate and magnesium nitrate in pseudostem extract and proved that the juice extract possess an amazing capacity to dissolve kidney stones.

Saravanan and Aradya (2011) analysed the antioxidant properties of banana stem extract. Proto catechize acid, gentisic acid, cinnamic acid catechin, caffeic acid and Ferulic acid, *etc*. which comes under phenolic acids were present in banana stem extract. These acids inhibit the initiation of oxidative chain reactions. The antioxidant properties of polyphenols reduced the risk of cancer and cardiovascular diseases and may prevent or repair cell damage caused by reactive oxygen species.

Sampath *et al.* (2012) studied the importance and medicinal value of banana plant and its traditional use as an ayurvedic medicine. This study revealed that pseudostem juice can improve the functional efficiency of kidney and liver. It helps in dissolution of calcium oxalate, a cause for the formation of kidney stones. Diuretic character of pseudostem juice assisted in detoxification of the body and the presence of vitamin B_6 promoted in haemoglobin and insulin production.

Gopinathan (2013) conducted studies on anti-ulcer activity of aloe vera juice, banana stem and flower juice combinations in rats. It evidenced that banana stem juice inhibited the alcohol induced ulcer congestion, haemorrhage, necrosis and reduced gastric ailments in rats.

Spray-dried banana stem juice powder was estimated by Ponnambalam and Sellapan (2014). The juice powder was examined using inductively coupled plasma mass spectrometry (ICP –MS). Various elements necessary to human health *(viz.* Al, Ca, Cu, K, Fe, Mg, Mn, Ni, P, Si and Zn) were identified which varied from 375.445 µg/l to 901.382 mg/l. Concentration of three elements (K-901.382 mg/l, Mg-18.634 mg/l, and Na-3.82 mg/l) were found to be high in samples that aided in diuretic and urolithiatic activity.

2.1.2 Value added products from pseudostem

For better utilisation of banana pseudostem, a project was certified by National Agricultural Innovation Project (NAIP). Various value added products *viz.,* fibre, fabrics, yarn, vermi compost, liquid fertilizer, papers, pickles and candy were developed from banana pseudostem (NAIP, 2011).

Bornare and Sumaiya (2015) developed a Ready-To-Serve (RTS) healthy beverage by blending equal ratio of pseudostem juice and papaya pulp. It showed a good score during sensory analysis.

Present study on development and quality evaluation of banana pseudostem juice powder includes fortification of banana pseudostem by incorporating diverse healthy components like horse gram and milk. Natural flavourings like ginger extract and cardamom powder were used for enhancing oraganoleptic properties.

2.2 Horse gram (*Macrotyloma uniflorum Lam.)*

Horse gram (*Macrotyloma uniflorum Lam. or Dolichos biflorus Linn.)* is a popular pulse rich in protein, iron, calcium and phenols mostly used for the treatment of diseases like heart diseases, bronchitis, asthma, urinary discharges and kidney stones. Apart from this, its inherent property to deal with obesity was significant (Mehra and Upadhaya, 2013).

Bhuvaneshwari *et al.* (2014 a) studied the anti-obesity activity of *Dolichos biflorus* in Albino rats. During their experiment, rats were grouped into four groups with three male and female rats in each group. Hot and cold extracts were fed with different proportions to each group. The rats fed with a dose of 5 mg/kg showed best result. The result was best prominent in males than females.

Bhuvaneshwari *et al.* (2014 b) conducted studies on the anti-obesity activity of horse gram in a group of human volunteers. Males and females were grouped with 10 members in each group. Horse gram extracts were given for each one. Reduction in body weight was noted. A significant response of horse gram was observed in males than females.

Verma *et al.* (2014) developed food products from horse gram bovine milk blends. Horse gram extract were taken for blending with bovine milk in different ratios (40:60, 50:50 and 60:40). The results revealed that horse gram extract contained 91.99 g moisture, 3.64 g protein, 0.25 g fat, 0.80 g crude fiber, 0.13 g ash and 3.19 g carbohydrates per 100 ml. All the variants of developed products were acceptable in sensory evaluation conducted at 9-point hedonic scale.

2.3 Milk

As proposed in Charaka samhitha, benefits of cow milk has innumerable benefits. It nourishes the body tissues, helps in rebuilding tissues, increases life expectancy, improves intelligence, strength, assists in easy peristalsis and relieves tiredness *etc*. Diverse products were already developed by incorporating milk with other components. Enrichment of components with milk will give additional health benefits and increased nutritional value of products.

Laxminarayana *et al.* (1997) described the method of preparation of milk shake powder from cow milk blended with *Musa cavendish* variety of banana (5:1). Banana pieces were heated with water and carboxy methyl cellulose was added. The mix was spray dried and ground sugar was blended with dried mix to obtain final sugar content of 42.5% in banana milk shake powder.

Rehman *et al.* (2007) developed ready to drink soy-cow milk blend. The astringency of soy milk was reduced by blending skim milk powder and it also improved the fat and sugar content of final product.

Takami *et al.* (2014) developed low lactose flavoured milk powder which promoted increased milk consumption and adequate calcium intake. It could be suggested as a nutritive alternative for lactose intolerant people to maintain their milk-drinking habits.

2.4 Flavourings

Flavourings are added to foods to impart taste and aroma. There are certain natural flavours which are derived from herbs and spices. These natural food flavors are not included in the definition of flavorings for regulatory purposes. The ginger and cardamom were the selected flavours for the pseudostem juice powder.

2.4.1 Ginger extract

Zingiber officinale Ros. commonly known as ginger is a spice with wide range of medicinal applications. From earlier times, it was used for most of the digestive disorders. Apart from this, it has anti-inflammatory and chemo-protective effects (Malhotra and Singh, 2003).

Iheagwara (2013) studied the stability and sensorial quality of mackerel fish by addition of ginger extract and its effect on it. Peroxide value, mould count *etc.,* were analysed for over 20 days storage and noted that samples with ginger extract showed low mould count and samples with 5% ginger extract showed higher acceptance than control without ginger extract.

2.4.2 Cardamom powder.

Cardamom is an ancient spice known as the "Queen of spices". Sharma *et al.* (2011) had reported its uses as anti-venom drug, lower blood pressure, analgesic activity, anti-oxidant activity *etc.*

Agaoglu *et al.* (2005) conducted studies on anti-microbial effect of cardamom seed. Seed extracts were tested for bacteria and fungus and determined inhibitory activity on some of the strains and it was least in case of *Escherichia coli.*

A major problem associated with the pseudostem is its perishability. Immediate browning reactions lead to its reduced shelf life. Pretreatment of pseudostem juice is essential prior to product development.

2.5 Pre-treatments of banana pseudo stem

Priya *et al.* (2014) studied the quick browning reaction of banana central core. Various chemicals like citric acid, potassium meta-bi-sulfate (KMS) and ascorbic acid (AA) with varying combinations (0.05%, 0.1% and 0.2%) were used for standardising the pre-treatment method based on colour, pH and microbial load. Combination of (0.1% KMS + 0.1% AA) gave good result under 3 days in ambient and 5 days in refrigerated condition.

Nithya *et al.* (2014) developed banana pseudostem powder by means of spray drying method. Prior to drying fresh pseudostem slices were treated with 0.3% citric acid solution and steam blanched at 100˚C for 30 seconds and one minute respectively. Samples blanched at one minute interval were standardised based on peroxidase test.

2.6 Microencapsulation by spray drying

Microencapsulation in food refers to protecting sensitive food components against nutritional loss and preserves its flavor by coating tiny droplets with a suitable wall material. Key function of microencapsulation is the controlled release of food ingredients at right time at right place. This will improve the application and effectiveness of food ingredient delivery as well as resolve micronutrient deficiencies in the diet (Claude and Fustier, 2007).

Studies were conducted by Inglett *et al.* (1987) on encapsulation of orange oil using oligosaccharides prepared by the action of alpha-amylase on ordinary corn, waxy corn, amylo-maize, corn, rice, cassava, wheat and potato starches. The study supported the hypothesis that presence of high maltodextrins and syrup solids permit the formation of encapsulated products with excellent oxidative stability. Amylo-maize and potato starches exhibited poorer stabilities while normal corn, waxy corn, cassava, rice and wheat glucose syrup solids yielded the best and approximately equivalent shelf-lives.

Dolinsky *et al.* (2000) conducted studies on fruit drying and suggested that 30 - 55% maltodextrin should be added to the fruit and vegetable juices in order to obtain the microencapsulated fruit juice powder. Adhikari *et al.* (2003) also had reported that the addition of maltodextrins significantly reduced the stickiness of fructose solutions, proving it to be an effective drying aid.

Liu *et al.* (2007) investigated the encapsulated *Agaricus bisporus* flavor. He illustrated that depending on the properties of core material to be encapsulated and the purpose of micro-encapsulation, encapsulant materials are generally selected from a range of proteins, carbohydrates, lipids and waxes which may be used alone or in combination. The materials chosen as encapsulants must be typically film forming, pliable, odorless, tasteless and non-hygroscopic.

Kausadikar *et al*. (2015) microencapsulated lemon oil by spray drying to inspect its application on flour tea. Wall materials like maltodextrin, gum arabic, modified starches and its blends were used for drying process. Results suggested that maximum encapsulation efficiency was observed with wall material concentration (30%), core material concentration (10%) and the inlet temperature (175°C). Encapsulation efficiency found to be maximum for gum arabic. Blend of gum arabic to maltodextrin in the ratio of 50:50 gave the best combination for maximum encapsulation efficiency (82.60%) than other blends and found to be stable for 6 months in ice tea premix containing 1.5% encapsulated lemon oil.

2.7 Optimisation and standardisation of spray drying parameters

Spray drying system has been generally utilised for drying heat-sensitive foods, pharmaceuticals and substances, on account of the rapid evaporation of solvent from the droplets. Although it is considered as a dehydration process, which can also be used as an encapsulation method when it entraps 'active' material within a protective matrix. Unlike other microencapsulation methods, it offers an alluring point of preference in delivering microcapsules in simple continuous processes (Shahidi and Han, 1993).

Mainly microencapsulation by spray - drying involved four stages: preparation of dispersion or emulsion; homogenization of dispersion; atomisation of feed emulsion; and dehydration of atomised particles (Shahidi and Han, 1993). The main factors in spray-drying that must be optimised were feed temperature, air inlet temperature, and air outlet temperature (Liu *et al.*, 2007).

Chegini and Ghobadian, (2007) conducted studies on spray drying of orange juice at 65% concentration. Investigations were done on parameters like wall material, inlet and outlet temperature, feed flow rate and sticky point temperature. The experimental data showed that product yield and wall deposition are influenced by inlet temperature and feed flow rate. Optimum conditions for drying of orange juice feed flow rate of 15 ml /min , inlet air temperature of 130°C and outlet air temperature of 85°C and sticky point temperature was determined as 44°C for powder containing 2% moisture.

Fazaeli *et al.* (2012) studied the effect of processing conditions and carrier concentration for improving drying yield and other quality attributes of spray dried mulberry (*Morus nigra*) juice. Independent variables such as, inlet air temperature (110, 130 and 150°C), compressed air flow rate (400, 600 and 800 l/h), and maltodextrin concentration (8, 12 and 16%) were monitored. The optimal conditions for drying yield and total anthocyanin content corresponded to temperature (130°C), maltodextrin concentration (8%) and compressed air flow rate of 800 l/h.

Koc *et al.* (2012) studied the optimisation of spray drying conditions for producing yoghurt powder. At each condition, yoghurt powder was subjected to the measurement of physical attributes and the values of tapped and un tapped bulk densities of yogurt powder were 746 and 538 $kg.m^{-3}$ respectively.

Sabhadinde (2014) conducted a study on orange juice powder with the aid of pilot plant spray drier with concurrent air flow. Five concentrations of maltodextrin

(10, 12.5, 15, 17.5 and 20%) as wall material and inlet/outlet temperatures of 200°C and 120°C were selected for the study. The result demonstrated as physicochemical properties of powders produced depended on some process variables such as characteristics of liquid feed and drying air, as well that type of atomiser and carrier agents used.

Avila *et al.* (2015) evaluated the effect of maltodextrin (MD) and spray drying process conditions on sugarcane juice powder. Four factors such as maltodextrin, inlet air temperature, outlet air temperature and atomisation speed were optimised by a central composite design with a response surface analysis *i.e.,* MD- 20%, inlet air temperature- 130°C, Outlet air temperature-75°C, atomisation speed- 22,000 rpm.

2.8 Physico-chemical properties of powder

Gaoula and Adamopoulos (2010) conducted experiments on tomato soup powder and its moisture content under spray drying conditions and observed that increasing compressed airflow rate decreases the moisture content. That means moisture content of the powder decreased with inlet air temperature and decreased with air flow rate.

Influence of process conditions on properties of microencapsulated rosemary essential oil by spray drying was evaluated by employing a central composite rotatable experimental design. By the analysis, it was noted that bulk density increased with wall material concentration and decreased with inlet air temperature but the particle density decreased with both wall material concentration and the inlet air temperature variable. Moderate wall material concentration (24%), moderate feed flow rate (0.7 l/h) and low inlet air temperature (135°C) were standardised as the best spray drying conditions (Fernandes *et al*., 2013).

Silva *et al*. (2013) developed propolis powder using spray drying and evaluated its properties like water activity, particle size, hygroscopicity *etc*. Stable powder with particle size of 15-24 µm obtained with low hygroscopicity.

Patil *et al.* (2014) analysed the physical and nutritional properties of spray dried guava powder and noted a decreasing trend in moisture content with increased inlet temperature. A negative influence on bulk density was observed because of the increased porosity of the powder. Higher solubility was observed at low bulk density. For obtaining least hygroscopic, powder process conditions were optimised *i.e.,* inlet temperature above 185°C.

The physicochemical properties of grape juice powder under different spray drying conditions were evaluated by Sarabandi *et al.* (2014). Reduction in moisture content, bulk density, water activity and hygroscopicity values with high inlet air temperature were reported while, solubility and wettability decreased with temperature. Overall, increasing inlet air temperature and maltodextrin concentration led to reduced stickiness and enhances powder yield.

Shishir *et al.* (2015) carried out research to assess physical attributes of spray dried pink guava powder with different concentrations of maltodextrin (MD) at several inlet temperatures to preserve unique physical characteristics of final product. The results showed that both inlet temperatures and maltodextrin concentration have a significant influence on the powder properties. Samples spray dried at 150°C inlet temperature and 15% maltodextrin concentration exhibited better properties *viz.* lower moisture content, higher yield, better bulk density, good flowability and moderate colour characteristics.

Wang *et al.* (2015) conducted studies on "Impacts of spray-drying conditions on the physicochemical properties of soy sauce powders using maltodextrin as auxiliary drying carrier". Powder properties like bulk density, cohesiveness, particle size *etc*. showed a significant effect on spray drying conditions.

Zhou *et al.* (2004) conducted studies on spray drying of fermented liquor and analysed the effect of spray drying parameters on the developed product by establishing a mathematical model. The results were validated and optimised spray drying conditions as liquid feed rate of 60 ml/min, atomizing air pressure of 0.1 MPa and inlet air temperature of 180°C.

Spray drying operations were optimised to preserve *Lactobacillus paracasei* SD1in skim milk powder and the air outlet temperature was standardised as 80°C. It was safe after six month of storage at Storage at 4°C (108 cfu/g). At elevated temperature the level of survivability was found to be decreasing. The overall study revealed that the production of probiotic *L. paracase.i* SD1in large scale could be achieved by spray drying and it would be one of the cost effective method for the same (Teanpaisan *et al.,* 2012).

Carranza *et al.* (2014) evaluated microencapsulated *Lactobacillus casei* for its quality and survival during spray drying process with different vegetable extracts like asparagus, orange or grape peel *etc*. The quality of encapsulated powder produced at an inlet temperature of 145°C was analysed after 60 days of storage study at 25°C, 10^7 cfu/g of *L. casei* were survived, which guaranteed its use to develop functional food. Powder with less moisture content (<2%wb), water activity (<0.30 a_w) and reduced stickiness were obtained by using maltodextrin as adjunct.

Koc *et al.* (2014) evaluated spray-dried maltodextrin and studied its physical properties. The study revealed that atomising air flow and inlet air temperature had more effect than feed temperature and feed flow rate on the physical properties of maltodextrin powder. The results showed that the mean diameter was between 3.503 and 6.045 µm for maltodextrin powders.

Chegini and Taheri (2014) studied the physicochemical properties of spray dried whey powder with an aid of pilot-scale co-current spray dryer. Independent variables and response variables were inspected. The result illustrated that powder with 15% solid had low pH than powder with 30% solid. In addition, the pH of powder was found to be lower at an inlet temperature of 180°C and higher at 145°C. Besides, the electrical conductivity was more in high acidic powder. By scanning electron microscopy analysis, the particle size of powder was in range of 11.26–18.23 µm.

Ishiwu *et al.* (2014) studied the effect of inlet-air temperature on physico -chemical and sensory properties of spray-dried soy milk using a co-current spray drier with a constant feed rate of 20.5 ml/sec at air inlet temperatures of 204°C and 240°C. Developed samples were examined for proximate composition and physico-chemical properties. Protein content of 62.05 ± 0.23%, ash (1.41 ± 0.02 %), fat (19.92 ± 0.08%), lysine (5.02 ± 0.29%) and carbohydrate content (12.85 ± 0.01 %) were quantified. Physical properties *viz*. mean total solid (10.33 ± 0.33%) and pack bulk density (0.57 ± 0.00 g/ml) were computed. Lower solubility was found at 240°C with reconstitution temperature of 40°C and 60°C. The value of wettability for samples dried at 204°C was in the range of 36-22 sec and that for 240°C was 29-18 sec. By sensory evaluation, sample dried at 204°C scored high.

Morinda citrifolia L. fruit was spray dried with maltodextrin as wall material. Temperature and core to wall ratio were selected as independent variables. Optimisation of the product was done by response surface methodology (RSM) by analysing the effect of total phenolic content (TPC), 2, 2-diphenyl picryl hydrazyl (DPHH), and total flavonoid (TF). Optimised value for the core to wall material ratio was found to be 1:1.5 and inlet temperature of 95°C (Krishnaiah *et al.,* 2015).

Reddy *et al.* (2014) conducted studies on Osmanabadi goat milk and influence of spray drying conditions on developed powder. Proximate composition of powder was quantified (Moisture content-4.08%, Titrable acidity-0.14%, Protein-25.48%, Carbohydrate-36.99%, Ash -6.60% and Fat- 26.85%). Elevated temperature resulted in reduced loose and tapped bulk density. By Hausner ratio and Carr index analysis flowability was found to be possible and fair respectively.

2.9 Packaging and storage studies of spray dried products

Mary *et al.* (2007) conducted studies on the packaging and storage studies of spray dried ripe banana powder under ambient conditions and concluded that banana powder could be successfully stored under ambient conditions for one year by packing in nitrogen flushed aluminium foil laminated pouches with minimum changes in colour, flavour, texture, microbial load and organoleptic qualities.

Yu *et al.* (2013) conducted shelf life studies and storage stability of spray-dried bovine colostrum powder under different storage conditions. Aluminium-laminated polyethylene (ALPE) and polyethylene terephthalate (PET) pouches were taken as packaging material for storage study under different temperature and relative humidity. The shelf life of powder was evaluated as 425.5 and 86.5 days in ALPE and PET pouches at 25°C temperature and 50% relative humidity (RH). Storage stability of the powder in terms of colour change, moisture content, hydroxymethyl furfural, IgG concentration, and thiobarbituric acid were analysed. From the analysis, ALPE pouches were found to be the best packaging material for storage of bovine colostrum powder under storage condition of 4°C temperature and 40–70% RH.

Sagar and Kumar **(**2014**)** evaluated the effect of drying treatments and storage stability on quality characteristics of bael powder. To arrest caking, maltodextrin and tricalcium phosphate were added and dried in mechanical drier inorder to get dehydrated powder. Moisture content was between 4% - 5%. Sieved powders were packed in 400 gauge and 200 gauge HDPE, 150 gauge PP, LDPE and pouches and kept for storage at low temperature (7°C) and at ambient condition (18–35°C) up to 6 months. Quality characteristics of powder was evaluated before and after storage. The 200 gauge HDPE is exhibited as best packaging material for storage at low temperature with least changes in stored product.

2.10 Cost estimation of spray dried powders

Sunitha (2012) calculated the cost of production for *Garcinia cambogia* powder based on the data available from the market. Total fixed cost of production was estimated to be Rs.297840/- and variable cost calculated as Rs. 201,600/-. The cost incurred for the production of 100g of *Garcinia cambogia* powder was Rs.45/-.

Reddy *et al.* (2014) estimated the production cost for spray dried agglomerated goat milk. The equipment used for production of agglomerated goat milk powder was homogenizer, rotary vacuum flash evaporator, spray dryer and fluidized bed dryer. The operating cost of process equipment was calculated as 0.17, 18.4, 46.4 and 4.80 kWh/8h, respectively. The total production cost for 1 kg of agglomerated goat milk powder was estimated to be Rs. 475.04/-. The B: C ratio of agglomerated goat milk powder was determined (1.47:1). The B: C ratio shows that the developed process technology for agglomerated goat milk powder is economically feasible.

CHAPTER III

MATERIALS AND METHODS

This chapter deals with the materials used and methodology followed for the development and quality evaluation of microencapsulated pseudostem juice powder and are discussed in this chapter under the following sections.

Table 3.1 Raw materials

Raw materials	
Banana pseudostem	The fresh banana pseudostems of popular Kerala variety *Palayankodan* were collected from K.C.A.E.T instructional farm, Tavanur
Horse gram	Raw cleaned horse gram available in local markets were used for the preparation of extract
Milk	Pasteurized cow milk procured from local markets were used for sample preparation
Wall materials	Maltodextrin and corn starch which were procured from local markets were used for the microencapsulation process
Flavourings	Natural flavourings like ginger and cardamom extracts were extracted from fresh ginger and cardamom procured from local markets

3.1 Pretreatments of banana pseudostem

Pre-treatment of banana pseudostems were carried out to arrest the discolouration of samples. Pretreatments of banana pseudostem included steam blanching along with citric acid treatment. According to Ioannou and Ghoul, 2013 and Mazzeo *et al.* (2011) steam blanching needed less blanching time and less leaching of water soluble nutrients compared to water blanching. Hence sliced pseudostems treated with different citric acid concentrations (0.1%, 0.2% and 0.3%) were steam blanched at 100°C.

The steam blancher unit (Plate 3.1) in the Department of Food and Agricultural Process Engineering, KCAET, Tavanur was used for standardising the blanching time of pseudostem. Blanching was performed for various durations *viz.* 30 s, one, two and three minutes.

Plate 3.1 Steam blancher

A batch type steam blancher (600×500 mm) comprised of a blanching chamber, pressure discharging valve, inlet and outlet valve with pressure gage was used for this investigation. An arrangement of perforated stainless steel trays on which the citric acid treated slices were held and were arranged parallel inside the blanching chamber. Then, the food grade steam from a steam blancher was supplied to the trays to maintain the chamber temperature approximately at 100˚C and was controlled by inlet valves. The blanching trials were carried for 30 s, one and two minute durations (Sotome *et al.,* 2009).

3.1.1 Standardisation of pretreatment

Standardisation of blanching time for the citric acid treated pseudostem samples were estimated by peroxidase test and catalase test (Ndiaye *et al*., 2009).

3.1.1.1 Peroxidase test

Peroxidase test was carried out to verify the enzyme inactivation (*i.e.,* peroxidase inactivation) in steam blanched pseudostem samples. The test procedure included crushing of steam blanched pseudostem samples which was taken immediately after blanching. Two grams of crushed pseudostem samples were taken in a test tube with 20 ml distilled water. About one ml of 1% guicol solution and 1.6 ml of 0.3% hydrogen peroxide were added to this and thoroughly mixed. Immediate discoloration of samples to a brown colour was the indication of peroxidase activity. The absence of discoloration even after 5 min indicated enzyme inactivation (Shivhare *et al.,* 2009)

3.1.1.2 Catalase test

Catalase test was carried out for standardisation of blanching time of pre-treated pseudostem samples by analysing the inactivation of catalase enzyme present in the pseudostem samples. Approximately two grams of crushed pseudostem samples were taken in a test tube immediately after blanching and was mixed with 20 ml of distilled water. It was kept undisturbed for 15 min. After 15 min, 0.5 ml of 1% hydrogen peroxide was added. Strong gas release in the form of bubbles in samples was the indication of catalase enzyme and its absence (Shivhare *et al.,* 2007 and Grimm *et al.,* 2012). Standardisation of blanching of pre treated pseudostem samples was done by considering the factors like enzyme inactivation, colour with different blanching preservatives and time combinations **(**Prajapaty *et al.,* 2011).

3.2 Experiment I

3.2.1 Process technology for production and optimisation of spray dried banana pseudostem juice powder (Product-I)

Microencapsulated nutraceutical powders were developed from banana pseudostem juice with maltodextrin and corn starch as wall materials and are discussed under subsequent sections.

3.2.2 Preparation of feed solution

Pre-treated banana pseudostem samples were crushed by a mixer and pressed manually to squeeze out the juice. Squeezed out juice was filtered in a clean muslin cloth and it was mixed with wall materials like maltodextrin and corn starch along with sugar at various concentrations. Ginger extract was added as a natural flavouring in all the samples. Various treatment combinations for the development of pseudostem juice powder is given in Table.3.1 and the detailed process flow chart for the preparation of feed solution is shown in Fig.3.1.

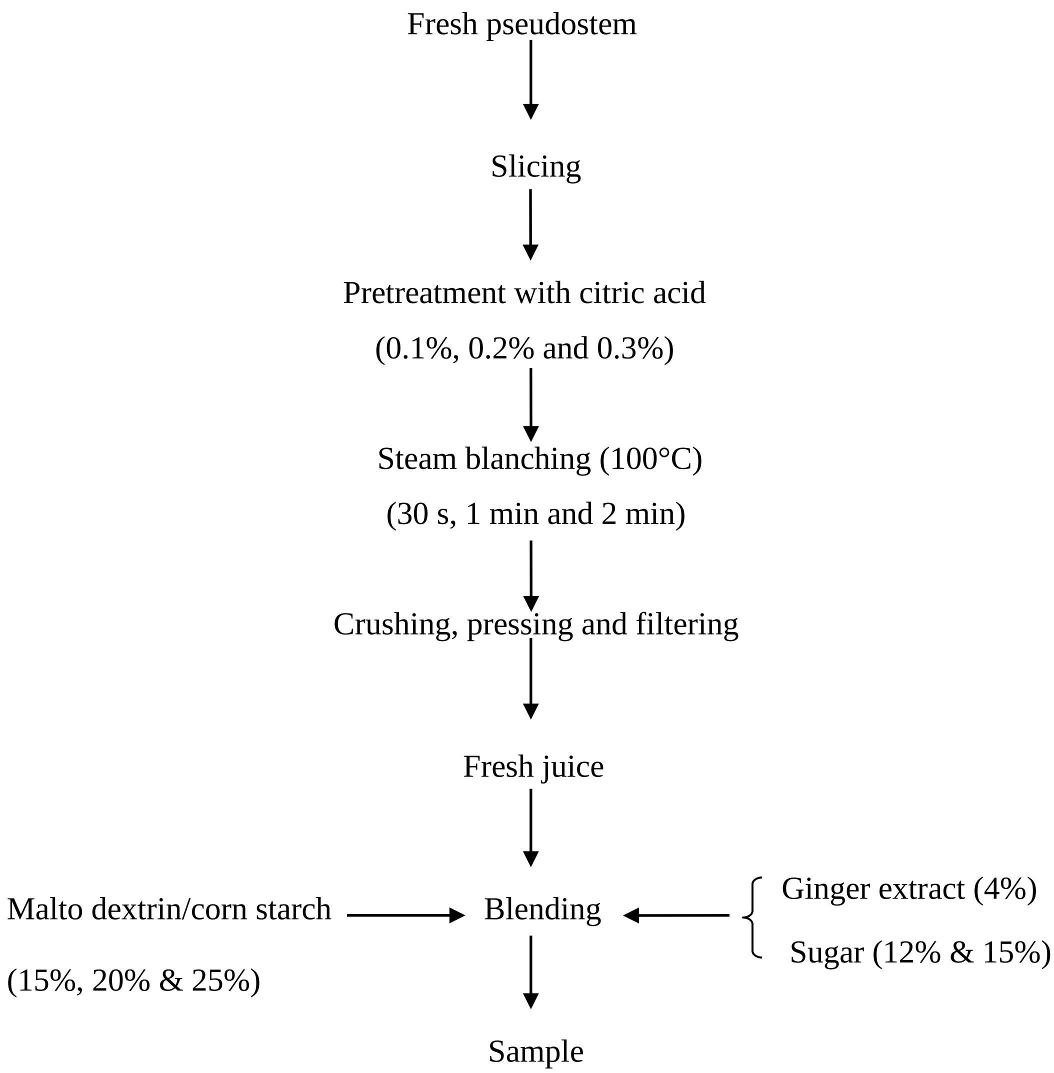

Fig. 3.1 Process flow chart of feed solution

3.2.3 Raw material concentration and combination

Raw materials like juice from pretreated pseudostem, sugar and wall materials such as maltodextrin and corn starch were taken in various concentrations in each treatment. Equal proportion of ginger extract (4%) was added in all the treatments during the study. Pseudostem based nutraceutical powder was developed by microencapsulating with the aid of spray drying under different operating conditions.

Table 3.2 Treatment combinations

Combinations		
Maltodextrin	Corn starch	**Raw materials (%)**
T1	T7	P_{69}:S_{12}:M_{15}/C_{15}
T2	T8	P_{66}:S_{15}:M_{15}/C_{15}
T3	T9	P_{64}:S_{12}:M_{20}/C_{20}
T4	T10	P_{61}:S_{15}:M_{20}/C_{20}
T5	T11	P_{59}:S_{12}:M_{25}/C_{25}
T6	T12	P_{56}:S_{15}:M_{25}/C_{25}

P=Pseudostem juice, S=Sugar, M=Maltodextrin, C=Corn starch

3.3 Experiment II

3.3.1 Spray drying of banana pseudostem juice-horse gram extract blend (Product-II)

Ginger flavoured banana pseudostem juice powders were developed by blending horse gram extract in different proportions. Microencapsulation by spray drying technology was adopted for the product development. Detailed methodology for the development of banana pseudostem juice-horse gram extract blend is discussed under following sections.

3.3.2 Preparation of feed solution

Feed solution was prepared by blending freshly prepared pseudostem juice from the pretreated banana pseudostems, horse gram extract and the adjunct. Maltodextrin and corn starch were used as adjunct and equal proportion of ginger extract was added in all treatment combinations for improved sensory quality of final powder. Various treatment combinations for the development of pseudostem juice powder is given in Table 3.3.

Horse gram extract was prepared by the method explained by Verma *et al.* (2014). Raw horse gram was weighed, cleaned and soaked in water for 12 h. Soaked horse gram was pressure cooked for about 10 min and crushed to get the pulp. Pulp which was extracted from the cooked horse gram was allowed to pass through a 125µ sieve to get the clear extract. The procedure for extracting horse gram extract is presented in Fig. 3.2.

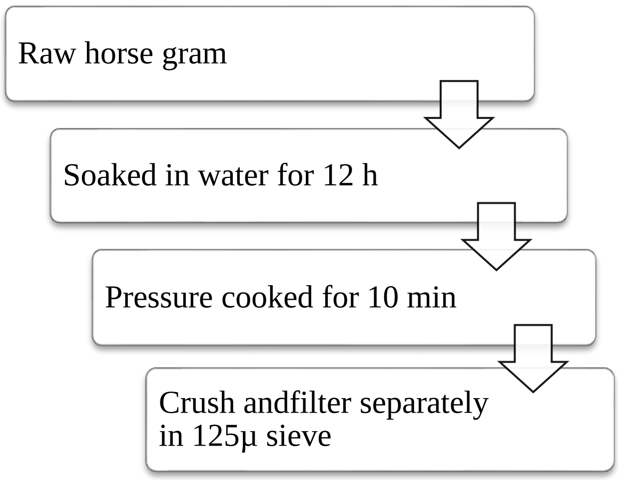

Fig. 3.2 Preparation of horse gram extract

3.3.3 Raw material concentration and combination

Raw materials like juice from pretreated pseudostem, horse gram extract and wall materials such as maltodextrin and corn starch were taken in various concentrations in each treatment. Equal proportions of ginger extract (2%) were added in all the treatments during the study. Pseudostem based nutraceutical powder was developed by micro encapsulating each treatment with the aid of spray drying under different operating conditions. Treatments with raw material combinations were listed in Table 3.3 given below.

Table 3.3 Treatment combinations

Combinations		
Maltodextrin	Corn starch	**Raw materials (%)**
T1	T7	P_{68}:HG_{10}:M_{20}/C_{20}
T2	T8	P_{58}:HG_{20}:M_{20}/C_{20}
T3	T9	P_{48}:HG_{30}:M_{20}/C_{20}
T4	T10	P_{63}:HG_{10}:M_{25}/C_{25}
T5	T11	P_{53}:HG_{20}:M_{25}/C_{25}
T6	T12	P_{43}:HG_{30}:M_{25}/C_{25}

P=Pseudostem juice, HG=Horse gram extract, M=Maltodextrin, C=Corn starch

3.4 Experiment III

3.4.1 Development and quality evaluation of milk fortified banana pseudostem juice powder (Product-III)

Fortified banana pseudostem juice powder was developed by incorporating milk and horse gram in various proportions. The detailed methodology adopted for its development is discussed in subsequent sections.

3.4.2 Feed preparation

Freshly prepared pseudostem juice squeezed out from the pre-treated pseudostem slices and horse gram extract along with milk were blended together during feed preparation. Horse gram extract which was prepared from the pressure cooked horse gram and the pasteurised milk were blended at different concentrations. Various treatment combinations and their concentrations in each treatment is tabulated and given in the Table 3.4.Cardamom powder made from dried cardamom seeds were added in equal proportions among all treatments. Process flow chart for the preparation of feed solution is shown in Fig. 3.3.

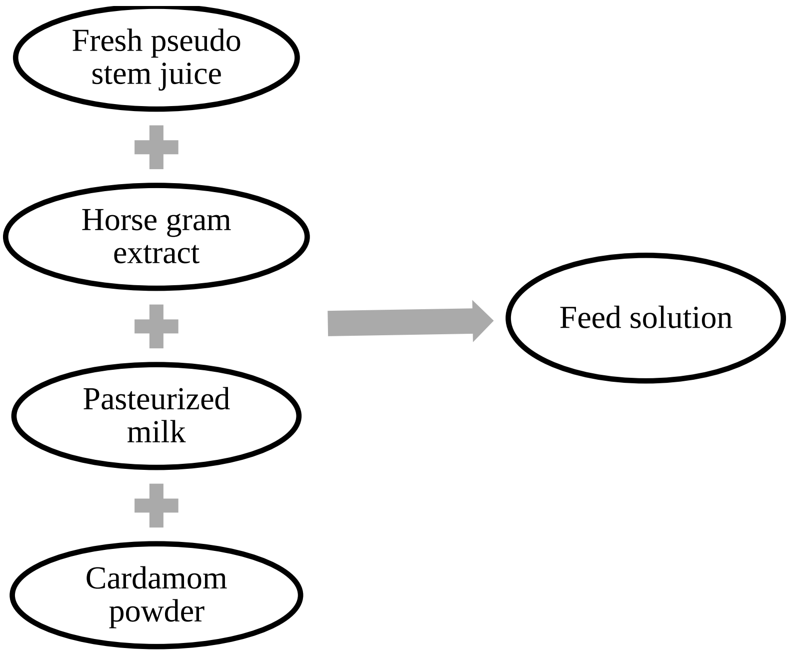

Fig. 3.3 Process flow chart of feed solution

3.4.3 Raw material concentration and combination

Different concentrations of raw materials such as, pretreated pseudostem juice, horse gram extract and milk were blended in each treatment. Since milk is a good carrier, wall materials such as maltodextrin and corn starch were not added for the development of product-III. An equal proportion of cardamom powder (2 pinches, *i.e,* 0.625 g) was added in all the treatments during the study for enhanced sensorial quality. Pseudostem based nutraceutical powder was developed by micro encapsulating each treatment with the aid of spray drying under different operating conditions. Treatments with raw material combinations were listed in Table 3.4 given below.

Table 3.4 Treatment combinations

Combinations	Raw materials (%)
T1	P_{75}:HG_{10}:ML_{15}
T2	P_{65}:HG_{20}:ML_{15}
T3	P_{55}:HG_{30}:ML_{15}
T4	P_{65}:HG_{10}:ML_{25}
T5	P_{55}:HG_{20}:ML_{25}
T6	P_{45}:HG_{30}:ML_{25}
T7	P_{60}:HG_{10}:ML_{30}
T8	P_{50}:HG_{20}:ML_{30}
T9	P_{40}:HG_{30}:ML_{30}
T10	P_{40}:HG_{10}:ML_{50}
T11	P_{30}:HG_{20}:ML_{50}
T12	P_{20}:HG_{30}:ML_{50}

P=Pseudostem juice, HG=Horse gram extract, ML=milk, CP=Cardamom powder

3.5 Microencapsulation by spray drying

Spray drying method was used to obtain pseudostem based nutraceutical powders which were made from different composition (feed solutions prepared in experiment I, II and III). A lab model vertical co-current SMST tall type spray dryer (Plate 3.4) with an evaporation rate of 1000 $ml.h^{-1}$ was used during the research work. It comprised of air filter, air heater, air distributor, fluid nozzle, drying chamber, collection glass bottles, cyclone separator and an air compressor.

The main factors influencing the powder quality included the spray drying parameters like inlet air temperature, outlet air temperature, feed rate and atomizer speed. For present study distilled water was pumped into the drying chamber in order to adjust the spray drying temperature. This was done about 30 min prior to feeding. The feed was introduced into the spray dryer through feed pipes when it reached the pre-set inlet temperature. Drying was carried out at different inlet air temperature and feed pump speeds to develop microencapsulated banana pseudostem juice powders.

Plate 3.2 Spray dryer

3.5.1 Standardisation of spray dryer parameters

The spray drying parameters were optimised based on the yield and external appearance of the powder. It is having a significant role in producing higher powder efficiency and yield. These response variables were selected as they had significant influence on quality characteristics of the final product (Chegini and Ghobadian, 2007). Spray dryer parameters like feed pump rpm, main blower rpm, Inlet temperature, outlet temperature were optimised from preliminary studies. Spray drying parameters to be standardised are presented in Table 3.5 given below.

Table 3.5 Spray dryer parameters

Sl. No.	Parameter	Experiment I	Experiment II	Experiment III
1	Main blower rpm	1800	1800	1800
2	Inlet temperature(ºC)	180 - 190	180 - 190	185 - 200
3	Feed pump rpm	10-20	10-20	10-20
4	Pressure (Kg/cm^2)	2	2	2

Based on a thorough review of literature and the preliminary studies conducted, the process parameters which would influence the product quality characteristics, utilisation potential and storage stability were chosen as independent variables. The product quality characteristics which are characteristics of these parameters were selected as dependent variables.

3.6 Physicochemical properties of microencapsulated pseudostem powder

Pseudostem juice powder samples were analysed for physicochemical properties as described in AOAC and from the literature collected.

3.6.1 Moisture content

Hot air oven method described in AOAC (No. 990.20; AOAC, 2005) was carried out for moisture content analysis. The moisture content of pseudostem juice powder was determined by weighing one gram powder sample in a pre-weighed petri dish and dried in an oven at 100ºC for 4 h. Weight differences of the samples were noted after cooling it in desiccators. Procedure was repeated until two similar successive readings were obtained. Determination of moisture content of samples was carried out three times and the average value was considered as moisture content of spray pseudostem juice powder. The moisture content of the sample on percent (w.b) was calculated by using the following formula;

$$\text{Moisture content (\%)} = \frac{W_1 - W_2}{W_1} \times 100 \qquad \ldots.\ 3.1$$

Where, W_1 (g) = Initial weight of sample, W_2 (g) = Final weight of sample

3.6.2 Total soluble solids

Total soluble solid (TSS) in fresh pseudostem juice and the diluted pseudostem juice powder was measured using a hand refractometer (Erma inc, Tokyo). Pseudostem powder was mixed with water and allows the sample to settle. One or two drops of the prepared sample were placed on the hand refractometer for TSS measurement. It was expressed in degree Brix (AOAC, 1990).

3.6.4 pH

The pH of the reconstituted pseudostem juice powder was measured using a digital pH meter (Systonics, Naroda) available at Dept. FAPE, Tavanur. Distilled water of pH 7 was used to calibrate the pH meter before determination of pH of powder. Ten milliliters of diluted powder sample was taken in a beaker and the electrode of pH meter was immersed in the sample to determine pH. The reading was directly recorded from the pH meter and was repeated thrice for precision. Average value was considered as pH of powder (AOAC, 1990).

3.6.5 Titrable acidity

Acidity of pseudostem samples was determined by the titration method (No. 947.05 AOAC 2005). Ten ml of diluted powder sample (one gram powder in 10 ml distilled water) was taken in a conical flask and two to three drops of phenolphthalein indicator were added to it. The sample containing indicator was titrated against 0.1N NaOH until light pink end point appeared for few seconds. Volume of 0.1N NaOH used was recorded. Determination of titratable acidity of samples was carried out three times and the average value was considered as titratable acidity of the sample. The acidity of pseudostem powder was computed by using the following expressions:

$$\text{Percentage acidity of powder} = \frac{9 \times \text{ml of 0.1 N NaOH} \times 0.1}{\text{Weight of powder (g)}} \qquad \text{. . . . 3.2}$$

3.6.6 Water activity

The water activity of pseudostem juice powder was carried out using Aqua lab water activity meter (M/s. Aqua Lab, U.S.A; model: Series 3TE). Water activity (a_w) is a measure of the amount of water available (Troller and Christian, 1978). For determining the water activity, the pseudostem powder was filled in the disposable cups of the water activity meter and the sample drawer knob is turned to OPEN position. After opening the drawer, the disposable cup with powder was then placed in the drawer and closed. The sample drawer knob was then turned to the READ position and the water activity of powder was noted from the LCD display of the water activity meter. Experiment repeated three times and the average value taken as the water activity.

3.6.7 Total ash

The total ash content of pseudostem powder was determined by muffle furnace method described in AOAC, 2005 (Method No.930.30). One gram of powder samples weighed into a pre weighed crucible of 7-8 cm diameter. Crucibles along with weighed samples were loaded into muffle furnace. Samples were heated about 5 h at 550°C. It was then cooled in desiccator and weighed. The difference in weights taken as the total ash content and is expressed in percentage.

$$\text{Total ash (\%)} = \frac{\text{Weight of ash (g)}}{\text{Weight of sample (g)}} \times 100 \qquad \text{. . . . 3.3}$$

3.6.8 Bulk density

The bulk density of spray dried powder obtained from different treatments was measured according to the procedure described by Gong *et al.* (2008) and Lebrun *et al.* (2012). Approximately, one gram of powder was freely poured into a 10 ml graduated cylinder without tapping. The level of samples in cylinder was noted for measuring loose bulk density of spray dried powder. Same samples were repeatedly tapped manually by lifting and dropping the cylinder under its own weight at a vertical distance. This was done until negligible difference in volume between succeeding measurements was observed and is used for the measurement of tapped bulk density of powder. Experiment was repeated for accuracy and average values were considered as loose bulk density and tapped bulk density of samples. The bulk density of powder was computed using the following expression

$$\text{Loose bulk density (g/ml)} = \frac{\text{Weight of sample (g)}}{\text{Bulk sample volume (ml)}} \quad \ldots . 3.4$$

$$\text{Tapped bulk density (g/cm}^3\text{)} = \frac{\text{Weight of sample (g)}}{\text{Tapped power volume (cm}^3\text{)}} \quad \ldots . 3.5$$

3.6.9 Colour characteristics

Colour of product is an important parameter that will be valued during product marketing. Colour of the pseudostem based nutraceutical powders were measured using Hunter lab colour flex meter (Hunter Associates Laboratory, Reston, Virginia, USA). The colour was measured by using CIELAB scale at 10° observer at D_{65} illuminant. It works on the principle of focusing the light and measuring the energy reflected from the sample across the entire visible spectrum. The three dimensional scale L*, a* and b* values were used for colour measurement. The luminance (L*) forms the vertical axis, which indicates light - dark spectrum with a range from 0 (black) to 100 (white). In the same way, a* indicates the green - red spectrum with a range of - 60 (green) to + 60 (red) and b* indicates the blue - yellow spectrum with a range from - 60 (blue) to + 60 (yellow) dimensions respectively (Reddy *et al.*, 2014).

The instrument was standardised before placing the sample by placing black and white tile provided with the instrument. Once the instrument was standardised, it was ready to measure the colour. It can also be cross checked by placing the white tile which was provided by the L*, a* and b* values. The sample was filled in the sample cup. The deviation of the colour of the sample to standard was also observed and recorded in the computer interface. The experiment was repeated thrice for each sample and average was taken as color range.

3.6.10 Particle size analysis by Scanning Electron Microscopy (SEM)

The morphology of powder was determined using scanning electron microscope (SEM) in NIIST, Trivandrum. The scanning electron microscope (SEM) determines the particle size of a powder by using a beam of high energy electrons and electromagnet.

Scanning electron microscopy analysis of the samples was carried out using, JSM-6400 scanning electron microscope (JEOL, Tokyo, Japan). Prior to examination, the samples were uniformly spread on a sample holding stub made of aluminium. A carbon tape was stuck to the sample holding side of the stub and then a thin uniform layer of samples was coated. These samples being non-conductive were sputter coated with gold to render them electrically conductive by using HUMMLE VII Sputter Coating Device (Anatech Electronics, Garfield, N.J., USA). The sputter coated samples were examined at 15 kV. The micrographs were taken at different magnifications.

3.7 Reconstitution properties of spray dried pseudostem juice powder

Reconstituted properties of food powders are important for its market quality and consumer acceptability. Reconstitution properties such as solubility, wettability, water solubility index and water absorption index of spray dried pseudostem juice powder were determined using standard procedures as explained below.

3.7.1 Wettability

Time in seconds necessary to achieve complete wetting of the pseudostem juice powder when it is poured into water at room temperature is noted as wettability. For wettability determination, a glass funnel held on a stand and was set over the beaker containing 100 ml of distilled water at room temperature. A glass rod was kept inside the funnel to block its lower opening. To this setup, one gram sample was placed around the glass rod and then the glass rod was lifted.

The time taken for complete wetting of powder particles were noted using a stop watch. Determination of wettability was carried out thrice for spray dried powder and the average value was considered wettability of powder (Jinapong *et al.*, 2008, Desousa *et al*., 2008, Falade and Omojola, 2010).

3.7.2 Solubility

Solubility of pseudostem powder was carried by the method explained by Chauca *et al*. (2005). One gram pseudostem powder was mixed with 100 ml of water at room temperature for 30 min. A 10 ml aliquot of the supernatant solution was transferred to a 15 ml centrifuge tube and centrifuged for 15 min at 15,000 rpm. The aliquot of the supernatant was then taken in a pre-weighed aluminum moisture dish, evaporated on a steam bath and dried in an oven at 110°C overnight. The solubility was calculated as per equation 3.7.

$$\text{Solubility (\%)} = \frac{10 \times \text{Solid in supernatant (g)}}{\text{sample weight (g)}} \times 100 \qquad \text{. . . . 3.6}$$

3.7.3 Water solubility index

The water solubility index of pseudostem juice powder was determined by mixing 2.5 g powder sample and distilled water (30 ml) vigorously in a 100 ml centrifuge tube, incubated in a 37°C water bath for 30 min and then centrifuged for 20 min at 10,000 rpm in a centrifuge (Rotek, 50Cps). The supernatant was carefully collected in a pre-weighed beaker and oven dried at a temperature of 103 ± 2°C (Anderson, 1969 and Sabhadinde, 2014). Water solubility index was calculated as follows

$$\text{Water solubility index (\%)} = \frac{\text{Weight of supernatant}}{\text{Weight of sample}} \times 100 \qquad \text{. . . . 3.7}$$

3.7.4 Water absorption index

Water absorption index of the pseudostem juice powder was determined by agitating suspension of 2.5 g powder in 25 ml distilled water for one hour followed by centrifugation at 3000 rpm for 10 min. The free water was removed from the wet residue, which was then drained for 10 min. The wet residue was then weighed which was taken as the water absorption index of pseudostem juice powder (Sabhadinde, 2014).

$$\text{Water absorption index (\%)} = \frac{\text{Weight of residual}}{\text{Weight of sample}} \times 100 \qquad \text{. . . . 3.8}$$

3.8 Proximate analysis

3.8.1 Determination of total carbohydrate

Total carbohydrate present in pseudostem juice powder was determined by Anthrone method. The sample (100 mg) was taken in a boiling tube. It was hydrolyzed by keeping it in a boiling water bath for three hours with 5 ml of 2.5 N hydro chloric acid and cool to room temperature. Followed by neutralisation of the sample with solid sodium carbonate until the effervescence ceases. Again the volume was made up to 100 ml and centrifuged. Supernatant was collected and 0.5 and one milliliter aliquots were taken for analysis. Standards (100 mg glucose + 100 ml distilled water) were prepared by taking 0, 0.2, 0.4, 0.6, 0.8 and one milliliter of the working standard in which, '0' serves as blank. By adding distilled water, volume was made up to one milliliter in all the tubes including the sample tubes. Then 4 ml of anthrone reagent was added and is heated for 8 minutes in a boiling water bath. The readings were taken using spectrometer (*i.e.,* Green to dark green colour at 630 nm was read after cooling) and concentration of the standard versus, absorbance graph was plotted. From the graph, amount of carbohydrate present in the sample tube was calculated by the equation given below (Nithya *et al.,* 2014).

$$\text{Carbohydrate (\%)} = \frac{\text{mg of glucose}}{\text{Volume of test sample}} \times 100 \qquad \text{. . . . 3.9}$$

3.8.2 Mineral analysis

3.8.2.1 Atomic absorption spectrometry (AAS)

Pseudostem juice and horse gram extract both are rich in minerals and vitamins. To quantify the minerals present in the spray dried pseudostem juice atomic absorption sprectrophotometer present in Radio tracer laboratory, Vellanikkara campus, Thrissur was used. Atomic absorption spectrometry (AAS) is used as an analytical method to measure the concentrations of elements present in the sample. Atomic absorption is so sensitive that it can measure down to parts per billion of a gram ($\mu g\ dm^{-3}$) in a sample (Ponnambalam and Sellappan, 2014).

3.9 Protein

The nitrogen content in pseudostem powder sample was estimated by using Kjeldahl instrument by Micro-Kjeldahl method (AOAC 2005). Seven grams of Potassium sulfate (K_2SO_4), 0.8 g of cupper (II) sulphate penta hydroxide ($CuSO_4.5H_2O$) and one gram of powder sample were added to digestion tubes and then 12 ml of hydrochloric acid (H_2SO_4) was added slowly. The digestion tubes were placed on fume ejection system until the digest cleared (clear with light blue–green colour) and was then cooled to room temperature. Digested sample was distilled with 40% sodium hydroxide (NaOH) solution. The distillate was collected in 30 ml of 4% boric acid solution and sample after distillation were titrated against 0.1N hydro chloric acid (HCl) until get the light pink colour was obtained. Methyl red indicator solution and bromocresol green indicator solutions were used as an indicator during titration. The protein content was calculated as:

$$\text{Protein (\%)} = \frac{(14 \times \text{titrate value} \times \text{Normality of alkali} \times 6.25)}{\text{Sample weight}} \times 100 \qquad \ldots.3.10$$

3.10 Flowability and Cohesiveness

3.10.1 Carr's index (CI)

The compressibility index or the Carr's index can be measured from the predetermined bulk density and tapped bulk density values. The index of pseudostem samples was determined by equation 3.11 given below and its powder characteristics was determined by referring the values tabulated by Lebrun *et al.* (2012).

$$\text{Carr's index (\%)} = \frac{\text{Tapped bulk density (g/ml) - Loose bulk density (g/ml)}}{\text{Tapped bulk density (g/ml)}} \quad \text{....3.11}$$

3.10.2 Hausner ratio (HR)

Hausner ratio of the pseudostem juice powder was determined by the method described by Shisir *et al.* (2015). HR value for the powder was calculated by the formula given by:

$$\text{Hausner ratio (HR)} = \frac{\text{Tapped bulk density (g/ml)}}{\text{Loose bulk density (g/ml)}} \quad \text{. . . . 3.12}$$

Table 3.6 Specifications for Carr's Index and Hausner Ratio

Sl. No.	Flowability	Carr's Index (%)	Hausner Ratio
1	Excellent	0-10	1-1.11
2	Good	11-15	1.12-1.18
3	Fair	16-20	1.19-1.25
4	Possible	21-25	1.26-1.34
5	Poor	26-31	1.35-1.45
6	Very poor	32-37	1.46-1.59
7	Very, very poor	>38	>1.60

Source: Lebrun *et al.* (2012)

3.11 Microbiological Analysis

Microbiological analysis of prepared samples included determination of total viable count. Nutrient agar media was used for the microbial analysis. For carrying out microbial analysis, agar media and glass wares were autoclaved at 121°C for 15 min to make them sterile. One gram of the pseudostem juice powder was taken and added to 10 ml of sterile water blank. Emulsion was shaken well for 10 to 15 min to obtain homogenised suspension of microorganisms and this gave a dilution of 10^{-1}. One ml from (10^{-1}) this dilution was transferred to 9 ml of sterile water blank with a sterile one ml pipette, which gave a dilution of 10^{-2}. The process was repeated up to 10^{-4} dilutions with the sterile water blank. Sterile one ml aliquots from all dilutions were transferred to the sterile petri dishes with nutrient agar for the enumeration of microbes. The experiments were carried out in triplicate for greater accuracy. About 15-20 ml of growth media were poured to plates at temperature (45-50°C) and the plates were rotated clockwise and anticlockwise directions on the flat surface to have a uniform distribution of colonies. Plates were kept undisturbed until the agar gets solidify. After solidification, the plates were inverted and incubated at room temperature for 2-5 days (bacteria one day, yeast and fungi three days). Total plate counts (TPC) were determined on plate count agar pour plates and enumerated after an incubation period of 48-72 h at 30°C (Stillings *et al.,* 1998). The colonies were counted after the incubation period and the number of colony forming units per ml of sample were calculated by applying the following formula:

Number of colony forming units (CFU’s) per gram of the sample

$$\text{CFU} = \frac{\text{Mean number of CFU's} \times \text{Dilution factor}}{\text{Quality of sample on weight basis}} \quad \ldots . 3.13$$

3.12 Product yield

Pseudostem powder recovered after feeding was estimated by taking the ratio of weight of sample collected to the juice fed to the drier (Arslan *et al.,* 2015 and Fazaeli *et al.,* 2012) and is given by:

$$\text{Product yield } (\%) = \frac{\text{Solid content in product}}{\text{Solid content in feed}} \times 100 \qquad \ldots .\ 3.14$$

3.13 Packaging and storage study

Pseudostem juice powders developed by each experiment were packed in LDPE zip pouches and were inserted in aluminium pouches and sealed using a hand sealing machine (Sharma *et al.,* 2003). Sealed pouches were stored in ambient condition for a period of six months and quality parameters *viz.* moisture content, water activity, TSS, pH, titrable acidity, solubility, wettability, bulk density, solid content and colour values of the powders were recorded in each month (Liu *et al.,* 2010 and Cristina *et al.,* 2008).

3.14 Sensory evaluation

The drink prepared from powder was assessed for their sensory attributes like appearance, flavour, taste and overall acceptability by a 9-point hedonic scale test (Appendix H). Optimised pseudostem powders developed by spray drying method were reconstituted with normal water at 1:10 ratio during sensory analysis. The prepared products were evaluated for sensory characteristics by a panel of 12 judges. Fresh fortified pseudostem juice which was made prior to drying was kept as control for comparison (Neto *et al.,* 2015).

3.15 Statistical analysis

3.15.1 Experimental design

All the experiments in the study were conducted in triplicate and mean values were reported. Completely randomised design (CRD) by Design expert software 7.0 was used to analyse the data. After proper analysis, data were accommodated in the tables as per the needs of objectives for interpretation of results. Statistical significance was examined by analysis of variance (ANOVA) for each response. The p-values were used as a tool to check the significance of each of the coefficients, which, in turn were necessary to understand the pattern of the mutual interactions between the test variables. The smaller the magnitude of the p, the more significant is the corresponding coefficient.

CHAPTER IV

RESULTS AND DISCUSSION

This chapter enunciates the experiments conducted to standardise various parameters for developing spray dried pseudostem juice powder. The chapter also discusses in detail on quality changes that occurred during storage period of optimised product.

4.1 Pretreatment standardisation

The pretreatment (blanching) was done to inactivate enzymes and browning of pseudostem. Pretreatments were carried out by dipping the sliced pseudostem pieces in different concentrations (0.1, 0.2 and 0.3%) of citric acid solution. Samples treated with citric acid were steam blanched at 100°C for 30 s, one and two minutes. The pretreatment was standardised using peroxidase and catalase test. The samples treated with 0.3% citric acid solution and steam blanched at one minute showed negative signals in both test indicating enzyme inactivation. Thus, the blanching time for pseudostem was standardised as one minute and 0.3% citric acid concentration for pre-treatment was fixed and similar results were reported by Nithya *et al.* (2014).

4.2 Physicochemical characteristics of fresh pseudostem juice

Physico-chemical characteristics of fresh pseudostem juice were quantified prior to spray drying process and are presented in Table 4.1.

Table 4.1 Characteristics of fresh pseudostem juice

Characteristics	Mean ± SD
Moisture content (% w.b.)	94.8±0.65
Total soluble solids (°Brix)	3±0.360
pH	6.5±0.060

SD - Standard deviation

The present study on quality evaluation of three products at its fresh form and during storage were investigated and given in subsequent sessions.

4.3 Experiment I: Process technology for production and optimisation of spray dried banana pseudostem juice powder

4.4 Experiment II: Spray drying of banana pseudostem juice-horse gram extract blend

4.5 Experiment III: Development and quality evaluation of milk fortified banana pseudostem juice powder

4.3 Experiment I

4.3.1 Process protocol for production and optimisation of spray dried banana pseudostem juice powder (Product-I)

The detailed processing methodology for the production of spray dried pseudostem juice powder was explained in Chapter III. Different concentrations of wall materials *viz.*, maltodextrin (MD) and corn starch (15, 20 and 25%) and sugar (12 and 15%) were blended with pre-treated pseudostem juice as presented in earlier chapter. These blends were dried in spray dryer at inlet temperatures of 180, 185 and 190°C with varying feed pump speed of 10, 15 and 20 rpm to produce pseudostem juice powder. The main blower rpm of dryer was kept constant at 1800 rpm throughout the study. Different raw material combinations and spray drying parameters were fixed according to the preliminary trials and were statistically analysed using analysis of variance (ANOVA) for product optimisation. From preliminary trials conducted at different feed pump rpm 10, 15 and 20, it was noted that at higher rpm, the outlet temperature was lowered to 48ºC. This drastic difference between inlet and outlet temperature led to high moisture (>7%) product. At lower feed pump speed of 10 rpm, it took long time for processing the juice to powder leading to increase in product cost and time of processing (Suzihaque *et al.*, 2015). Thus a medium feed pump rpm of 15 was selected for further studies while low and high feed pump speed were omitted. In case of wall material, very less yield (<10%) was obtained with corn starch compared with MD. Therefore corn starch was not considered for further studies.

Treatments with different combination of MD, sugar and pseudostem juice mentioned in Chapter III at temperature of 180, 185 and 190ºC were considered for development of spray dried pseudostem juice powder.

Plate 4.1 Spray dried banana pseudostem juice powder

The effect of processing conditions *viz*., raw material concentration and inlet air temperature on physico-chemical properties, reconstitution properties, flow properties, microbial analysis, proximate composition, yield and storage stability of spray dried pseudostem powder were determined and are explained in following sections.

4.3.2 Physico-chemical properties of spray dried banana pseudostem powder

4.3.2.1 Effect of spray drying parameters on moisture content

Moisture content of spray dried pseudostem juice powder was in the range of 2.99-4.60% (w.b.) (Appendix A1). As expected, it was observed that at elevated inlet air temperature (190ºC) moisture content of sample decreased due to rapid evaporation. Similar trend in moisture content was observed in tomato pulp powder (Gaoula and Adamapoulos, 2010), pineapple (Abadio *et al*., 2004) and orange juice powder (Chegini and Ghobadian, 2007). Considering the effect of wall material, higher MD concentrations showed a positive effect in reducing the moisture content of spray-dried powder. This phenomenon was explained by

Kha *et al*. (2010) and Shishira *et al.* (2014). According to their study on spray dried gac aril powder and pink guava powder addition of MD increased the total solids of feed and reduced the amount of water for evaporation. This led to reduced moisture content (2.99%) with increase in MD concentration (25%). It was observed that the moisture content of spray dried pseudostem powder increased slightly with increase in sugar concentration. The variation in moisture content of spray dried banana pseudostem powder at different process parameter is shown in Fig. 4.1.

Treatment with 25% MD and 12% sugar and spray dried at 190°C inlet air temperature scored the best moisture value. The effect of spray drying parameters on moisture content of spray dried pseudostem powder were statistically analysed and given in Appendix I1. Statistical analysis indicated that various spray drying parameters and MD concentration showed significant effect ($p<0.0001$) on moisture content.

4.3.2.2 Effect of spray drying parameters on water activity

Water activity is an important parameter for determining the product stability. Stability of food usually decreases with increase in water activity. The water activity of spray dried pseudostem juice powder varied from 0.295 to 0.430 (Appendix A2). The effects of independent variables on water activity were in agreement with results reported by Gaoula and Adamopoulos (2010) and Chegini and Ghobadian (2007) in orange and tomato juice powder, respectively. Powder with low moisture content of 3.10% and high sugar concentration of 15% showed low water activity of 0.295. Similar findings were reported by Nithya *et al.* (2014). At low moisture content and high sugar concentration, the available water for microbial growth gets reduced and thus powder stability increases.

It is evident from Fig. 4.2 that the water activity is maximum of 0.430 for T1 treatment and minimum of 0.295 for T6 treatment. In general, the water activity for all the treatments was found to be at safe level, *i.e.*, below 0.6 as suggested by Fennema (1996). The results from statistical analysis illustrates significant effect of various spray drying parameters and MD concentration on water activity

($p<0.0001$). The ANOVA associated with completely randomized design was implemented and presented in Appendix I2.

4.3.2.3 Effect of spray drying parameters on bulk density

Loose and tapped bulk density values of developed pseudostem juice powders with various raw material concentrations at different spray drying parameters were investigated. Tapped bulk density (TBD) of banana pseudostem juice powder samples ranged between 0.410-0.510 g/ml (Appendix A3) and loose bulk density (LBD) ranged from 0.258 to 0.457 g/ml (Appendix A4). It was observed that the bulk densities of spray dried banana pseudostem juice powder decreased with increase in inlet air temperature. As a result of rapid evaporation, vapour droplets were formed and gets expanded at high inlet air temperature of 190ºC. Thus at elevated temperature micro particles become hollowed and results in low bulk density (TBD - 0.410 g/ml and LBD - 0.258 g/ml). Similar results were reported by Samborska and Bienkowska, (2013) for spray dried honey powder and Chegini and Ghobadian (2007) for orange juice powder.

The changes in bulk density pertaining to MD concentration were analysed for all the six treatments. The results confirmed that both loose and tapped bulk density of final product decreased with increase in MD concentration. This might be due to high porosity of powder observed with increase in wall material concentration (Caparino *et al.*, 2012). The study on spray dried tomato pulp by Shrestha *et al.* (2007) illustrated an increase in MD concentration with a decrease in the bulk density. Lower bulk density values were observed at 25% MD concentration.

Figures 4.3 and 4.4 represent the changes in bulk density values (*i.e.*, TBD and LBD) of spray dried banana pseudostem juice powder at different process parameter. It is clear that the bulk density values of powder decreased with decrease in sugar concentration. The effect of spray drying on bulk density of banana pseudostem juice powder were statistically examined and tabulated in Appendix I3 and I4. From the statistical analysis, it is evident that spray drying parameters and MD concentration affects the bulk density significantly ($p<0.0001$).

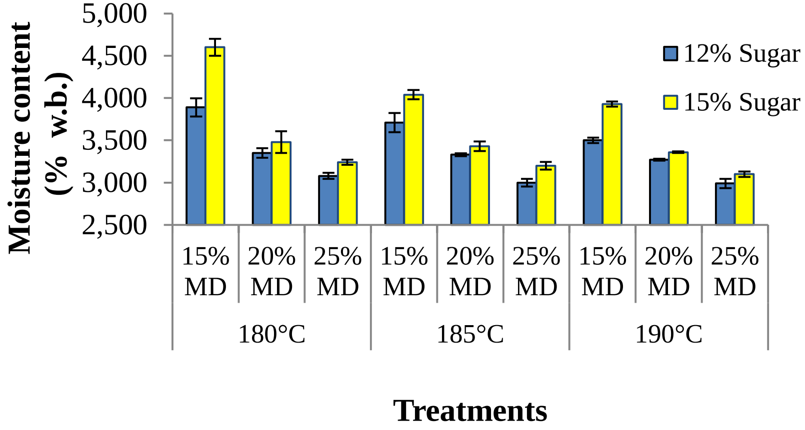

Fig. 4.1 Moisture content of Product-I

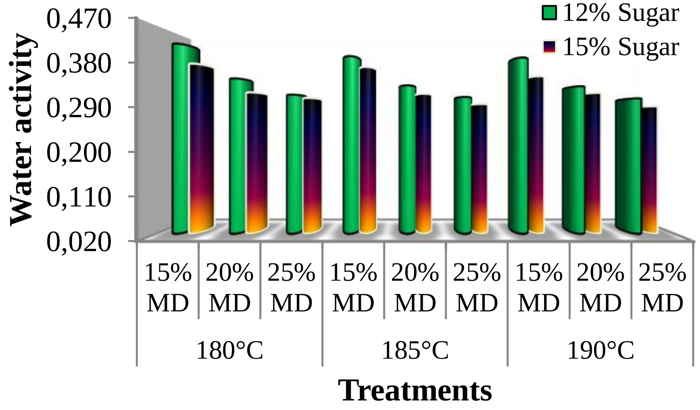

Fig. 4.2 Water activity of Product-I

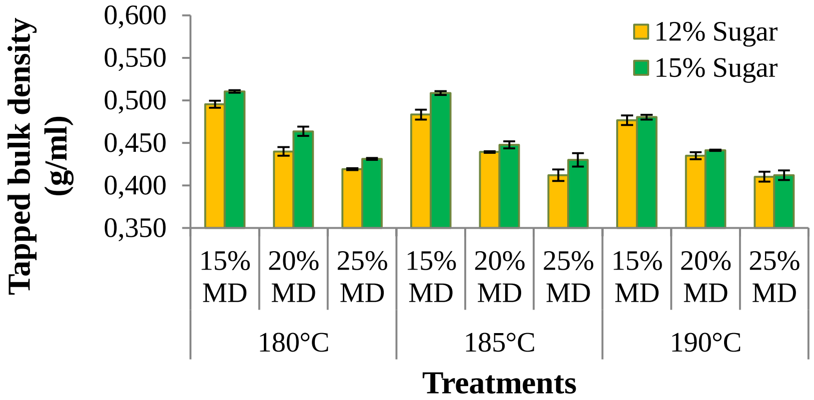

Fig. 4.3 Tapped bulk density of Product-I

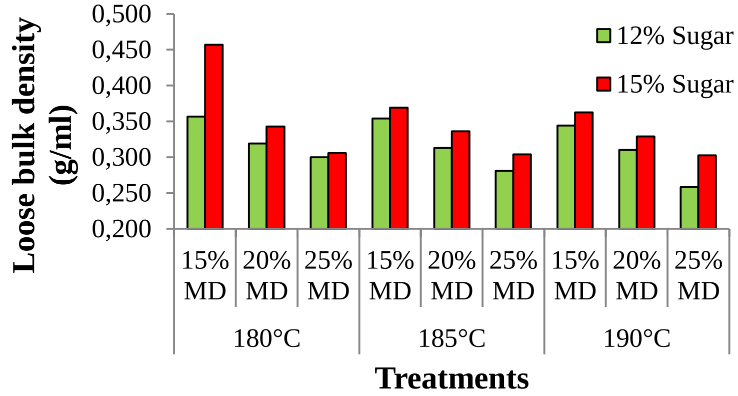

Fig. 4.4 Loose bulk density of Product-I

4.3.2.4 Colour characteristics

Colour is one of the important parameter as it determines consumer acceptance in food applications. It was observed that ‘L^*’ value indicating lightness varied from 77.50 to 92.30 and maximum ‘L^*’ value of 92.30 was recorded in treatment T6. The variation of ‘L^*’ values for different treatments are given in Table 4.2.

Table 4.2 Colour characteristics of Product-I

Colour characteristics	Inlet temperature (°C)	T1	T2	T3	T4	T5	T6
	180	78.850	80.000	83.000	86.140	88.060	92.030
L^*	185	78.010	79.910	83.200	86.600	88.010	92.300
	190	77.500	79.000	85.710	85.500	87.500	90.200
	180	1.520	0.610	0.500	0.430	0.400	0.270
a^*	185	1.270	1.180	0.510	0.440	0.410	0.340
	190	2.240	0.530	0.510	0.470	0.420	0.380
	180	6.020	6.340	4.600	4.010	4.100	5.240
b^*	185	5.210	6.000	5.000	5.800	6.700	5.770
	190	7.700	7.500	6.600	4.310	5.680	7.650

A significant increase in ‘L^*’ value was observed with increase in concentration of MD wall material. The variation in ‘L^*’ values from T1 to T6 might be due to the effect of MD concentration. The inherent whitish colour of MD contributes for the bright colour of final powder. Similar results were obtained during spray drying of tamarind pulp by Muzaffar and Kumar (2015). A significant decrease in a^* (0.270-2.240) and b^* (4.010-7.700) values were noted with increase in MD and decrease in inlet air temperature. The ‘L^*’, ‘a^*’ and ‘b^*’ values of spray dried pseudostem powder were analysed statistically and given in Appendix I5, I6 and I7 respectively.

4.3.2.5 Total soluble solids (TSS)

Analysis of total soluble solids in reconstituted pseudostem juice powder (one gram powder in 10 ml distilled water) ranged from 10 to 16.10°B (Appendix A5). The result obtained was in agreement with observations of Nithya *et al.,* (2014) in pseudostem juice powder. The experimental results assessed from current study revealed that increase in TSS value might be due to the increased MD concentration and sugar. High TSS value of 16.10°B was noted in treatment with 25% MD and 15% sugar. During this study, the effect of temperature was found to be insignificant. Fig. 4.5 represents the change in TSS with different process parameter.

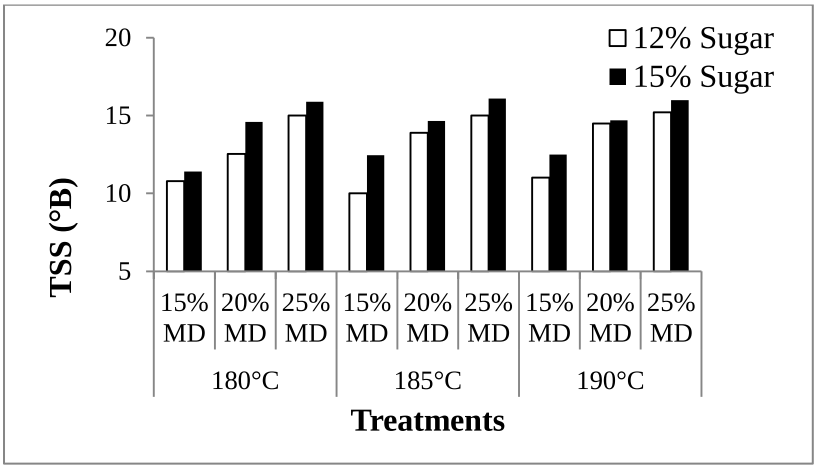

Fig. 4.5 Total soluble solids of Product-I

4.3.2.6 pH and Titrable acidity

The pH of fresh pseudostem juice obtained from the present investigation was found to be 6.5 and for reconstituted powder it was 5.80 to 6.61. These values were similar to those determined by Nithya *et al.* (2014). The titrable acidity of pseudostem juice powder was determined between 0.115-0.140% in all treatments. Increase in pH and decrease in titrable acidity among treatments might be due to the addition of ginger extract (4%), sugar and wall material concentration. From Table 4.3, it is clear that pH value found to be less than the neutral value. So the powder can graded as low acid foods

Table 4.3 pH and titrable acidity of Product-I

	Inlet temperature (°C)	T1	T2	T3	T4	T5	T6
pH	180	5.800	6.140	6.400	6.570	6.560	6.600
	185	5.900	6.280	6.390	6.470	6.580	6.610
	190	6.060	6.150	6.540	6.580	6.600	6.600
Titrable acidity (%)	180	0.140	0.140	0.132	0.122	0.119	0.129
	185	0.139	0.131	0.138	0.128	0.128	0.115
	190	0.133	0.134	0.130	0.122	0.129	0.128

.

4.3.3 Reconstitution properties of spray dried pseudostem juice powder

4.3.3.1 Solubility

Solubility showed decreasing trend with increase in inlet air temperature. This might be due the effect of inlet air temperature on particle size. Elevated air temperature aids in forming larger particle size which increased the dissolving time of the powder. This was due to rapid formation of dried layer formed on droplet surface (Chegini and Ghobadian, 2007).

The solubility of powder ranged from 76.53 to 85 % (T1 to T6) (Appendix A6). From Fig.4.6, the highest solubility value of 85% was found in T1 and least for T6 (76.53%). Statistical analysis was done for verifying the significance of independent variable on solubility. The ANOVA for the solubility parameters are presented in Appendix I8, showed a significant ($p<0.0001$) effect.

4.3.3.2 Wettability

The wetting time of the powder ranges from 73.05 to 80.06 s (Fig.4.7). It was observed that the temperature and wettability were proportional to each other. This might be due to the reduced product moisture content at high temperature as reported by Bhandari *et al*. (1993) and Jumah *et al*. (2000). The wettability value was also influenced by the MD concentration. The wettability increased with increase in concentration of MD due to its lower dissolution capacity. However, powders with higher moisture content showed less time of wettability, due to its agglomeration tendency which helps in reconstitution process (Martinez *et al.*, 2015).

Highest wettability value (80.06 s) was found in T6 while minimum of 73.05 s for T1 (Appendix A7). The effect of wall material concentration and inlet air temperature on wettability of pseudostem powder was statistically analysed using analysis of variance (ANOVA) and is presented Appendix I9. Spray drying parameters and MD concentration showed significant effect ($p<0.0001$) on wettability of banana pseudostem juice powder.

4.3.3.3 Water solubility index

The value of water solubility index (WSI) varied from 33.4 to 57.03% (Appendix A8) for the spray dried powder. From Fig 4.8, it is evident that the water solubility index increased with increase in inlet air temperature (*i.e.,* 180°C to 190°C) and MD concentration. This might be due to low moisture content of powder formed at elevated temperature and high MD concentration which resulted in increased insoluble solids in powders (Jumah *et al*., 2000). Similar trend in water solubility index was observed in spray dried *Garcinia combogia* powder by Sunitha (2012).

4.3.3.4 Water absorption index

The water absorption index (WAI) of experimented powder samples ranged between 90.50 to 99.45% (Fig.4.9). WAI value decreased to 90.50% with increase in inlet air temperature (190°C) and MD concentration of 25% (Appendix A9). The obtained result agreed with the study of Phoungchandang and Sertwasana (2010) on ginger powder. Addition of MD during drying made a layer around the drops which affected the surface stickiness of particles and cohesion between them. Reduced cohesion between particles leads to less clustering resulted in low water absorption index (Grabowski *et al.,* 2006 and Adhikari *et al.,* 2003).

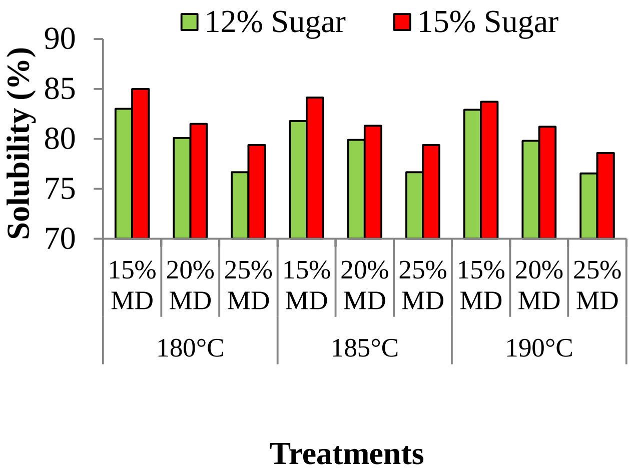

Fig. 4.6 Solubility of Product-I

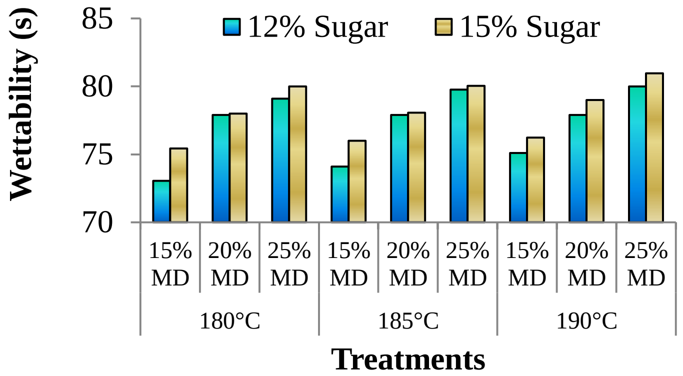

Fig. 4.7 Wettability of Product-I

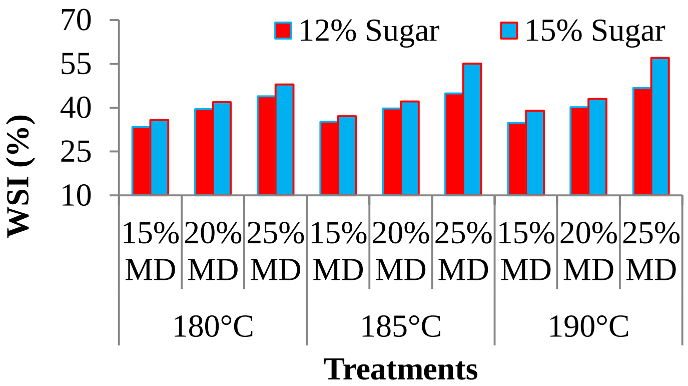

Fig. 4.8 WSI of Product-I

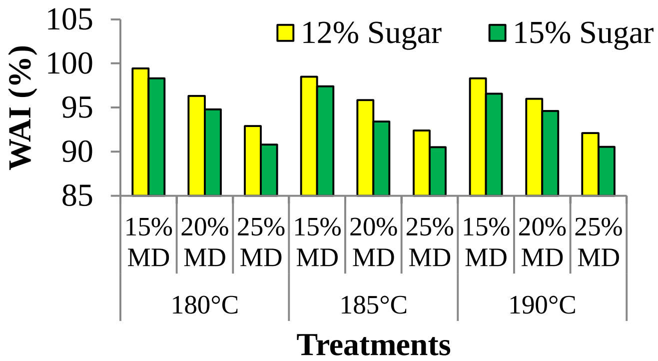

Fig. 4.9 WAI of Product-I

4.3.4 Flowability and Cohesiveness

4.3.4.1 Carr's index (CI) and Hausner ratio (HR)

Flowability and Cohesiveness property of any powder product can be well understand through Carr's index (CI) and Hausner ratio (HR). The results showed that Carr's index (CI) value ranges from 10.457 to 37.043% and the Hausner ratio (HR) of banana pseudostem juice powder varied from 1.117 to 1.588 (Table 4.4).

Table 4.4 Flow properties of Product-I

	Inlet temperature (°C)	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**
	180	27.995	10.457	27.500	26.024	28.400	29.134
CI (%)	185	26.759	27.392	28.756	24.944	31.715	29.302
	190	27.762	24.497	28.736	25.453	37.043	26.541
	180	1.389	1.117	1.379	1.352	1.398	1.411
HR	185	1.365	1.377	1.404	1.332	1.464	1.414
	190	1.384	1.324	1.403	1.342	1.588	1.361

With respect to standard table values (Table3.6) of CI and HR, treatment T2 spray dried at 180°C showed good flowability. Treatment T2 (190°C) and T4 (185°C) exhibited possible flowability values and other treatments showed poor flowability values. Flowability and cohesiveness of powders depends on size of the particles and also cohesive and frictional forces within the particles. Particle size depends mainly on atomization airflow (Wang *et al.*, 2015). Apart from the particle size and internal forces flowability and cohesiveness was also affected by many other factors like moisture content, hardness, surface asperity, elasticity *etc* as reported by Chen *et al.* (2010). Therefore it was difficult to point out appropriate reason for the change in CI and HR values within treatments.

4.3.5 Product yield

Yield of banana pseudostem juice powder ranged from 28.601 to 56.738%. It was found that product yield having significant effect on wall material concentration and inlet air temperature. At low inlet air temperature and high wall material concentration product yield increased due to reduced powder stickiness and higher solid concentration (Arslan *et al.,* 2015 and Fazaeli *et al.,* 2012). During the study, product yield was taken as one of an important parameter for the product optimisation. The influence of spray drying parameters and wall material concentrations on yield of encapsulated banana pseudostem juice powder is presented in Table 4.5.

Table 4.5 Product yield of spray dried banana pseudostem juice powder

	Inlet temperature (°C)	T1	T2	T3	T4	T5	T6
Product yield (%)	180	29.164	32.034	36.834	42.022	43.451	56.738
	185	29.079	31.711	36.268	41.970	38.247	56.664
	190	28.601	31.092	35.460	38.224	39.171	53.663

From the given table, it is evident that yield decreased with temperature and wall material concentration. Treatment T6 exhibited the higher yield at 180°C. The ANOVA associated with general factorial design was implemented (Appendix I10) for statistical analysis and verified the significance ($p<0.0001$).

4.3.6 Optimisation of spray dried parameters for banana pseudostem juice powder

Based on the results obtained from physiochemical and reconstitution properties of spray dried pseudostem juice powder which was discussed in previous section, it was confirmed that treatments T6 (56% pseudostem juice +

25% MD+ 15% sugar) was superior in its powder qualities. The banana pseudostem juice powder produced under these treatments showed low moisture content and water activity also it exhibited appreciable pH, bulk density and TSS, better colour and reconstitution properties. The treatment T6 illustrated maximum product yield at different temperatures compared to the rest of other treatments. The optimised process parameters for the powder are presented in Table 4.6. The statistical analysis revealed that all the quality parameters were significant at 1% level. So T6 was selected as best treatment and the T6 sample produced from various temperature combinations (180, 185 and 190°C) were stored in ambient condition for further shelf life studies.

Table 4.6 Optimised process parameters for the production of pseudostem powder by spray drying

Sl. No.	Process parameters	Optimised condition
1	Speed of the atomizer (rpm)	1800
2	Inlet air temperature (°C)	180
3	Outlet temperature (°C)	65-68
4	Feed pump speed (rpm)	15

4.3.7 Microbiological Analysis

The microbial analysis authenticates the shelf life of spray dried pseudostem juice powder. It was observed that, microbial colonies were absent in fresh pseudostem juice powder samples. So the spray dried powder was suggested to be safe for consumption based on microbial analysis. The absence of colony count might be due to low moisture content and water activity. The former was due to drying temperature which removed moisture while the later was due to both drying temperature and addition of sugar (Olivera *et al.*, 2000 and Sariga, 2015). The details of microbial analysis of the powder were tabulated and are given Appendix G1.

4.3.8 Particle size

The morphology of the spray dried powder which was produced at optimised process conditions was examined using scanning electron microscope (SEM) and the observed images are presented in Plate 4.2. The particle size of spray dried powder sample was found to be 50 and 10 μm at 500 and 1000 resolutions respectively.

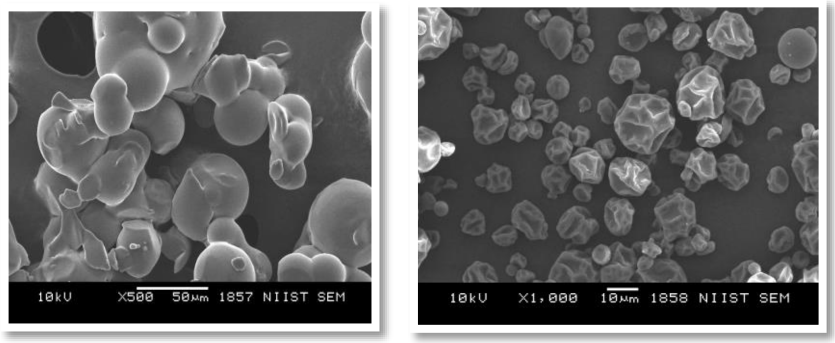

Plate 4.2 SEM micrographs of Product-I

The result obtained in present study was confirmatory with the observations of Krishnan *et al.* (2005). According to them the particle size of spray dried powder comes under the range of 5-50 μm.

4.3.9 Proximate analysis

The pseudostem is naturally rich source of micro nutrients. Since the drying was carried out with MD as wall material which is a good source of carbohydrate. The experimentally optimised processed powders were examined for its carbohydrates, protein and minerals. The carbohydrate content of optimised powder was 76.31% and protein 3.03%. Pseudostem powder composed of several minerals like K, Mg, Ca. Mineral composition of wheat flour mixed pseudostem flour were analysed by Ho *et al.* 2012. Their study confessed the presence of higher Na, K, Ca, Mg and P. Mineral profile analysis of optimised samples were carried out through atomic absorption spectro photometry and is listed in the Table 4.7. Ash content of powder was also determined by muffle furnace method and presented in the Table 4.7. According to Patil *et al.* (2014) solids present in guava powder increased with MD concentration which lowers the ash content. Treatment T6 exhibited a lowest ash content of 3.60% and is presented below.

Table 4.7 Proximate composition of Product-I

Sl. No	Composition	%
1.	Carbohydrate	76.31
2.	Protein	3.03
3.	Total ash	3.60
4.	Potassium	0.48
5.	Calcium	1.88
6.	Magnesium	0.23

4.3.10 Packaging of banana pseudostem juice powder

The optimised pseudostem powder samples were packed for shelf life studies in LDPE pouches covered with a laminated aluminum film and were sealed hermetically using hand sealing machine. Sealed packets were stored in ambient condition and tested for its quality attributes. Similar packaging practices were followed by Sunitha, (2012) and Sariga, (2015) for packaging spray dried *Garcinia* powder and vanilla extract powder respectively.

Plate 4.3 Packaged pseudostem juice powder samples in LDPE pouches and aluminium foil pouches

4.3.11 Storage studies

The packed and stored samples (Plate 4.3) at ambient condition were investigated for its quality attributes at two months interval as per analysis methods explained in chapter III.

4.3.11.1 Changes in moisture content and water activity of pseudostem powder during storage

It was observed that the moisture content and water activity of the powder changed significantly during storage (Fig. 4.10 and Fig. 4.11). During filling and sealing the powder is highly susceptible to absorb moisture. This might be due to exposure of product to the external environment. Permeability of packaging material was also an important factor for increased product moisture and water activity values during storage (Pua *et al.,* 2007).

It was noted that the moisture value of T6 at 180, 185 and 190°C showed comparatively less variation during storage period Treatment T6 at 190°C maintained a lowest moisture value of 3.29% at the end of 6th month storage. Water activity at the 6th month of storage for T6 190°C was 0.326. The values of moisture content and water activity at 6th month were acceptable and offered appreciable stability to the product (Appendix B1 and B2). The effect of drying method and storage on moisture content and water activity of pseudostem juice powder were analysed statistically and confirmed the significance ($p<0.0001$). The ANOVA table related with moisture content and water activity are presented in appendix J1 and J2.

4.3.11.2 Changes in Bulk density of pseudostem powder during storage

Bulk density of the pseudostem powder increased linearly with storage. At the 6th month of storage the tapped bulk density exhibited maximum value 0.443 g/ml and loose bulk density was 0.356 g/ml (Appendix B3 and B4). This might be due to proportionality relation of bulk density with moisture content. It has been reported that bulk density have significant co-relation with the moisture content of the powder. Increase in moisture content tends to raise the bulking weight of the product which apparently results with high bulk density. Powders having higher moisture content showed higher bulk density of 0.443 g/ml. Similar trend in bulk density was observed by Sunitha (2012) during the storage of *Garcinia cambogia* powder. The changes in tapped and loose bulk density values during the storage were poltted and are given in Fig. 4.12 and 4.13.

The effect of drying method and storage on bulk density of pseudostem juice powder were analysed statistically and confirmed the significance ($p<0.0001$). The ANOVA table related with tapped and loose bulk density is presented in appendix J3 and J4.

4.3.11.3 Changes in colour characteristics of pseudostem powder during storage

Lightness L^* value of the spray dried powder reduced during storage period. Chudy *et al*. (2015) stated that the enzymatic browning occurred due to Maillard reaction, lipid oxidation, deterioration of ascorbic acid *etc* contribute for reduction in lightness during storage. The lowest L^* value of 89.270 was observed in treatment T6 (190°C) at the end of 6^{th} month storage.

During the study a^* (redness) and b^* (yellowness) values of powder found to be increased during storage and T6 (190°C) exhibited the highest a* and b* values (0.415 and 7.715). The variation in colour values is illustrated in Table 4.8.

The effect of drying method and storage on colour characteristics of banana pseudostem juice powder were analysed statistically and confirmed the significance of a* and b* ($p<0.0001$) while L* values showed non significance at 1% level. The ANOVA table related with colour characteristics of pseudostem juice powder is presented in appendix J5, J6 and J7.

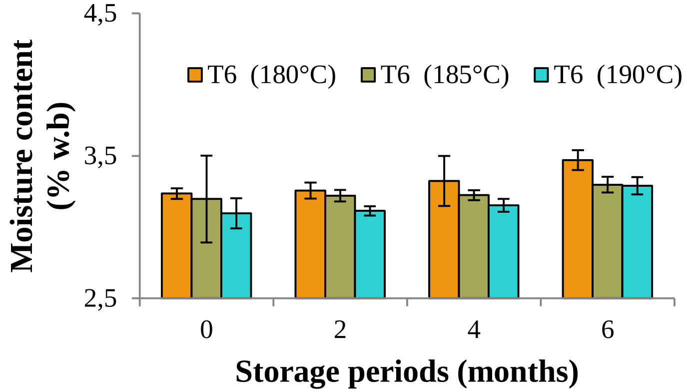

Fig. 4.10. Moisture content of Product-I during storage

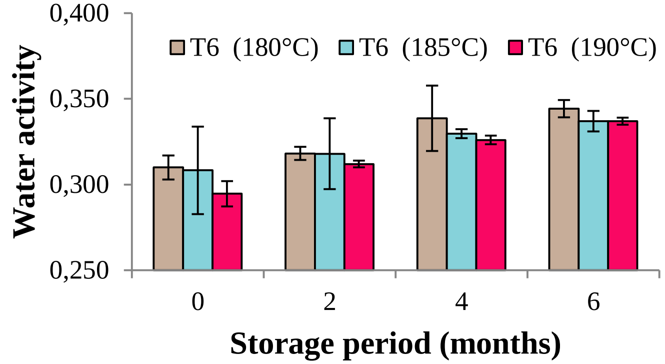

Fig.4.11 Water activity of Product-I during storage

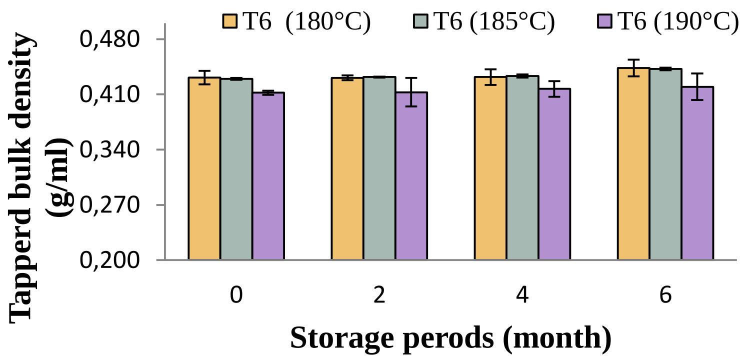

Fig. 4.12 Tapped bulk density of Product-I during storage

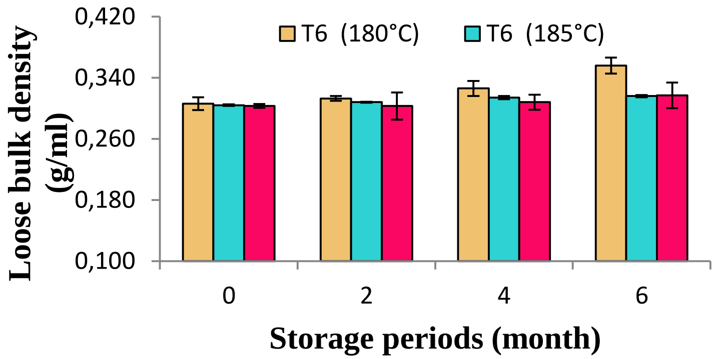

Fig.4.13 Loose bulk density of Product-I during

Table 4.8 Changes in colour characteristics of Product-I

Colour characteristics	Treatments	Storage periods (month)			
		0	2	4	6
L*	T6 (180°C)	92.030	92.000	92.000	91.870
	T6 (185°C)	92.300	92.100	92.000	91.930
	T6 (190°C)	90.200	90.100	89.380	89.270
a*	T6 (180°C)	0.270	0.276	0.282	0.297
	T6 (185°C)	0.340	0.350	0.356	0.404
	T6 (190°C)	0.380	0.350	0.357	0.415
b*	T6 (180°C)	5.240	5.243	5.248	5.253
	T6 (185°C)	5.770	5.830	5.836	5.850
	T6 (190°C)	7.650	7.661	7.663	7.715

4.3.11.4 Changes in pH and titrable acidity of banana pseudostem juice powder during storage

The pH and titrable acidity of banana pseudostem juice powder varied with storage period. During storage pH of powder found to be decreased from 6.6-6.520 and titrable acidity increased from 0.115-0.138%. This difference in pH and titrable acidity values during storage might be due to formation of acids in powder through chemical conversion of sugars or by other chemical reactions that occurred during storage (Verma *et al*., 2013). From the Table 4.9, it is clear that a significant increase in titrable acidity value was noted on 6th month of storage. It might be due to increased rate of chemical reaction during 6th month of storage. Sample dried at 190°C showed comparatively low chemical reactions during storage period resulting in slight variation in pH and titrable acidity.

Table 4.9 Changes in pH and titrable acidity of Product-I

	Treatments	Storage periods (month)			
		0	2	4	6
pH	T6 (180°C)	6.600	6.600	6.580	6.550
	T6 (185°C)	6.610	6.600	6.520	6.520
	T6 (190°C)	6.600	6.590	6.580	6.580
Titrable acidity (%)	T6 (180°C)	0.129	0.129	0.130	0.138
	T6 (185°C)	0.115	0.115	0.116	0.119
	T6 (190°C)	0.128	0.128	0.130	0.130

4.3.11.5 Changes in solubility and wettability of pseudostem juice powder during storage

Solubility of powder decreased with storage period, conversely wettability of the product increased (Appendix B5 and B6). This might be due to alteration in moisture content of powder. Samborska and Bienkowska, (2013) suggest that the changes in solubility of powders was accompanied with changes in proteins, moisture content and also the characteristics of drying aid and drying conditions. Change in wettability value also rest on the same reason as reported by Samborska and Bienkowska, (2013).

Solubility of powder decreased from 79.40% to 77.13% (Fig. 4.14) and wettability increased from 80.00 to 80.63 s (Fig. 4.15) during storage. The statistical analysis of reconstitution properties showed non significant effect on storage. The ANOVA table related with reconstitution properties of banana pseudostem juice powder is presented in appendix J8, and J9.

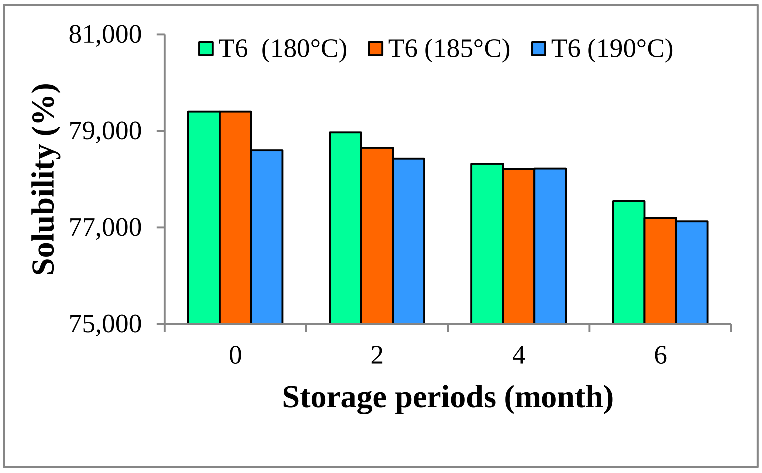

Fig. 4.14 Solubility of Product-I during storage

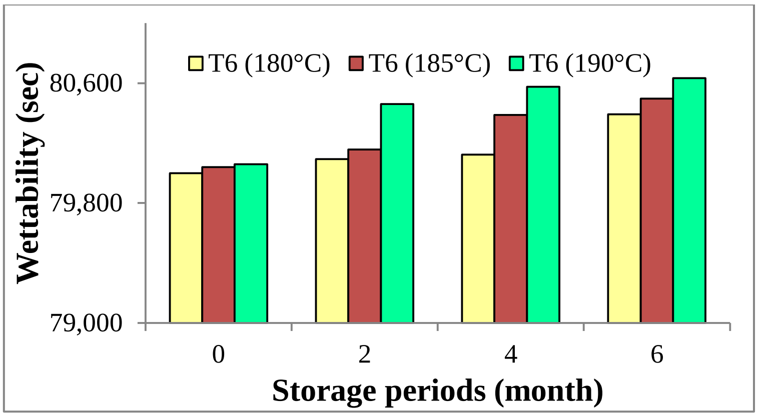

Fig. 4.15 Wettability of Product-I during storage

4.3.11.6 Microbial analysis

The microbial load of samples was examined using pour plate method. Bacterial colony of 1×10^1 cfu/g was noted at the end of sixth month storage for T6 (180°C) and in other samples the microbial colonies were absent. It was noted that colonies were well below permissible limit (*i.e.*, $<10^4$) for T6 (180°C) recommended by International commission for microbial specifications for foods. The spray dried powder was suggested to be safe and stable during storage of six months. The presence of colony count might be due to the increased moisture content and water activity during storage. The details of microbial analysis of the powder were tabulated and are given Appendix G4.

4.3.12 Sensory analysis

Sensory analysis is an important parameter for consumer acceptability. The products were analysed by 12 semi – trained sensory panelists. The optimised treatments of banana pseudostem juice powder were reconstituted and kept for sensory evaluation. Powders were reconstituted with normal water in 1:10. The fresh banana pseudostem juice with ginger and sugar was taken as control. The results of the sensory evaluation of the samples are depicted in Fig. 4.16.

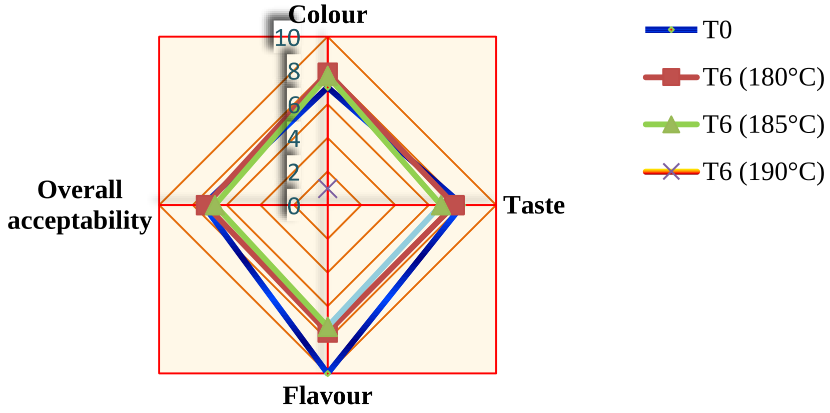

Fig. 4.16 Sensory score obtained for Product-I

Based on sensory analysis, treatment T6 (180°C) scored an overall acceptability of 7.22 which was the highest score among other samples except control. Control sample scored the best score of 7.38, which was on par with the treatment T6 (180°C). Apart from this, T6 (180°C) exhibited appreciable product quality and stability during six month storage. Thus T6 (a treatment combination of 56% pseudostem juice, 25% MD and 15% sugar at inlet air temperature of 180°C) was optimised as the best treatment.

4.4 Experiment II

4.4.1 Spray dried banana pseudo stem juice-horse gram extract blend (product-II)

The aim of this work was to develop a nutraceutical powder from pre-treated banana pseudostem juice and horse gram extract by utilizing the novel spray drying technology. The effect of spray drying conditions on powder quality was investigated during the study. Various independent and dependent variables related to this experiment were fixed by conducting preliminary experiments. Spray drying parameters such as feed pump and blower speed were kept constant throughout the study as mentioned in previous experiment (*i.e.*, 1800 and 15 rpm). Different temperature combinations such as 180, 185 and 190°C were chosen for product development. Wall material combinations (20 and 25%) and raw materials such as horse gram extract and pseudo stem juice varied from one trial to other (Table3.3).

Analysing final powder for quality verification was a key objective of this study and it includes analysis of:-

- Physico-chemical properties
- Reconstitution properties
- Flow properties
- Proximate composition
- Particle size

4.4.1.1 Physico-chemical properties

4.4.1.1.1 Moisture content

The moisture content of pseudostem juice powder ranged from 3.930-4.523% (w.b.) and is given in Appendix C1. The effect of process parameters like inlet air temperature and maltodextrin (MD) on the powder moisture content is plotted in Fig.4.17. From the figure, it is clear that the product moisture content followed a similar trend as reported in the earlier experiment. Increase in solid content in feed mixture at higher MD concentration and rapid evaporation at high temperature resulted in moisture reduction (Quek *et al.*, 2007). Horuz *et al.* (2012) also reported similar fluctuation of product moisture in spray dried pomegranate juice powder, in which the moisture of pomegranate powder found to be increased from 3.44 to 9.13%. Comparing with the previous experiments, moisture content of current sample showed high moisture values. The addition of horse gram might be the reason for this variation.

During the study, higher moisture content was observed in T1 treatment (20% MD and 10% horse gram) spray dried at 180°C inlet air temperature and the lowest value was noted in T6 (3.93%) dried at 190°C. Effect of process conditions on the moisture content of powder was analysed statistically by one-way ANOVA for evaluating the significance of product moisture and its details are given in Appendix K1. Statistical results showed a significant effect of different process conditions on moisture content ($p<0.0001$).

4.4.1.1.2 Water activity

Water activity value indicates the microbial stability of food. The water activity assessed for banana pseudostem juice-horse gram blend powders were in the range of 0.314-0.407 (Appendix C2). Fennema, (1996) suggest that water activity values should be below 0.6 for stable foods. From the observed values, it was evident that the water activity values were in the safe range and microbiologically stable. Increased inlet air temperature reduced the moisture of product thus the available water for microbial growth gets to drop down resulted in low water activity. The concentration of MD and raw materials does not affect the water activity values significantly. However their combined outcome with temperature exhibited a significant effect on water activity values (Susantikarn and Donlao, 2016). Water activity of 0.407 was found in sample dried at 180°C having 20% MD concentration and 10% horse gram extract. The lowest value (0.314) was observed in powder produced at 190°C inlet air temperature with 25% MD (Fig. 4.18). Statistical results revealed a significant effect of different process parameters on water activity ($p<0.0001$) and is given in Appendix K2.

4.4.1.1.3 Bulk density

Bulk density values such as tapped bulk density (TBD) and loose bulk density values of spray dried pseudostem juice powders were calculated by standard procedures explained in earlier section. TBD values of powder ranged from 0.416-0.577 g/ml (Appendix C3) and LBD of powder ranged from 0.316-0.474 g/ml (Appendix C4). Obtained results were varied in such a manner that, at elevated inlet air temperature bulk density of the powder gets decreased. Fazaeli *et* *al.* (2012) illustrates that decreased bulk density in powders at elevated temperatures was due to the poorer shrinkage of powder particles occurred with rapid evaporation.

The lower value of bulk density was obtained at high MD concentration owing to the fact that, the particle size of the powder increased when the feed concentration increased. Similar results were reported by Sarabandi *et al.* (2014). Their study revealed that the bulk density of spray dried grape juice powder decreased at higher feed concentration. In present study, higher bulk density value observed in treatments having 20% MD and lower values recorded in T6 treatment with 25% MD. Variation in TBD and LBD values are given Fig. 4.19 and Fig. 4.20. Details of the statistical study and ANOVA table were illustrated in Appendix K3 and K4. Statistical study on bulk density values revealed its significance at 1% level.

4.4.1.1.4 Colour characteristics

The colour characteristics such as L^*, a^* and b^* of banana pseudostem juice-horse gram extract blend powder were recorded as: L^* (80.133-93.333), a* (0.296-2.216) and b* (5.000-12.800). From Table 4.10 it is clear that treatment T6 at 180°C had a higher L^* value. There was a decrease in L^* value, more reflected when inlet temperature increased. Maximum and minimum values of L^* were observed in T6 and T1 treatments respectively. The results revealed that L^* value was increased to maximum with higher ratio of MD concentration. Similar observation was reported in the spray dried barberry extract powder by Sharifi *et al.* (2015), in which powder showed highest L^* at 100% MD concentration.

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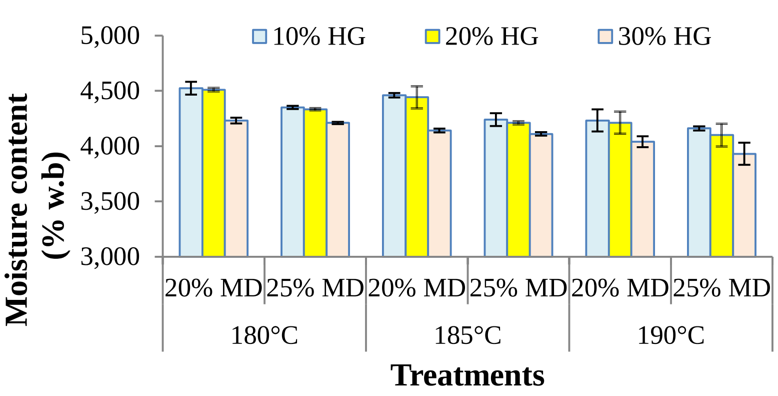

Fig. 4.17 Moisture content of product-II

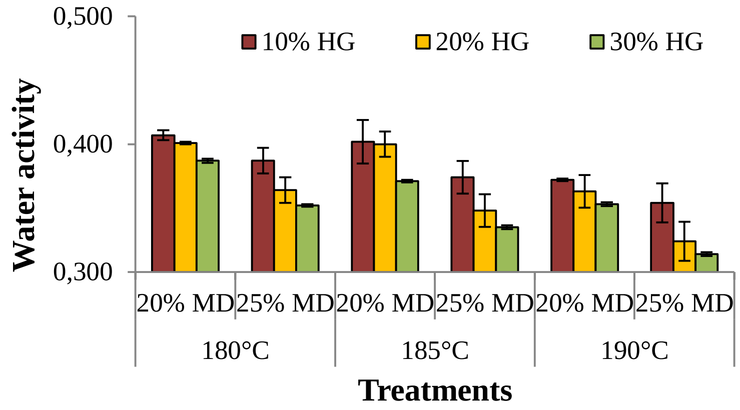

Fig. 4.18 Water activity of product-II

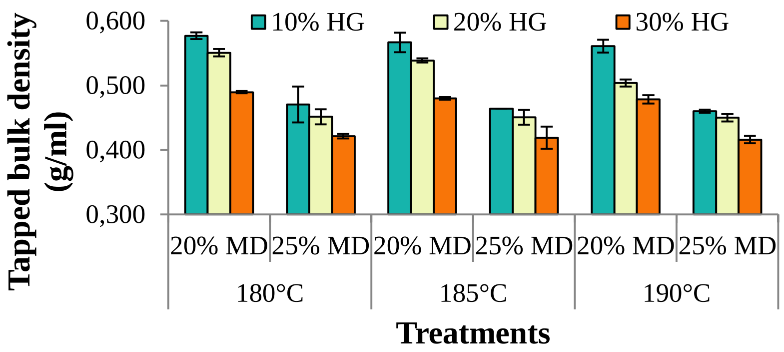

Fig. 4.19 Tapped bulk density of product-II

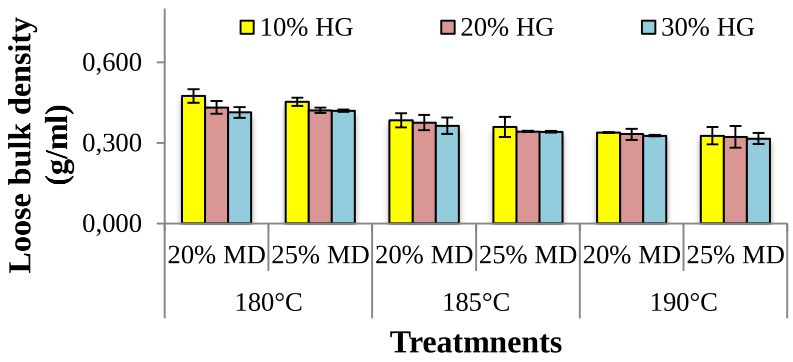

Fig. 4.20 Loose bulk density of product-II

Similar trend in a^* and b^* values were noted as mentioned in previous experiment. Higher a^*(2.216) and b^*(12.8) values were observed in T1 at 190°C. As mentioned earlier in first experiment, colour characteristics of powder were also influenced by inlet air temperatures. Reduction in L* and increased a* and b* values were obtained at higher temperature. This result was confirmatory with Poungchandang and Sertwasana, (2010). Their study revealed that spray dried ginger powder exhibited best colour values (L*- 78.06±0.47 and a^*/b^*-0.09) at 120°C among other samples dried at 135 and 150°C.

Plate 4.4 Spray dried banana pseudostem-horse gram extract blend powder

Table 4.10 Colour characteristics of Product-II

Colour characteristics	Inlet temperature (°C)	T1	T2	T3	T4	T5	T6
	180	83.160	86.376	88.356	90.176	92.100	93.333
L^*	185	80.370	83.366	88.193	90.003	91.466	92.526
	190	80.133	85.346	86.450	88.594	90.766	92.366
	180	0.510	0.446	0.296	0.520	0.510	0.357
a^*	185	1.830	0.782	0.403	0.817	0.477	0.403
	190	2.216	1.293	0.446	1.400	0.782	0.403
	180	5.600	5.600	5.210	5.340	5.030	5.000
b^*	185	8.600	6.680	5.600	6.800	6.500	6.340
	190	12.800	8.500	7.300	12.500	9.310	6.700

The colour characteristics of products showed non significance at 1% level. The corresponding ANOVA tables were given in Appendix K5, K6 and K7.

4.4.1.1.5 Total soluble solids (TSS)

Total soluble solids contained in banana pseudostem juice-horse gram extract blend powder were recorded by standard procedures as mentioned in previous chapter. The powder TSS found to be increased from T1 to T6 (Fig. 4.21) *i.e.*, 14 - 24°B (Appendix C5). Increased solid concentration by addition of wall material and horse gram extract might be the reason for the increased TSS value (T6). Nithya *et al.* (2014) conducted studies on spray drying of pseudostem-sugar mix. During the study, it was observed that the value of TSS increased with concentration. The highest value of 15°B was noted at higher feed concentration.

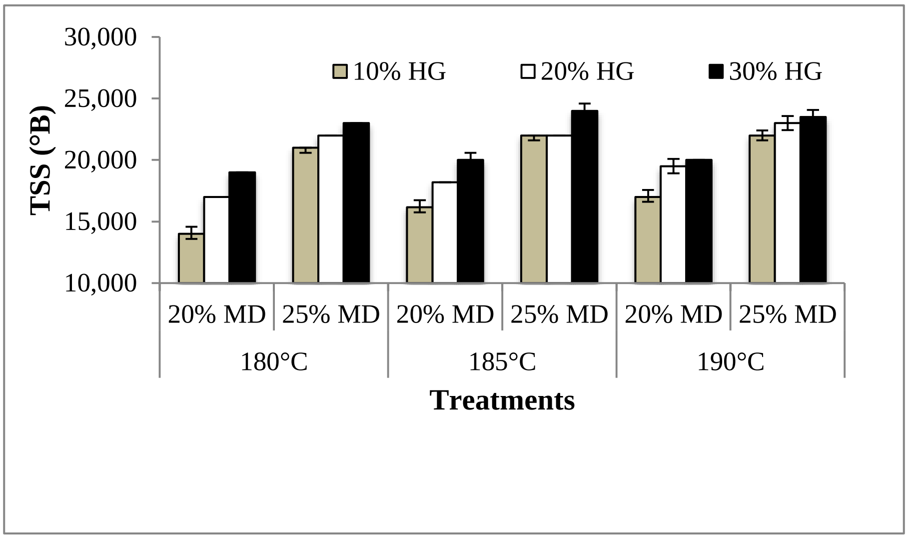

Fig. 4.21 TSS of Product-II

TSS of the current sample was comparatively higher than that of the previous sample as it contains horse gram extract. Evaluation of product TSS revealed that process temperatures have no influence on given results.

4.4.1.1.6 Titrable acidity and pH

The chemical properties like titrable acidity and pH of powder were obtained by standard lab procedures. These values were used to investigate the product's acidic characteristics. The values of titrable acidity and pH of pseudostem juice-horse gram extract blend powder varied from 0.118-0.153% and 5.28-6.910.

Table 4.11 Titrable acidity and pH of Product-II

	Inlet temperature (°C)	T1	T2	T3	T4	T5	T6
pH	180	6.880	6.600	6.910	6.530	6.410	6.430
	185	6.370	6.270	6.550	5.830	6.030	5.280
	190	5.600	5.910	6.200	5.600	5.550	6.000
Titrable acidity (%)	180	0.118	0.128	0.125	0.143	0.136	0.148
	185	0.147	0.140	0.126	0.147	0.139	0.153
	190	0.152	0.142	0.128	0.151	0.147	0.150

The results showed that as the inlet air temperature increased, the titrable acidity increased while the pH value got reduced (Table 4.11). As the moisture content of powder decreased, the feed becomes more concentrated resulting in lower pH and higher acidity values (Rodriguez *et al.*, 2005). Highest titrable acidity of 0.153% and lowest pH of 5.28 observed in T6 treatment. Addition of ginger extract also influenced the titrable acidity and pH values as mentioned in earlier experiment and showed near values of pH and acidity.

4.4.1.2 Reconstitution properties

Reconstitution properties of powder having significant effect on powder quality. The powder reconstitution properties of pseudostem juice-horse gram extract blend powder were analysed and discussed in the following section.

4.4.1.2.1 Solubility

Solubility is one of the main quality aspects in powder products. In this investigation this parameter was found between 97.48 and 99.20% (Appendix C6). As mentioned previously in first experiment, solubility of spray dried banana pseudostem juice-horse gram extract blend powder also showed decrease in solubility at higher temperature and low MD concentration (Fig.4.22). Caparino *et al.* (2012) conducted studies on mango powders and its quality charactreistics. Their study revealed that maltodextrin acted as an encapsulating agent which increased the solubility at lower concentrations. During their study mango powder with 10% MD spray dried at 180°C exhibited a high solubility of 95.31±0.112%. The results obtained during the current study were confirmatory with the observations by Caparino *et al.* (2012).

Higher solubility value of 99.20% observed in treatment T1 at 180°C and lowest for T6 at 190°C. Statistical analysis showed that solubility values were significant at 1% level. The detailed ANOVA table for significance in solubility is presented in Appendix K8.

4.4.1.2.2 Wettability

The wettability values followed similar trend observed in previous powder sample. However the wettability values were high. During the experiments, the wettability values of powder found to be increased from 481.783 to 564.027 s (Appendix C7). Highest wettability value (564.027 s) was found in T6 while minimum of 481.783 s for T1. Martinez *et al*. (2015) analysed beetroot-orange juice powder and observed a higher wettability value of 192.7±11.8 s when 7% MD was added and spray dried at 150°C. They stated that moisture content variation in powder and lower dissolution property of MD were the cause for increased wettability. Wettability values of spray dried banana pseudostem juice-horse gram extract blend powder was analysed statistically and confirmed its significance ($p<0.0001$) (Appendix K9).

4.4.1.2.3 Water solubility index and Water absorption index

The value of water solubility index (WSI) and water absorption index (WAI) of powder varied from 32.81-60.46% (Appendix C8) and 97.12-102.00% (Appendix C9). Both WSI and WAI values found to be directly proportional to inlet air temperature (Fig. 4.24 and 4.25). Increased inlet air temperature (190°C) led to increased WSI and WAI values (60.46% and 102.00%). According to Sunitha (2012) effect of MD towards WSI and WAI were due to moisture fluctuations and surface properties of powder. Higher WSI and WAI values were observed in treatment T6 at 190°C and T3 at 190°C respectively.

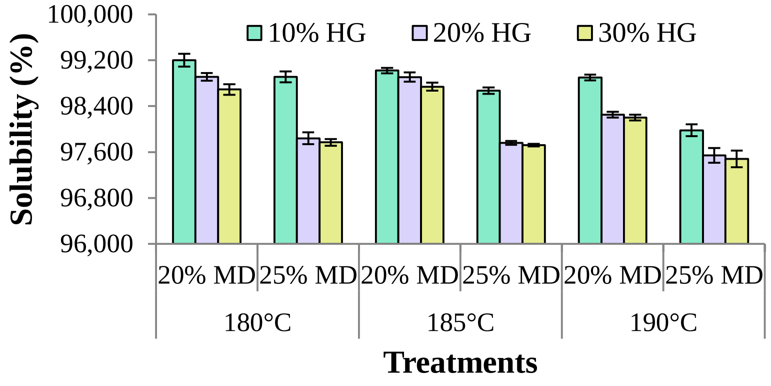

Fig. 4.22 Solubility of Product-II

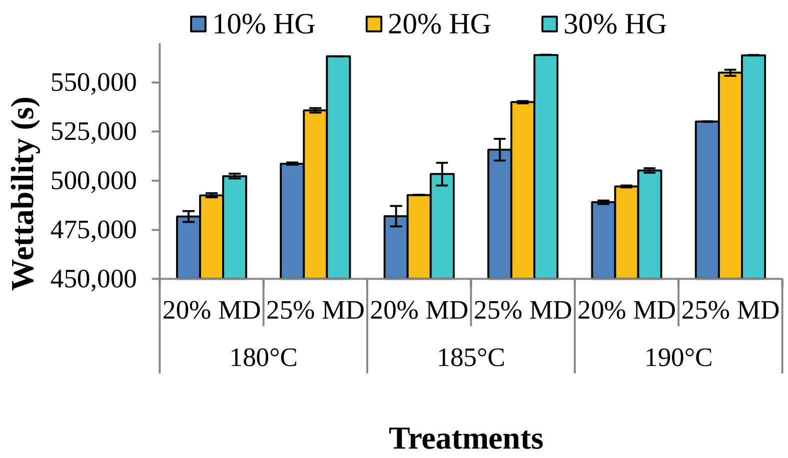

Fig. 4.23 Wettability of Product-II

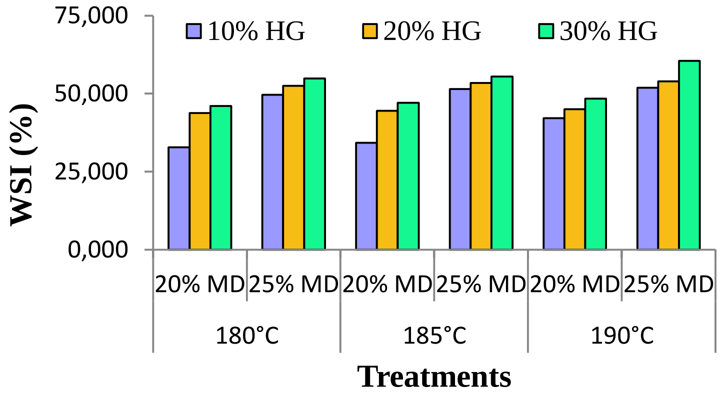

Fig. 4.24 Water solubility index of Product-II

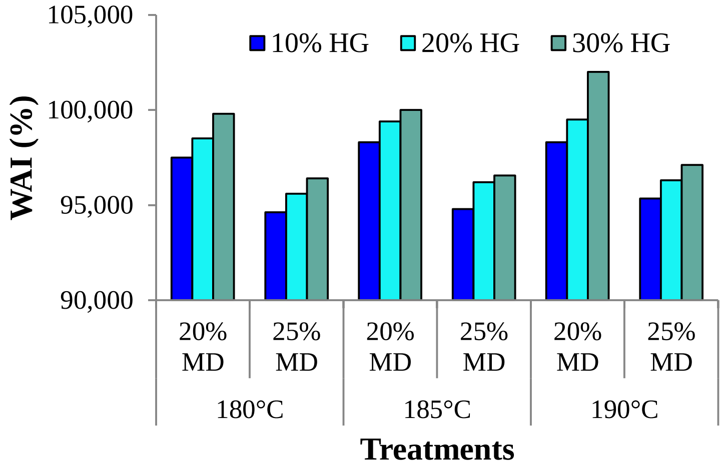

Fig. 4.25. Water absorption index of Product-II

4.4.1.3 Flow properties

4.4.1.3.1 Carr's index (CI) and Hausner ratio (HR)

Flow properties such as CI and HR were calculated from observed tapped bulk density and loose bulk density values. The results showed that CI of pseudostem juice powder varied from 0.316 to 39.750% and HR value ranged from 1.00 to 1.66 (Table 4.12). The values of spray dried banana pseudostem juice powder were compared with the standard table values (Table 3.6) and confirmed an excellent flowability of treatment T6 at 180°C.

Table 4.12 Flowability values of Product-II

	Inlet temperature (°C)	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**
CI (%)	180	17.851	21.550	15.628	3.685	6.720	0.316
	185	32.235	30.383	24.166	22.623	24.118	18.615
	190	39.750	34.083	31.642	29.166	28.444	24.038
HR	180	1.217	1.275	1.185	1.038	1.072	1.003
	185	1.476	1.436	1.319	1.292	1.317	1.228
	190	1.660	1.517	1.463	1.412	1.398	1.316

As mentioned earlier, fluctuating trend in CI and HR values of remaining treatments were due to frictional and cohesive forces and also due to moisture content, particle size *etc*. Shishir *et al*. (2014) conducted studies on spray dried pink guava powder and flowability of powder noted as HR-1.18 and CI-15%. According to their study, MD and temperature were the key parameters that influenced the flow properties of powder. Increase in temperature and MD concentration increased the CI and HR values during their study.

4.4.1.4 Product yield

Yield of banana pseudostem juice-horse gram extract blend powder ranged from 47.47-78.21%. It was found that product yield had significant effect on wall material concentration and inlet air temperature and is given in Table 4.13. In present study, yield of powder reduced at higher inlet air temperature of 190°C due to stickiness and increased with MD concentration as reported by Papadakis *et al.* (2006). Fazeli *et al.* (2012) observed that powder yield of spray dried black mulberry powder varied from 45 to 82% at an inlet temperature range of 110-150°C and 8-16% wall material concentration.

Table 4.13 Product yield of spray dried banana pseudostem juice- horse gram extract blend

	Inlet temperature (°C)	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**
Product yield (%)	180	52.370	54.460	69.960	56.460	64.810	73.080
	185	53.380	54.730	69.680	56.390	64.200	78.210
	190	50.120	50.110	69.590	47.470	52.140	78.150

Treatment T6 at 185°C showed high yield of 78.21% and T4 spray dried at 190°C having low yield of 47.47%. Comparing with previous experiments, banana pseudostem juice-horse gram extract blend exhibited higher yield. This might be due to the higher feed concentration contributed by horse gram and MD. Statistical studies revealed that powder yield was non significant at 1% level (Appendix K10).

4.4.1.5 Optimisation of spray dried parameters

Statistical models were employed to determine numerical optimisation to fix the optimal process parameters for developing fortified pseudostem juice powders. In the present investigation, the independent variables were kept within the range and dependent variables were chosen as maximum and minimum. Inlet temperature of 180°C, outlet temperature of 65-68°C, feed pump and blower rpm of 15 and 1800 were optimised during the study. Optimised sample (T6) was kept for shelf life studies under ambient conditions. Treatment T6 developed at different inlet temperatures (180, 185 and 190°C) were selected to evaluate its quality during the storage period of six months.

4.4.1.6 Microbiological stability

The microbial analysis was carried out for the optimised powder samples. Shelf life and storage stability of the product were predicted based on its microbial load. The results showed that microbial colony was absent in fresh powder samples (Appendix G2). Arawwawala *et al*. (2011) analysed microbial growth in spray dried piper beetle extract and absence of *Escherichia coli*, *Pseudomonas aeroginosa*, *Staphylococcus aureus* and *Salmonella* spp. were confirmed.

4.4.1.7 SEM study

Particle size of product was analysed by SEM analysis as mentioned earlier. Particle size of powder varied from 10-50 µm (Plate 4.5.) at 1000 and 500 resolutions. Sarkar *et al*. (2016) conducted studies on micro structural studies on spray dried emulsion of high oil content prepared from whey protein. The particle size of powders were analysed by scanning electron microscope and the particle size of powder found to be varied from 37.27- 42.88 µm.

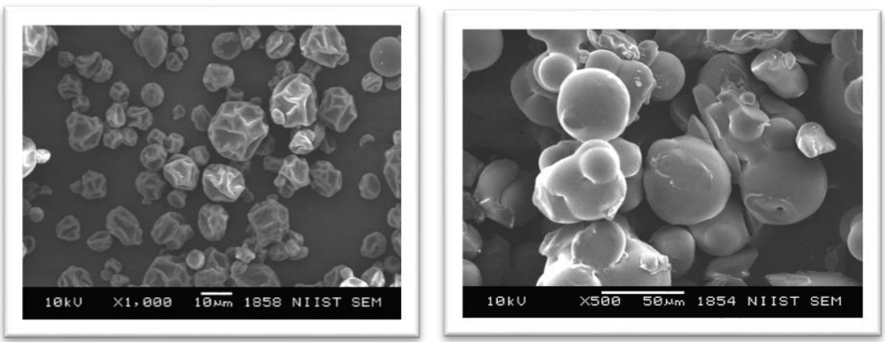

Plate 4.5. SEM micrographs of Product-II

4.4.1.8 Proximate analysis

Nutritional components like minerals, carbohydrate and protein present in the powder samples were analysed by standard procedures. The pseudostem juice-horse gram extract blend powder found to be highly rich in carbohydrate (85.01%), protein (3.8%) and minerals like K (0.69%), Ca (1.98%) and Mg (0.31%) (Table 4.14). Comparing with the previous sample (Experiment I), present sample showed more nutritional compounds. This might be due to the addition of horse gram extract which enriched the powder with high amount of nutrients. Increased concentration in powder reduced the ash content to 2.5%. However the ash content of Product-I was 3.60%.

Table 4.14 Proximate composition of Product-II

Sl. No	COMPOSITION	%
1.	Carbohydrate	85.01
2.	Protein	3.80
3.	Total ash	2.50
4.	Potassium	0.69
5.	Calcium	1.98
6.	Magnesium	0.31

4.4.1.9 Packaging and shelf life study

To arrest quality deterioration, standardised powder samples were packed in LDPE pouches. The packed sample was covered with a laminated aluminium film and sealed hermetically using hand sealing machine. Aluminium foils having superior flavor retention capacity and check deterioration of product by providing barriers to light, air, water and most other gases and liquids. Similar packaging practices were followed by Sunitha (2012) and Sariga (2015) for packaging spray dried *Garcinia* powder and vanilla extract powder respectively. Sealed packets were stored in ambient condition and tested for its quality attributes. Changes in quality attributes during six month storage were analysed and discussed in following sections.

4.4.1.9.1 Changes in moisture content and water activity

Moisture content and water activity of powder changed significantly during six months of storage period (Fig. 4.26 and 4.27). Moisture content of 4.110% of T6 (185°C) increased to 4.319% after six month (Appendix D, Table D1) and least moisture variation observed in T6 (190°C) after six month (*i.e.*, 3.930 to 4.122%). Water activity variation was comparatively high at T6 (180°C) *i.e.*, 0.355 and T6 at (190°C) showed less water activity value of 0.324 after six month of storage (Appendix D, Table D2). Samborska and Bienkowska, (2013) conducted storage studies on spray dried honey powder and reported that moisture content and water activity of honey powder found to be increased from 1.8-2.9% (w.b.) and 0.151-0.215 respectively during nine month storage period. The study concluded that, addition of MD and moisture absorption during storage might be the reason for moisture and water activity variation in powders. Variation of moisture content and water activity is given Fig. 4.26 and Fig. 4.27. Statistical studies revealed that moisture content and water activity values were significant and the related ANOVA table is given in Appendix L1 and L2.

4.4.1.9.2 Changes in bulk densities of powder

As reported in previous experiment, both tapped bulk density and loose bulk density of spray dried banana pseudostem juice-horse gram extract blend powder increased during storage (Fig. 4.28 and Fig. 4. 29). The tapped bulk density of 0.421 g/ml (T6-180°C) increased to 0.438 g/ml at the end of 6th month (Appendix D3). Similar increase in loose bulk density was also observed and was 0.429 g/ml at the end of 6th month (Appendix D, Table D4). Treatment T6 at 190°C showed lowest values of tapped and loose bulk density at the end of 6th month storage (*i.e.*, 0.347 g/ml and 0.425 g/ml). Sunitha (2012) conducted studies on spray drying of *Garcinia combogia* powder and observed changes in bulk density values during six month storage. The study revealed that increase in bulk density from 0.428 to 0.540 g/cm^3 might be due to the increased moisture absorption during storage. Statistical studies revealed that bulk density values were significant and the related ANOVA table is given in Appendix L3 and L4.

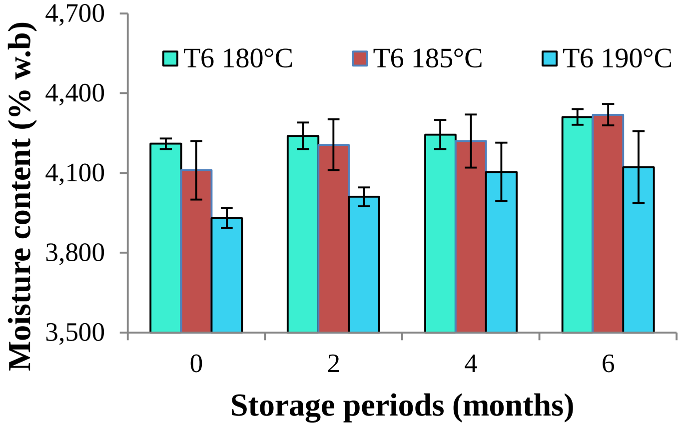

Fig. 4.26 Moisture content of Product-II during storage

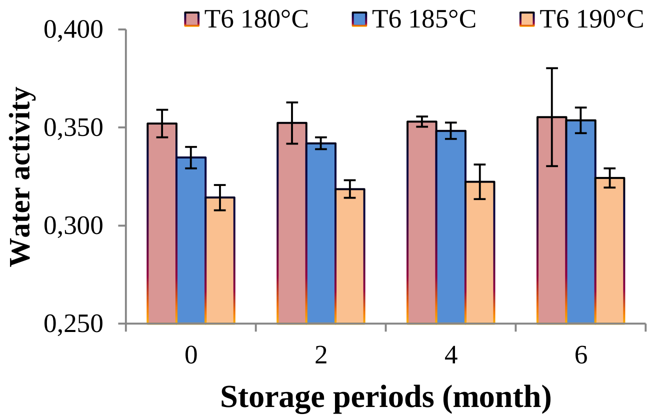

Fig. 4.27 Water activity of Product-II during storage

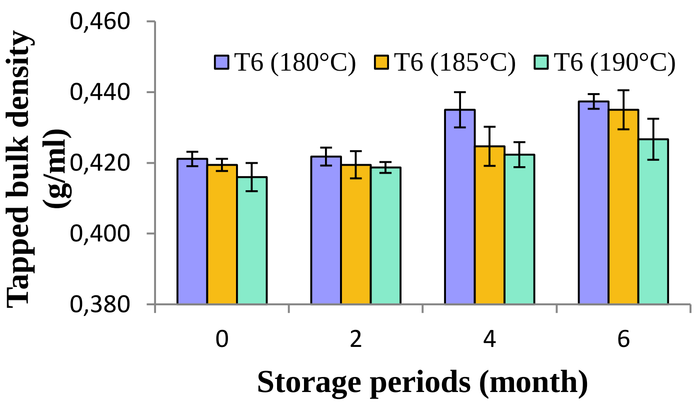

Fig. 4.28 Tapped bulk density of Product-II during storage

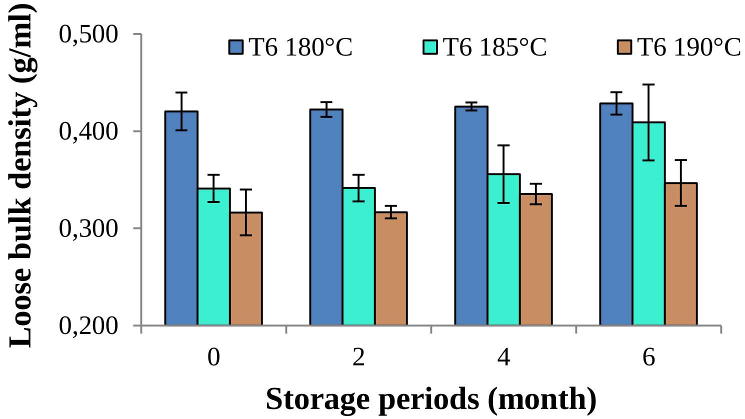

Fig. 4.29 Loose bulk density of Product-II during storage

4.4.1.9.3 Changes in colour characteristics of powder

During storage colour values of powder changed slightly. It was noted that the L* value of powder decreased during storage and the change was more pronounced between 4th and 6th month (Table 4.15). According to Liu *et al.* (2010) decreased L* value might be the non enzymatic reaction occurred during storage and they observed a decrease in colour value in tomato powder (37.60±0.25 to 35.05±0.23) during five months storage. The colour values such as a* and b* of powder retained without appreciable fluctuations and are significant at 1% level.

Table 4.15 Colour characteristics of Product-II during storage

Colour characteristics	Treatments	Storage periods (month)			
		0	2	4	6
L*	T6 (180°C)	93.333	93.333	93.310	93.010
	T6 (185°C)	94.366	94.364	94.361	94.267
	T6 (190°C)	94.366	94.360	94.342	94.200
a*	T6 (180°C)	0.403	0.403	0.403	0.404
	T6 (185°C)	0.357	0.357	0.358	0.358
	T6 (190°C)	0.403	0.403	0.403	0.404
b*	T6 (180°C)	5.000	5.000	5.001	5.010
	T6 (185°C)	6.340	6.341	6.341	6.341
	T6 (190°C)	6.700	6.701	6.701	6.705

Statistical studies revealed that colour values were significant and the related ANOVA table is given in Appendix L5, L6 and L7.

4.4.1.9.4 Changes in pH and titrable acidity of powder

pH and titrable acidity of powder varied significantly during storage. Titrable acidity and pH of tomato powder were analysed by Liu *et al.* (2010) and reported that titrable acidity of tomato powder increased from 7.61 to 8.02% and pH varied from 4.17 to 3.87 during five month storage at 25°C. According to them, increased titrable acidity and pH might be due to the effect of storage conditions and the conversion of sugar to acids by maillard reaction. Similar trend in pH and titrable acidity was observed in current study and is given in Table 4.16

Table 4.16 Changes in pH and titrable acidity of Product-II during storage

	Treatments	**Storage periods (month)**			
		0	**2**	**4**	**6**
pH	**T6 (180°C)**	6.880	6.821	6.723	6.510
	T6 (185°C)	6.370	6.345	6.254	6.163
	T6 (190°C)	5.280	5.251	5.233	5.193
Titrable acidity (%)	**T6 (180°C)**	0.118	0.118	0.119	0.121
	T6 (185°C)	0.129	0.126	0.126	0.124
	T6 (190°C)	0.153	0.154	0.152	0.150

4.4.1.9.5 Changes in solubility and wettability of powder

Solubility and wettability of pseudostem juice-horse gram extract blend powder was analysed during each month to confirm the stability. Experimental results showed a decreased solubility and increased wettability values during storage (Table 4.17). Solubility of T6 (185°C) retained higher solubility value at 6^{th} month storage and T6 (180°C) showed higher wettability value at the end of 6^{th} month.

Ramachandran *et al.* (2014) observed a decrease in solubility value of papaya powder containing (56.5±5% to 50.5±5%) during 30 days storage and Sariga (2015) reported an increased wettability values *(i.e.,* 3.503-45.13 s) in spray dried vanilla extract powder during six month storage. According to Ramachandran *et al.* (2014) and Sariga (2015), the solubility change and wettability variations might be due to the moisture absorption in powders during storage. The results obtained during present study were confirmatory with the former studies and followed similar trend in solubility and wettability values during storage. Statistical studies revealed that solubility and wettability values were significant and the related ANOVA table is given in Appendix L8 and L9.

Table 4.17 Changes in solubility and wettability of Product-II during storage

	Treatments	**Storage periods (month)**			
		0	**2**	**4**	**6**
	T6 (180°C)	97.770	97.770	97.721	97.540
	T6 (185°C)	97.720	97.770	97.693	97.665
Solubility (%)	**T6 (190°C)**	97.480	97.453	97.450	97.361
	T6 (180°C)	563.300	563.345	563.440	563.501
	T6 (185°C)	564.027	564.054	563.074	563.088
Wettability (s)	**T6 (190°C)**	563.867	563.900	563.050	563.110

4.4.1.9.6 Microbial stability of powder during storage

The microbial load of samples was examined using pour plate method and depicted in Appendix G3. Among stored samples T6 at 185°C showed comparatively higher colony count and at the end of sixth month storage and it was 3×10^1 cfu/g. It was noted that colonies were well below permissible limit

(<10^4) (T6-190°C) recommended by International commission for microbial specifications for foods. The spray dried powder was suggested to be safe and stable during storage of six months. The presence of colony count might be due to increase in moisture content and water activity during storage.

4.4.1.10 Sensory analysis

Sensory analysis of products was done by 12- semi-trained sensory panelists. The optimised powder samples were reconstituted and kept for sensory evaluation. Powders were reconstituted with normal water in 1:10 ratio. The fresh pseudostem juice, freshly prepared horse gram extract with ginger and sugar was taken as control. The results of the sensory evaluation of the samples are given in Fig. 4.30.

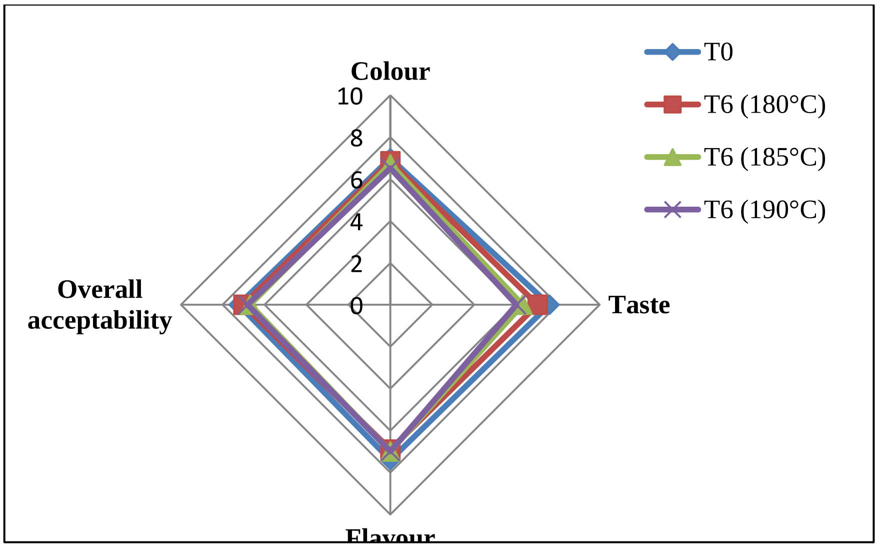

Fig. 4.30 Sensory score obtained for Product-II

Based on sensory evaluation treatment, T6 (180°C) scored an overall acceptability of 7.02 which was the highest secured among the other samples except control (Appendix D, Table D5). Control samples scored the best score of 7.24. Comparing with control treatment, T6 (180°C) maintained similar sensory quality. Apart from this T6 (180°C) exhibited appreciable product stability during six month storage. Thus T6 (43% banana pseudostem juice, 30% horse gram extract and 25% MD with 2% ginger extract) at inlet air temperature of 180°C was optimised as the best treatment.

4.5 Experiment III

4.5.1 Development and quality evaluation of milk fortified banana pseudostem juice powder (product-III)

A process has been developed for the preparation of fortified banana pseudo stem juice powder using the spray drying technology. In order to improve the tastiness and nutritional value of powder, milk (15, 25, 30 and 50%) and horse gram extract (10, 20 and 30%) were incorporated in predefined concentration. Cardamom powder was added during drying to enhance the sensorial quality. Quality parameters of the powder which was obtained in different spray drying temperatures (185, 190 and 200°C) with selected feed pump and blower rpm of 15 and 1800 respectively were judged by standard methods and the results obtained are discussed in the following sections.

4.5.1.1 Quality evaluation of fortified pseudostem juice powder

4.5.1.1.1 Moisture content

Moisture of the pseudostem powder was found to be in the range of 3.64-4.5% w.b (Appendix E, Table E1). It was observed that an increase in total solid content in feed reduced the moisture of final powder. As the total solid content in feed increased, the available water for evaporation gets decreased which led to the reduction in moisture content. In present study feed with 30% horse gram extract and 50% milk exhibited the lowest moisture value of 3.64% (Fig.4.31).

Powder dried at different spray drying temperatures (*i.e.,* 185 190 and 200°C) were analysed for moisture content. Efficient removal of water at high temperature yields a low moisture product. It can be elucidated that, elevated inlet air temperature offered an appreciable driving force for moisture deduction (Goula and Adamopoulos, 2010). A low moisture value of 3.64% was noted at 200°C and high moisture of 4.5% was present in samples dried at 185°C. However the product obtained at high temperatures were over dried. Statistical studies on moisture content of fortified pseudostem juice powder confirmed its significance at 1% level ($p<0.0001$) (Appendix M1).

4.5.1.1.2 Water activity

Water activity of the spray dried powder was analysed for predicting microbial intensification and shelf life stability. The water activity value observed for present study ranged from 0.221 to 0.376 (Appendix E2). Experimental results showed that the water activity and moisture content were related to each other. Water activity exhibited a sudden drop with an increase in inlet air temperature and decrease in moisture content (Fig. 4.32). These observations were comparable with the results illustrated by Schuck *et al*. (2005). Schuck *et al*. (2005) observed a lower water activity value of 0.16 in tomato powder spray dried at an inlet temperature of 210°C among the trials conducted at 140, 190 and 210°C. While, the higher water activity of 0.32 observed at 140°C.

Water activity of fortified pseudostem juice powder showed a higher value of 0.376 at 185°C and minimum of 0.221 at 200°C. Water activity recorded for the powder was found to be in the permissible limit as suggested by Stapelfeldt *et al.* (1997). According to their study, water activity range for best quality whole milk powder was observed at 0.11-0.23. Comparing the water activity value of fortified pseudostem juice powder with whole milk powder, water activity values were safe for fortified pseudostem juice powder samples. The water activity of pseudostem juice powder was analysed statistically. It was observed that water activity was significant at 1% level ($p<0.0001$) and the ANOVA table related with it is given in Appendix M2.

4.5.1.1.3 Bulk density

The loose and tapped bulk density of powdered samples under different experimental conditions was computed. The loose bulk density value ranged from 0.309-0.431 g/ml and tapped bulk density ranged from 0.387-0.543 g/ml (Appendix E3 and E4). Among different treatments, loose and tapped bulk density values were lowest for treatment T_1 (200°C) (*i.e.*, 0.309 g/ml and 0.387 g/ml) while, highest for treatment T_{12} (185°C) (*i.e.*, 0.431 and 0.543 g/ml). These experimental observations revealed that the bulk density values get decreased under elevated process temperatures. Research conducted on milk powder by

Nijdam and Langrish, (2006) provided key evidence for the former statement. According to their study, milk powders were produced at 120 and 200°C in which low bulk density values were observed at 200°C. Employing higher inlet air temperature resulted in enlarged particle formation due to rapid evaporation and layer development over feed droplets, thus leading to a low bulk density (Phisut, 2012, Jittanit *et al.*, 2011 and Reineccius, 2001).

From Fig.4.36, it is evident that an increase in bulk density values were observed with an increase in feed concentration. Chegini and Ghobadian (2008) and Kha *et al*. (2010) were stated that, increase in feed concentration leads to a decrease in particle volume and increase in bulk density. Samples with 30% horse gram extract and 50% milk showed the highest bulk density values of 0.431 and 0.543 g/ml at an inlet temperature of 185°C. Statistical analysis of product exhibited significance at 1% and the ANOVA table related with the bulk density values are presented in Appendix M3 and M4.

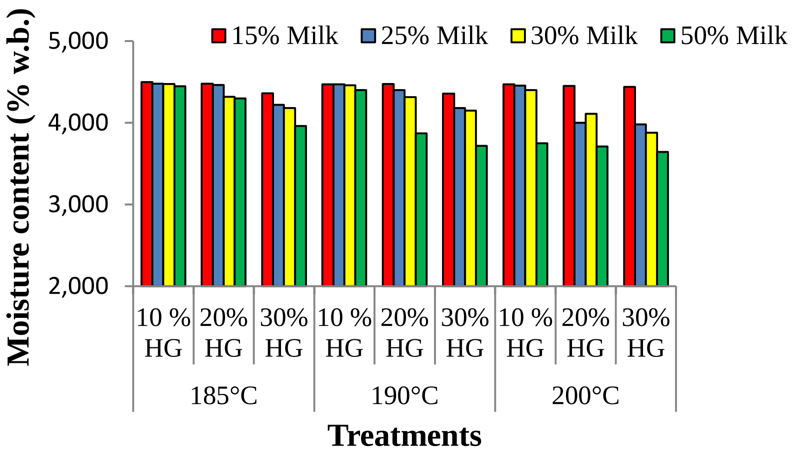

Fig. 4.31 Moisture content of Product-III

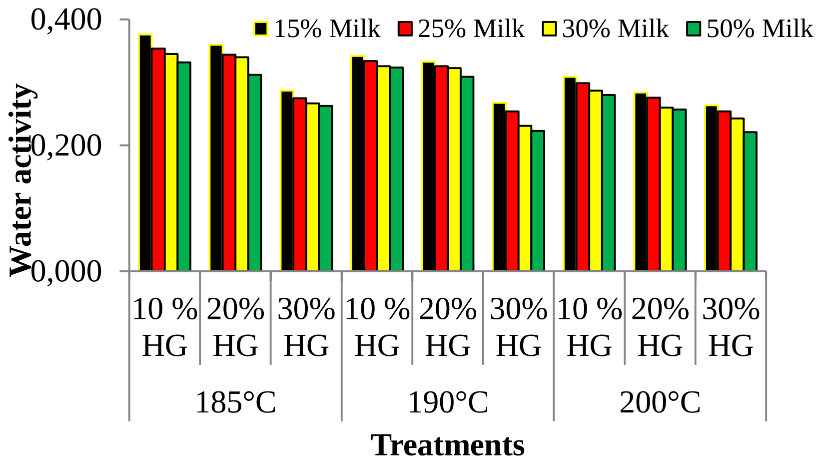

Fig. 4.32 Water activity of Product-III

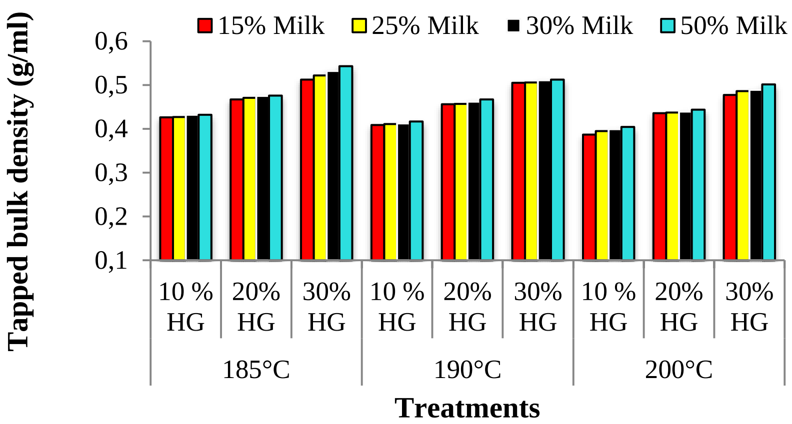

Fig. 4.33 Tapped bulk density of Product-III

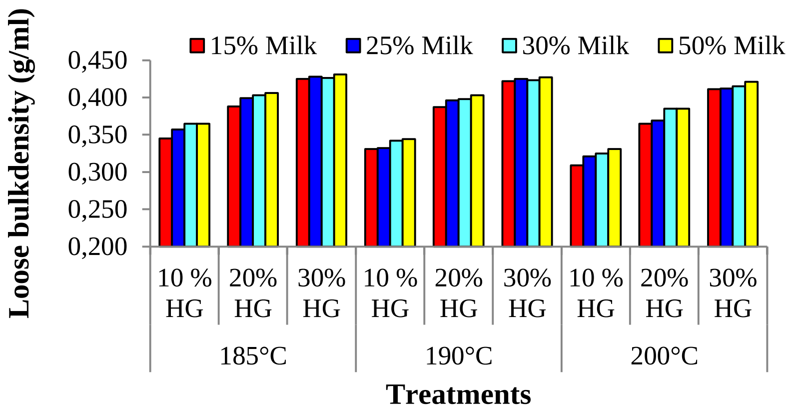

Fig. 4.34 Loose bulk density of Product-III

4.5.1.1.4 Colour characteristics

Colour characteristics of fortified pseudostem powder were examined using Hunter lab to verify the powder quality and consumer acceptability. Colour characteristics including L^*, a^* and b^* obtained from instrument were recorded as: L^* - 67 to 90.03, a^*- 4.94 to 10.63 and b^*- 15.19 to 24.71.

T12 (185°C) **T1 (200°C)**

Plate 4.6 Fortified pseudostem juice powder at different inlet air temperature

The luminance (L^*) of powder was found to be fair and acceptable Influence of inlet temperature and raw material concentrations showed a significant effect on L^* value. Treatments conducted at low temperature showed appreciable increase in L^* values (Appendix E5). Highest L^* value of 90.03 was recorded in treatment T_{12} at 185°C. At elevated temperature the chance of browning gets increased due to product oxidation (Bento *et al*., 2008 and Fonseca *et al.*, 2011). Thus at high temperature L^*values get decreased (Fig. 4.35) from 90.03 to 67.

The a^* values of powder under different spray drying temperatures along with varying concentration of raw materials were observed (Appendix E7). The maximum a^* value of 10.63 was found in the treatment T1, whereas minimum value of 4.94 was recorded in T12. In this study, a^* values of fortified pseudostem juice powder were significantly affected by feed concentration as well as inlet air temperature ($p<0.0001$) (Appendix M5, M6 and M7). The variation in a^* value of fortified pseudostem juice powder at different process is depicted in Fig. 4.36 given below.

A significant variation in b^* value was noted at high inlet air temperature (Appendix E7). The average b^* value of fortified pseudostem juice powder ranged from 15.19 to 24.71 (Fig. 4.37). Highest value of 24.71 was recorded in T1 (200°C) treatment and lowest value of 15.19 for T12 (185°C). Occurance of non enzymatic browning as a result of maillard reaction might be the reason for increased b^* value (Bento *et al.*, 2008 and Fonseca *et al.*, 2011).

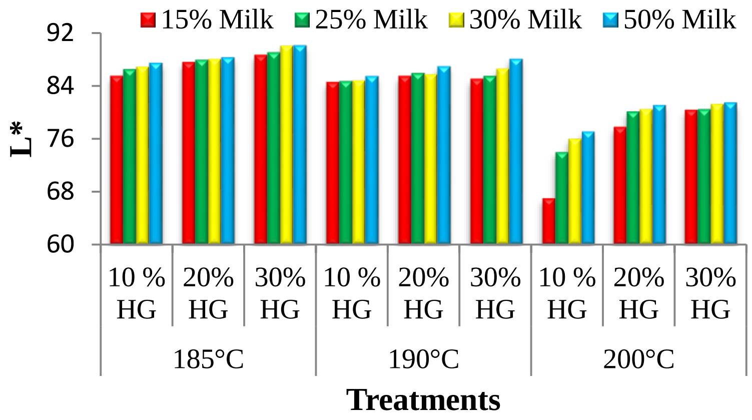

Fig. 4.35 L* value of Product-III

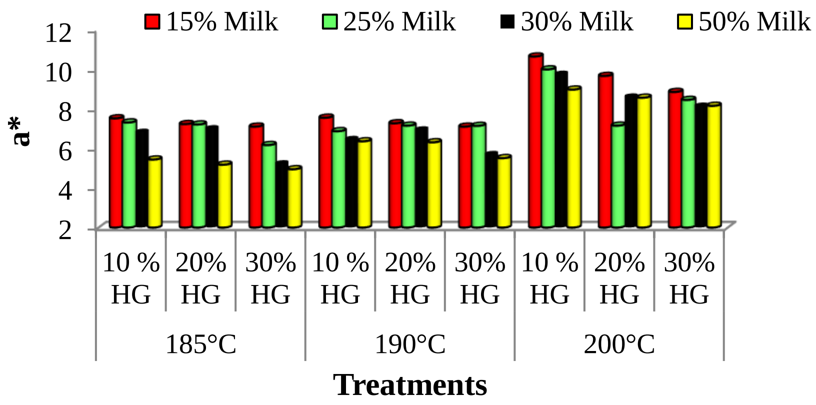

Fig. 4.36 a* value of Product-III

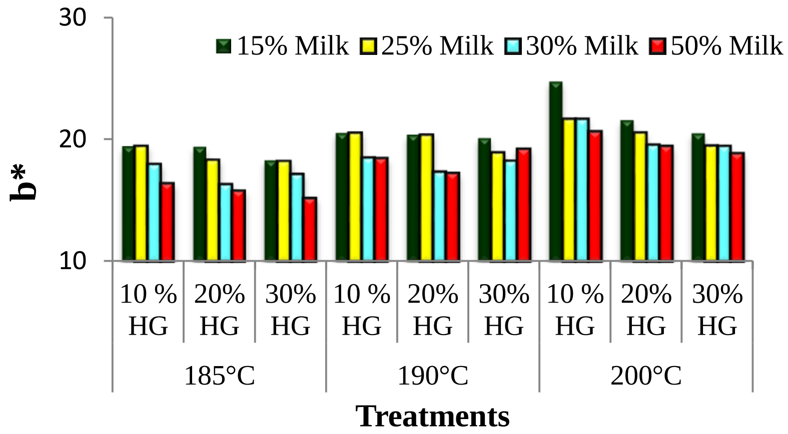

Fig. 4.37 b* value of Product-III

4.5.1.1.5 Total soluble solids (TSS)

TSS of reconstituted fortified pseudostem juice powders (one gram powder in 10 ml distilled water) were tested by using a digital hand refractometer.

TSS of the fortified pseudostem juice powder varied from 15-19.3°B (Appendix E8). For treatments with high feed concentration showed a slight variation in TSS. This might be due to the increased solid content in sample. Sample with 50% milk and 30% horse gram extract (T_{12} -190°C) showed high TSS of 19.3°B.

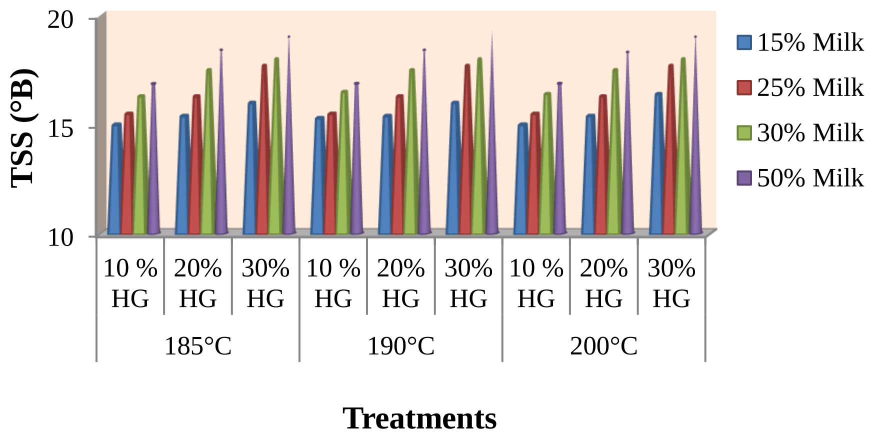

Fig. 4.38 Total soluble solids of Product-III

From Fig. 4.38, it is evident that spray drying temperature had no influence on the powder TSS. In the present study, TSS of fortified pseudostem juice powder was not significantly affected by concentration as well as by drying inlet air temperature.

4.5.1.1.6 Titrable acidity and pH

The titratable acidity of fortified pseudostem juice powder was found to be in range of 0.114-0.141% (Table 4.18). These results were analogous with those reported by Tracy *et al.* (1951). According to their study titrable acidity in whole milk powder was varied between 0.135 and 0.140%.

pH obtained for the reconstituted powders (one gram powder in 10 ml distilled water) were in range of 5.76-6.94 (Table 4.18). The results indicated that with increase in milk concentration, pH value increased. High pH value of milk might be the reason for its increment in powder pH.

Fortified pseudostem powders developed from 50% milk and 30% horse gram extract combination exhibited high pH value of 6.94. The lowest pH value of 5.76 was observed in the treatment T1 (15% milk + 10% horse gram extract).

4.5.1.2 Reconstitution properties

- Solubility
- Wettability
- Water solubility index
- Water absorption index

Reconstitution properties of fortified pseudostem juice powders were tested for validating product quality and its consumer acceptability. Standard test procedures mentioned under chapter III were followed to determine reconstitution properties. The observations for each reconstitution properties listed above were examined for standardizing the best product. The range of values and reason behind its specific trend is explained in subsequent sections.

4.5.1.2.1 Solubility

Solubility is a key parameter to be evaluated for assuring the quality of final powder. The solubility of fortified pseudostem under different spray drying conditions was investigated. During the study, it was observed that the solubility varied with process conditions. The solubility value of fortified pseudostem juice powder was found to be in the range of 43.80 - 93% (Appendix E9). Among various treatments with high feed concentration (30% horse gram and 50% milk) scored less solubility value (Fig. 4.39). The solubility decreased with increase in feed concentration and temperature, this might be due to denaturation of protein at high temperature resulted in low solubility. Chegini and Taheri, (2013) observed that at high temperature, the solubility reduced in spray dried powder due to the formation of a rigid surface film above the powder particles. The formed film act as barrier to water and therefore a larger fraction of powder remained as insoluble solids.

Fig. 4.39 shows the solubility variation of fortified pseudostem juice powder in different process conditions. From the graphical representation, it is evident that, a drastic reduction in solubility occurred from initial (T1) to final (T12) treatment. Higher solubility value of 93% was observed in T1 at lower temperature of 185°C and lower solubility value (43.8%) was found at 200°C for T12. Chudy *et al.* (2015) put forward the assumption that inappropriate production parameters may lead to reduction in solubility to below 50%. Statistical analysis showed its significance at 1% interval ($p<0.0001$) and the ANOVA related with it is given in Appendix M8.

4.5.1.2.2 Wettability

The wettability of fortified pseudostem juice powder under different spray drying inlet air temperatures and raw material concentrations was observed. From the results, wetting time of fortified pseudostem juice powder varied between 348 and 1290 s (Appendix E10). Kim *et al*. (2002) stated that good quality whole milk having a wetting time below 15 min (>900 s). From the experimental observations, fortified pseudostem juice powders of 185 and 190°C showed wetting time less than 900 s. The wetting time of fortified pseudostem juice powder values were in range at lower temperature and feed concentration. Effect of process parameters governing the wettability of fortified pseudostem juice powder was studied and depicted in Fig. 4.40.

The test results indicated a stated reduction in wettability with low inlet air temperature and raw material concentration. Moisture trend in powder occurred by different process parameters might be the reason for this result fluctuation. Apart from this, presence of free fat on droplet surface also contributed the wettability variation among trials (Chegini and Taheri, 2013 and Zbikowska and Zbikowski, 2006). Kim *et al*. (2002) propounds the view that deviation of wettability among treatments might be due to different particle size, surface area, density, porosity *etc*. Fair wettability value of 348 s and the unacceptable value of

1290 s were found in T1 (185°C) and T12 (200°C). Statistically the wettability values were significant on the process parameters and the ANOVA for the values were checked and tabulated in Appendix M9.

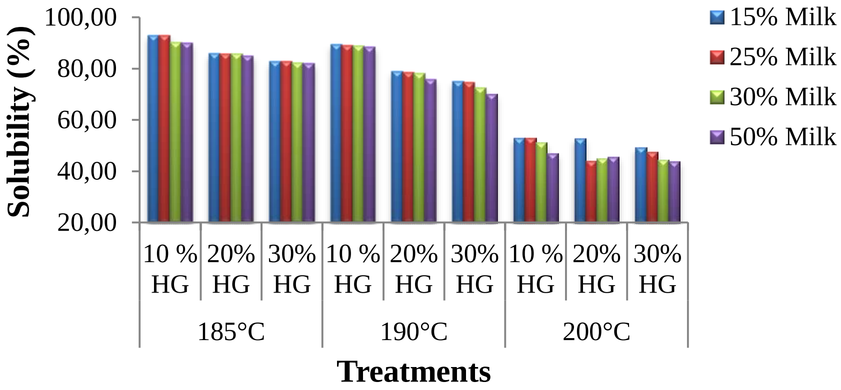

Fig. 4.39 Solubility of Product-III

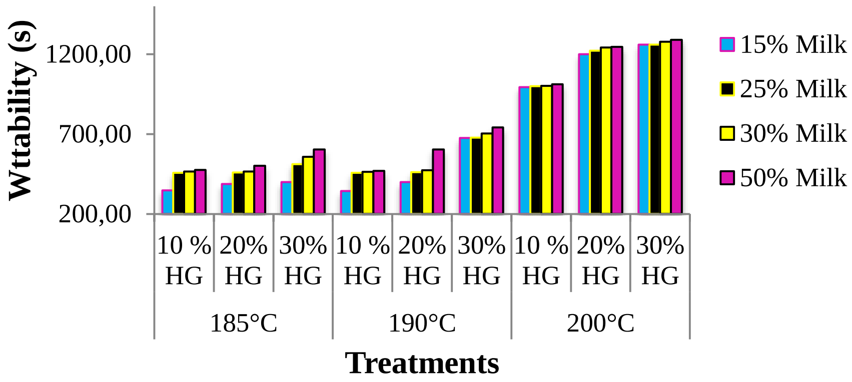

Fig. 4.40 Wettability of Product-II

4.5.1.2.3 Water solubility index (WSI)

Water solubility index of fortified pseudostem juice powder showed a slight variation among treatments. WSI values varied from 40.12% to 53.54% and are given in Table 4.19. Similar findings were observed by Jumah *et al*. (2000) according to them, as the inlet temperature increases the chance of formation of insoluble solids gets increased and resulted a higher WSI value. The result obtained for fortified pseudostem juice powder was comparable with the former study. At the higher temperature of 200°C maximum value of WSI (53.54%) was noted while a minimum of 40.12% was noted at 185°C.

4.5.1.2.4 Water absorption index (WAI)

WAI value of fortified pseudostem juice powder found to decrease from 93.35-88.24% (Table 4.19) with a decrease in inlet air temperature of 200ºC. The obtained result agreed with the study of Phoungchandang *et al*. (2010) on ginger powder. At elevated temperature cohesion between particles gets reduced which led to less clustering and low water absorption index (Grabowski *et al.,* 2006 and Adhikari *et al.,* 2003). Low WAI value of 88.24 was recorded in T1 (200°C) treatment and the highest value of 93.35% was recorded in T12 (185°C).

Table 4.18 pH and titrable acidity of Product-III

	Inlet air temperature (°C)	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
Titrable acidity (%)	**185**	0.140	0.132	0.113	0.138	0.140	0.124	0.133	0.131	0.141	0.128	0.140	0.140
	190	0.134	0.133	0.129	0.135	0.121	0.128	0.131	0.121	0.132	0.130	0.143	0.130
	200	0.134	0.121	0.132	0.114	0.113	0.114	0.118	0.131	0.135	0.129	0.131	0.119
pH	**185**	5.980	6.120	6.240	6.350	6.350	6.530	6.440	6.530	6.830	6.670	6.680	6.860
	190	5.760	6.140	6.220	6.320	6.330	6.550	6.440	6.550	6.860	6.670	6.680	6.940
	200	5.760	6.200	6.320	6.320	6.350	6.440	6.440	6.510	6.880	6.670	6.670	6.680

Table 4.19 Water solubility index and water absorption index of Product-III

	Inlet air temperature (°C)	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
WSI (%)	185	40.120	40.230	42.430	42.540	42.670	42.880	46.760	47.620	47.660	48.070	50.090	50.840
	190	40.180	40.250	42.530	42.540	42.690	43.000	48.040	47.770	47.670	48.500	50.140	51.430
	200	40.260	40.310	42.550	42.620	43.040	43.070	48.210	48.000	48.050	48.770	52.110	53.540
WAI (%)	185	93.040	93.120	93.120	93.170	93.190	93.230	93.230	93.280	93.300	93.280	93.330	93.350
	190	92.460	93.000	93.000	92.770	93.110	93.190	93.170	93.210	93.260	93.090	93.250	93.300
	200	88.240	88.240	90.000	89.250	90.030	89.950	89.460	90.090	89.950	90.020	90.110	90.050

4.5.1.3 Flow properties

- Carr's index (CI)
- Hausner ratio (HR)

Carr's index (CI) and Hausner ratio (HR) were the two key parameters that determining the flowability and cohesiveness characteristics of powder. The results showed that CI of fortified pseudostem juice powder varied from 1.15 to 1.26 and the value of HR ranges from 12.301 to 20.626 (Table 4. 20). Flowability and cohesiveness of powders depends on the size of the particles and also cohesive and frictional forces within the particles. Particle size depends mainly on atomization airflow (Wang *et al.,* 2015). Besides the particle size, internal forces, flowability and cohesiveness is also affected by many other factors like moisture content, hardness, elasticity *etc* as reported by Chen *et al*. (2010). Therefore, it was difficult to point out the appropriate reason for the change in CI and HR values within treatments. With respect to standard table values of CI shown in Table 3.6 the obtained values of CI and HR values for spray dried pseudostem powders showed good and fair and poor flowability value for different treatments as given in Table 4.20.

4.5.1.4 Product yield

Product yield of fortified pseudostem juice found to be in the range of 10.63 to 79.25% (Table 4.20). It was found that product yield was affected significantly by wall material concentration and inlet air temperature. Product yield was taken as one of the important parameter for the product optimisation (Arslan *et al.,* 2015 and Fazaeli *et al.,* 2012). Dolinsky *et al.* (2000) hypothesized that higher inlet air temperature leads in a negative effect on product yield.

Table 4.20 Flow properties and product yield of Product-III

	Inlet air temperature (°C)	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
	185	1.230	1.200	1.200	1.200	1.180	1.220	1.180	1.180	1.250	1.180	1.170	1.260
HR	**190**	1.240	1.180	1.200	1.240	1.150	1.190	1.200	1.160	1.210	1.210	1.160	1.200
	200	1.250	1.190	1.160	1.230	1.240	1.180	1.230	1.140	1.181	1.220	1.150	1.190
	185	19.014	16.916	16.992	16.393	15.287	18.008	15.809	15.158	19.925	15.509	14.706	20.626
CI (%)	**190**	19.071	15.132	16.436	19.221	13.348	16.008	16.990	13.853	17.221	17.506	13.704	16.602
	200	20.155	16.284	13.836	18.734	19.256	15.226	18.546	12.301	15.133	18.069	13.288	15.968
	185	55.750	73.280	75.320	57.230	76.860	75.490	66.370	77.340	76.860	71.690	77.330	78.730
Product yield (%)	**190**	55.480	73.280	75.280	60.720	76.360	77.230	69.080	74.230	78.380	71.590	72.820	79.250
	200	10.630	19.890	33.490	18.150	23.850	46.620	19.870	25.760	46.820	21.300	29.750	47.050

At elevated temperature powder melts and gets adhered to the drier wall there by resulting in a reduction in product yield. Product yield of 10.63% was found in T_1 treatment dried at 200°C and higher yield of 79.25% was achieved at 190°C (50% milk+30% horse gram extract+ 20% pseudostem juice). Statistical analysis showed a significant effect on yield at different process conditions ($p<0.0001$) and the ANOVA table with it is given in Appendix M10.

4.5.1.5 Microbiological stability

The microbial analysis was carried out for the standardised fortified pseudostem juice powder samples. Shelf life and storage stability of the product were predicted based on the microbial load. The results confirmed the absence of microbial colonies in spray dried powders (Appendix G3). Rajput *et al.* 2009 conducted microbal studies on 60 milk powder samples and quantified the toatal viable count as $3.1\times10^3 \pm 5\times10^2$ cfu/g.

4.5.1.6 Optimisation of process parameters

Optimisation of process variables especially inlet air temperature and raw material concentration were performed using the General composite design. Feed pump rpm and blower speed were already fixed based on preliminary trials. Statistical models were employed to determine numerical optimisation to fix the optimal process parameters for developing fortified banana pseudostem juice powders. In the present investigation, the independent variables were kept within the range and dependent variables were chosen as maximum and minimum. The experimental sample had the optimum process conditions of inlet air temperature (Table 4.20) and raw material concentration (30% horse gram extract and 50% milk+20% pseudostem juice).

Optimised sample (T12) was kept for shelf life studies under ambient conditions. Treatment T12 developed at different inlet temperatures (185, 190 and 200°C) were taken to compare its storage period. Due to limited time period, product-III was analysed only three months during shelf life study.

Table 4.21 Optimised spray drying parameters for Product-III

Sl. No.	Process parameters	Optimised Conditions
1	Speed of the atomizer (rpm)	1800
2	Inlet air temperature (°C)	185
4	Outlet temperature (°C)	74-92
3	Feed flow rate (rpm)	15

4.5.1.7 Particle size

Particle size of product was analysed by SEM analysis as mentioned earlier. Particle size of powder varied from 5-10 µm (Plate 4.7) at 5000 and 1000 resolutions respectively. Loksuwan, (2007) observed the particle size of spray-dried powers of modified tapioca starch, native tapioca starch, and maltodextrin and reported that, modified tapioca starch had granules size ranged from <5 to 30 µm, while native tapioca starch had more homogeneous granules ranged in size from 2 to 18 µm

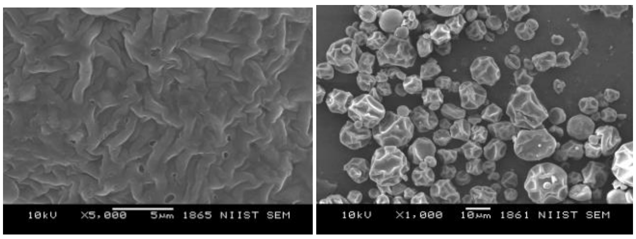

Plate 4.7 SEM micrographs of Product-III

4.5.1.8 Mineral profile analysis

Mineral profile analysis for fortified banana pseudostem juice powder was done by absorption spectro-photometry and confirmed its presence in the final product and are listed below.

- Carbohydrate -85.31%
- Protein - 3.80%
- Total ash- 4.10%
- Potassium - 1.18%
- Calcium - 2.88%
- Magnesium - 0.31%

Feriotti and Igutti (2011) quantified pseudostem sap proximate composition *viz.* Total solid- 0.308%, Protein- 0.0141%, Lipid- 0.005%, Total sugar - 0.191%, Ash -0.104% and mineral composition of sap (*viz*. Sodium- 88mg/l, Potassium - 874 mg/l, Calcium - 130 mg/l, Magnesium - 116 mg/l). Comparing the mineral analysis data obtained in this study for fortified banana pseudostem juice powder with the mineral content of fresh banana pseudostem sap, it is clear that the powder scored high in mineral content than fresh pulp. Thus for fortifying the pseudostem juice with horse gram extract and milk, the nutritious value of final powder could be significantly enhanced.

4.5.1.9 Packaging of banana pseudostem juice powder

The optimised banana pseudostem juice powder samples were packed for shelf life studies in LDPE pouches and inserted in laminated aluminium pouches and was sealed hermetically using a hand sealing machine. Sealed packets were stored in ambient condition and tested for its quality attributes. Sharma *et al.*, (2003) studied storage studies of apple powder packed in aluminium pouches. From their six month storage study, the powder quality was found to remain unchanged.

Plate 4.8 Packaged pseudostem juice powder samples in LDPE pouches and aluminium foil pouches

4.5.1.10 Storage stability

To consider the utility of spray-dried sample (fortified banana pseudo stem juice powder) for food industrial applications, it is important to assure its stability and quality during storage. In this context, the variation in different quality parameters during storage of three months was investigated and used as an indicator of product stability. Optimised samples of fortified pseudostem juice powder were stored under ambient conditions about three months. Shelf life study of experimental sample was done in every month to assess the fluctuations in powder characteristics. The data yielded during storage period were plotted in error graphs and its changes were discussed under this session.

4.5.1.10.1 Moisture content

The moisture content of the powder varied during storage period. Transfer of moisture to and from the product significantly influenced the stability of powder. A slight increase in moisture was noted during storage *i.e.,* 3.64-4.13% (Appendix F1). Cristina *et al.* (2008) also reported an increasing trend for moisture in whole milk powder.

Among three samples T12 at 185°C showed higher moisture absorption at 3rd month of storage. Moisture transfer might be due to the effect of storage conditions and permeability of packaging material. A significant change in moisture content was noted and was plotted, given below in Fig. 4.41. Statistical results revealed a significant effect of storage on moisture content ($p<0.0001$) and is given in Appendix N1.

4.5.1.10.2 Water activity

The change in water activity of packed fortified banana pseudostem samples was determined during three month storage study to verify the storage stability. Water activity of powder changed from 0.253 to 0.309 (Appendix F2) during storage. The shelf life study results showed that water activity of powder altered slightly during three month storage (Fig. 4.42).

Pua *et al.* (2007) observed similar trend in water activity during the storage of jackfruit powders. Statistical analysis showed a significant effect on moisture content ($p<0.0001$) and ANOVA related with it is presented in Appendix N2.

4.5.1.10.3 Bulk density

Bulk density values showed a slight increase with storage life. Bulk density and moisture content showed an indirect relation. Increase in moisture during storage led to an increased bulk density (Fig. 4.43 and 4.44). Bulk density values such as tapped bulk density and loose bulk density of powder found to be increased during storage (Appendix F3 and F4). Powders with higher moisture value showed higher loose bulk density and tapped bulk density of values of 0.450 and 0.553 g/ml (T12-185°C) respectively in the 3rd month. The increase in moisture content led to an increased bulk weight of product during storage. The increase in moisture might be due to the permeability of packaging material, variation in storage temperature *etc* (Pua *et al.*, 2007). Statistical study showed that bulk density values were significant ($p> 0.0001$) and the ANOVA related with it is given N3 and N4.

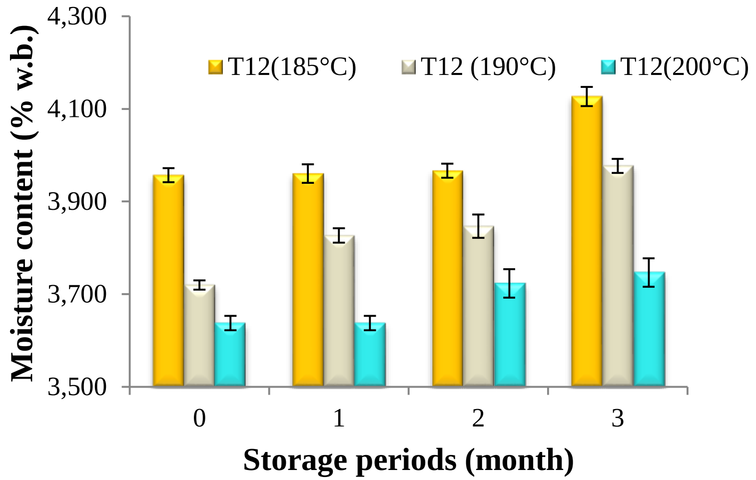

Fig 4. 41 Moisture content of Product-III during storage

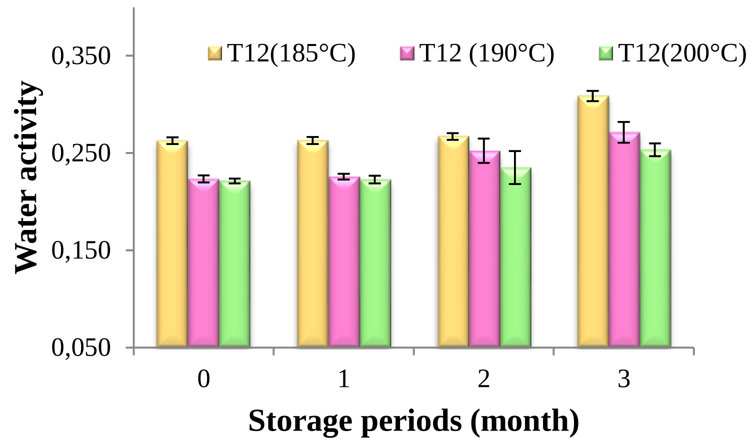

Fig 4. 42 Water activity of Product-III during storage

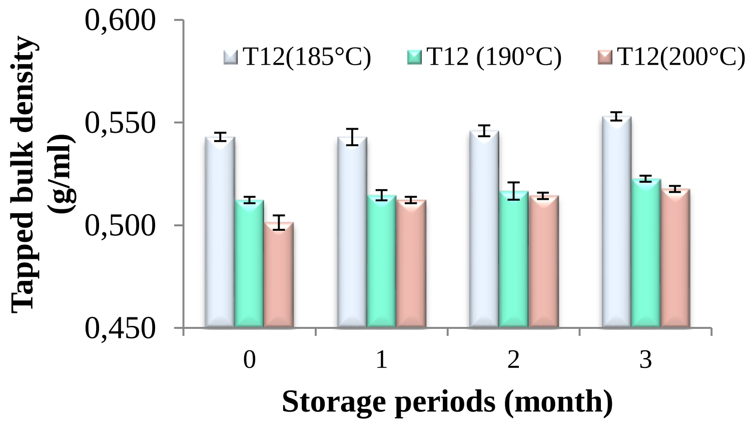

Fig 4.43 Tapped bulk density of Product-III during storage

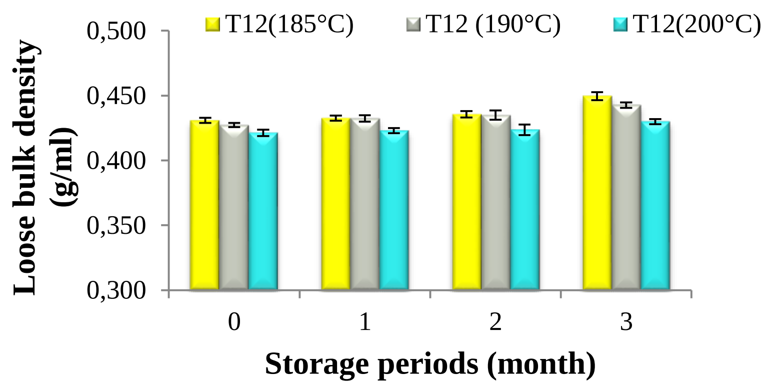

Fig 4. 44 Loose bulk density of Product-III during storage

4.5.1.10.4 Colour characteristics

Lightness L^* value of the spray dried powder reduced during storage period. Chudy *et al*. (2015) supported the prediction that enzymatic browning occurred due to Maillard reaction, lipid oxidiation, deterioration of ascorbic acid *etc* contributed for fade colour during storage. The decrease in lightness value was more pronounced in T12 (200°C) treatment at 2nd month (*i.e.*, 81.380).

It was noted that a^* (redness) and b^* (yellowness) values of powder increased during storage and T6 (200°C) exhibited the highest b* and a* values (8.147and 19.215) at the end of third month. The variation in colour values is illustrated in Table 4.22.

Table 4.22 Colour characteristics of Product-III during storage

Colour characteristics	Treatments	Storage periods (month)			
		0	1	2	3
L*	T6 (185°C)	90.030	90.300	90.000	90.000
	T6 (190°C)	88.000	88.000	87.810	87.871
	T6 (200°C)	81.490	81.410	81.380	81.380
a*	T6 (185°C)	4.940	4.930	4.935	4.915
	T6 (190°C)	5.500	5.500	5.500	5.504
	T6 (200°C)	8.140	8.140	8.146	8.147
b*	T6 (185°C)	15.190	15.200	15.200	15.213
	T6 (190°C)	18.820	18.830	18.830	18.850
	T6 (200°C)	19.210	19.210	19.251	19.251

The effect of drying method and storage on colour characteristics of fortified banana pseudostem juice powder were analysed statistically and confirmed the significance of L* and a* ($p<0.0001$) while b* showed non significance during storage. The ANOVA table related with colour characteristics of pseudostem juice powder is presented in appendix N5, N6 and N7.

4.5.1.10.5 pH and Titrable acidity

pH and titrable acidity values were analysed to investigate the extent of chemical reactions occurred during storage of fortified banana pseudo stem juice powder. The pH value of powders decreased after 3 months of storage and is given in Table 4.23. Verma *et al*. (2013) revealed that conversion of sugars into acids in powders led to increased acidic properties.

Table 4.23 Change in pH and titrable acidity of product-III

	Treatments	**Storage periods (month)**			
		0	**1**	**2**	**3**
pH	**T12 (185°C)**	6.860	6.860	6.841	6.840
	T12 (190°C)	6.940	6.940	6.940	6.939
	T12 (200°C)	6.680	6.680	6.680	6.680
Titrable acidity (%)	**T12 (185°C)**	0.140	0.140	0.140	0.136
	T12 (190°C)	0.130	0.130	0.130	0.128
	T12 (200°C)	0.119	0.119	0.119	0.118

4.5.1.10.6 Solubility and Wettability

Solubility and wettability of fortified banana pseudostem samples showed a significant effect on storage (Appendix F5 and F6). Supplee and Bellis *et al.* (1925) investigated the effect of storage on milk powders. Their study indicated a decrease in solubility during storage period (Fig. 4.45). It might be due to the increased moisture content of product. The observations on solubility of fortified banana pseudostem juice powder agreed with the results obtained in Product-I and II. Trend in wettability found to be contrary to the measured solubility. Wettability of powder increased with storage (Fig. 4.46), with similar reason as mentioned earlier for solubility (Sariga *et al.*, 2015).

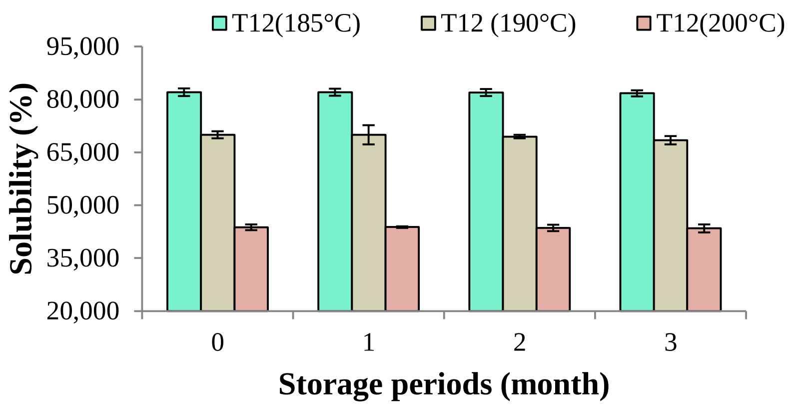

Fig. 4.45 Solubility of Product-III during storage

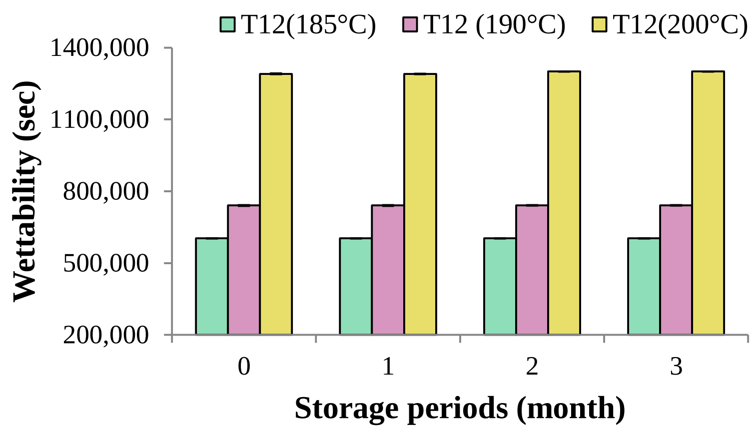

Fig. 4.46 Wettability of Product-III during storage

The effect of drying method and storage on solubility and wettability of fortified banana pseudostem juice powder were analysed statistically. Stastical studies reavealed that solubility and wettability of powders were non significant during storage ($p<0.0001$). The ANOVA table related with solubility and wettability characteristics of pseudostem juice powder is presented in appendix N8 and N9.

4.5.1.10.7 Microbial analysis

Stored samples were analysed for microbial load during storage period. Among stored samples T12 at 185°C showed comparatively higher colony count at the end of three month storage and it was 3×10^1 cfu/g. Sariga, (2015) conducted studies on spray dried vanilla extract and absence of microbial colony was reported in samples stored at ambient condition during six month periods. Details of microbial analysis are given in Appendix G4.

4.5.1.11 Sensory analysis

Sensory analysis is an important parameter for consumer acceptability. The products were analysed by 12 semi – trained sensory panelists. The optimised pseudostem juice powder was reconstituted with normal water in 1:10 ratio and sugar was added during sensory analysis. The fresh pseudostem juice with freshly prepared horse gram extract and pasteurized milk with sugar was taken as control. The results of the sensory evaluation of product are given Fig. 4.47.

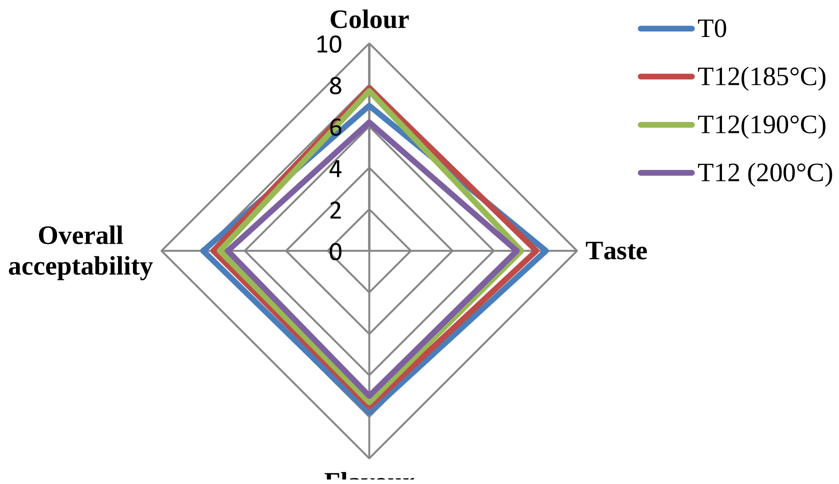

Fig. 4.47 Sensory score obtained for Product-III

Treatment T12 (185°C) scored highest value during sensory analysis. Control sample scored the best score of 8. Comparing with control treatment T12 (185°C) maintained similar sensory quality. Apart from this T12 (185°C) exhibited appreciable product stability during three months storage. Thus T12 (a treatment combination of banana pseudostem juice 20% and horse gram extract 30% with 50% milk at an inlet air temperature of 185°C) was optimised as the best treatment.

4.6 Cost analysis of pseudostem based powders

The computation of production cost for 1 kg and 50 g packet of spray dried pseudostem based powders were estimated by considering the variable cost and fixed cost of production and is given in Appendix N1. The cost of the production of 1 kg and 50 g banana pseudostem juice-sugar mix power was estimated to be Rs. 195/- and Rs. 9.75/-, respectively. The cost of powder produced from banana pseudostem juice and horse gram extract blend was calculated as Rs. 208/- for 1 kg pack and Rs. 10.40/- for its 50 g packs and for milk fortified powder, it was Rs. 243/- and Rs.12.15 /- respectively.

CHAPTER V

SUMMARY AND CONCLUSION

India has a large area of banana cultivation and its fruit and other parts are utilized as a low-cost food source. Generally, a huge biomass is produced during the post-harvest banana cultivation. A major share of this biomass includes a fibrous soft stem termed as banana pseudostem. Its massive accumulation and disposal lead to unhygienic surroundings and environmental pollution. Safe disposal of banana residue has become an unsolved issue in banana cultivation. Scientific studies revealed that banana pseudostem is rich in minerals like K, Mg, Na etc. Minerals present in banana pseudo stem have the ability to dissolve pre-formed kidney stones and also have anti-oxidant activities. In this context, utilisation and value addition of pseudostem will provide an additional income to banana growers. Though it has got high medicinal value, its usage is mostly constrained to non food applications like craft products. High perishability and its astringent tangy mouth feel might be the reason for its restricted application in food industry. Considering the above cited facts, a study was undertaken to obtain powdered product from pseudostem juice.

The intention of the study was to develop a process protocol for microencapsulated banana pseudostem juice powder, standardisation of the spray drying parameters for its development and quality analysis of fresh and stored product. Spray drying facilitates retention of product quality and preservation of heat sensitive components present in pseudostem juice. Microencapsulated banana pseudostem juice with suitable wall material could be suggested as a healthy ready to drink mix.

Three powder products were developed from banana pseudostem juice by spray drying technology. Banana pseudostem (Cv. Palayankodan) was collected from KCAET farm and pre-treated to arrest enzymatic activity. The pseudostem slices were dipped in 0.3% citric acid and blanched at 100°C for one minute to inactivate enzymes. Peroxidase and catalase test were done for checking the effectiveness of blanching. The major constituents of feed combination include;

banana pseudostem juice, sugar, horse gram extract and milk. Product-I comprised of pseudostem juice-sugar combination flavoured with ginger. Product-II consists of a blend of banana pseudostem juice and horse gram with ginger extract. However the third product, banana pseudostem juice was fortified with horse gram extract and milk flavoured cardamom.

Process parameters such as raw material concentration, wall material selection and drying conditions such as blower speed, feed speed and inlet air temperature combinations were fixed according to the preliminary trials. Blower speed of 1800 rpm and feed speed of 15 rpm were kept constant throughout the study. A process temperature of 180, 185 and 190°C were chosen for the development of product-I and II. However for product-III, the temperature selected was 185, 190 and 200°C. Maltodextrin and corn starch was selected as encapsulating agents for product-I and II, subsequently corn starch was omitted as it gave low yield during preliminary trails.

As part of quality evaluation of fresh product, physicochemical properties, reconstitution properties, and flow properties were analysed for the spray dried powder. Physicochemical properties of products such as moisture content, water activity, bulk density, TSS, titrable acidity, pH and colour characteristics were assessed by standard procedures. The reconstitution properties like solubility, wettability, water solubility index and water absorption index were done by standard laboratory methods and flow properties such as Carr’s index and Hausner ratio were calculated using standard formulae.

The experimental results revealed that spray drying conditions and raw material concentrations significantly affected the powder characteristics. Moisture content and water activity of all the three powders decreased at higher inlet air temperature and feed concentration. For Product-I moisture values ranged between 2.99-4.6% (w.b) and for Product-II it was 3.93-4.52%. In both products- I and II temperature as well as wall material concentration influenced the moisture reduction. Product-III, milk fortified sample showed a moisture range from 3.64 to 4.5% (w.b). Water activity values also followed the same decreasing trend for three products I, II and III and were found to be in the range of 0.295-0.430, 0.314 -0.407and 0.221-0.376, respectively.

Bulk density, an important parameter of powders found to decrease at elevated temperatures. The tapped and loose bulk densities of three products were assessed using standard laboratory procedures. Lower tapped bulk density of 0.410, 0.416 and 0.387g/ml were observed for the three products at low moisture conditions. Higher loose bulk density values noted at lower temperatures of 180 and 185°C and the highest loose bulk density value of 0.577 g/ml for product-II in was observed in Product-II at low temperature.

Total soluble solid (TSS) is an indicator of solids present in product and varied with raw material concentration. The TSS of pseudostem based products were 16, 24 and 19.3°B respectively, in which product-II exhibited the highest value (24ºB) due to its high feed concentration contributed by maltodextrin (25%) and horse gram extract (30%).

Analysis of acidic properties revealed that pH and titrable acidity values varied from product to product. Product-I and II exhibited a low pH and higher acidity values compared to product-III, due to the addition of ginger extract. However, product-III showed a high pH value (5.76-6.94) and low titrable acidity (0.114-0.141%) due to the addition of milk.

Colour characteristics of powder having great importance in consumer acceptability and market value. During the study it varied with inlet temperatures and the same was reflected significantly in product-III. The lowest L^* value of 67 and highest b^* value of 24.71 were observed at a higher inlet temperature of 200ºC for product-III. Other two products showed higher L^* values within a range of 77.50 to 94.52. The redness a^* was not appreciable in products except product-III, which exhibited a higher value of 10.63 at 200°C.

Reconstitution properties such as wettability, water absorption index and water solubility index increased with increase in inlet air temperature. At the same time solubility showed a decreasing trend towards increasing temperature. Highest solubility was found in product-II (97.48-99.20%) and lowest was in product-I (76.55-85%). Product-III showed a moderate solubility of 43.80-93% and wettability of 348-1290 s.

Considering the flow properties such as Carr's index and Hausner ratio product-I showed good and fair flowability, Product-II exhibited excellent and fair and for product-III flow properties were rated good.

In terms of yield, all the three products were good and showed a product yield range of 28.60 to 56.70, 47.72 to 78.20, and 10.60 to 79.20% for product-I, II and III respectively. High TSS contributed to a higher yield in case of product-II. Higher temperature resulted in a lowest yield of 10.6% in product-III.

Mineral profile analysis ensures and quantifies the nutritional quality of the developed product. An increased nutritional profile was noted from product-I to III. Presence of potassium which is the key ingredient that reduces the kidney stone formation was existed in all the three products and was found to be maximum in product-III (1.88%). Presence of magnesium was confirmed in all the three products and was high in product-II and III (*i.e.,* 0.31%). Fortification of pseudostem juice resulted in a highly nutritious health drink powder. Addition of horse gram increased the carbohydrate content whereas milk enriched the powder with calcium and protein. Among the three products, product-III showed high calcium and protein content (Ca- 2.15% and protein- 3.03%).

Particle size of the standard samples were analysed and found to be in the range of 10-50 µm for product I and II, and 5-10 µm for product III.

Storage study of standardised samples (Product-I and II) was done for six and three month periods (Product-III). For product I and II storage studies were done for six months under ambient storage conditions. Product III stored only upto three months due to limited time. Shelf life studies of sample confirmed that no appreciable changes occurred in quality and stability of powder during storage.

Moisture absorption and chemical reactions were observed during storage. This led to variation in physicochemical properties and reconstitution properties.

Moisture absorption increased the moisture content and water activity of powder, resulting in increased bulking weight of powder. Decreased pH and increased titrable acidity due to chemical reactions were also noted during storage. Degradation in colour characteristics was noted in all samples and it was more pronounced in product III. Reduced solubility and increased wettability values were the changes observed in reconstitution properties during storage period.

Microbial load in all the three products were found to be within the admissible limit and the products were safe for consumption.

Standardisation of best product from each combination was done by sensory analysis. Reconstituted powders along with their fresh feed samples were kept for sensory evaluation conducted with 12 semi trained panel members. Colour, taste, flavour and overall acceptability of reconstituted powder were judged and recorded in a 9- point Hedonic scale. From the sensory evaluation and quality analysis the best samples were selected from each combination. From the banana pseudostem juice - sugar combinations, trial T6 (15% sugar + 25% MD + 56% pseudostem juice) spray dried at 180°C scored high in quality evaluation, which was supported by statistical analysis and sensory analysis. In case of experiment-II, treatment T6 (25% maltodextrin + 30% horse gram extract + 43% pseudostem juice) at an inlet temperature 180°C showed he best result. However in third combination *i.e.,* pseudostem juice-horse gram extract blended with milk exhibited the best result at an inlet temperature of 185°C for the treatment T12 (50% milk + 30% horse gram extract + 20% pseudostem juice), based on the statistical and sensory analysis.

Cost analysis of the products were estimated by considering the variable and fixed cost of production. Cost of production for one kilogram and 50 g packets were estimated for all the three optimised product combinations. The production cost for one kilogram of product-I, II, and III was Rs.195/-, Rs.208/- and Rs.243/- respectively. The study revealed that the production of banana pseudostem juice based powder has good nutritional value and is economically viable. The adoption of microencapsulation technology using spray drying to produce pseudostem juice powder will be a promising technology and it will help banana growers, and banana based food industries. Due to its high nutritional value and appreciable price, the pseudostem juice powder has good scope to fetch high market price and will be preferred by all health conscious consumers.

CHAPTER VII

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APPENDIX A

QUALITY PARAMETERS OF SPRAY DRIED PSEUDOSTEM JUICE POWDER (Product-I)

Table A1 Moisture content

	Inlet air temperature (°C)	T1	T2	T3	T4	T5	T6
Moisture content (% w.b.)	180	3.890	4.600	3.350	3.480	3.080	3.240
	185	3.710	4.040	3.330	3.430	3.000	3.200
	190	3.500	3.930	3.270	3.360	2.990	3.100

Table A2 Water activity

	Inlet air temperature (°C)	T1	T2	T3	T4	T5	T6
Water activity	180	0.430	0.387	0.355	0.325	0.320	0.313
	185	0.403	0.380	0.340	0.322	0.315	0.300
	190	0.400	0.360	0.338	0.324	0.312	0.295

Table A3 Tapped bulk density

	Inlet air temperature (°C)	T1	T2	T3	T4	T5	T6
Tapped bulk density (g/ml)	180	0.495	0.510	0.440	0.464	0.419	0.431
	185	0.483	0.509	0.439	0.448	0.412	0.430
	190	0.477	0.480	0.435	0.441	0.410	0.412

Table A4 Loose bulk density

	Inlet air temperature (°C)	T1	T2	T3	T4	T5	T6
Loose bulk density (g/ml)	180	0.357	0.457	0.319	0.343	0.300	0.306
	185	0.354	0.369	0.313	0.336	0.281	0.304
	190	0.344	0.363	0.310	0.329	0.258	0.303

Table A5 Total soluble solids (TSS)

	Inlet air temperature (°C)	T1	T2	T3	T4	T5	T6
TSS (°B)	180	10.800	11.400	12.540	14.600	15.000	15.890
	185	10.000	12.450	13.900	14.650	15.000	16.100
	190	11.020	12.500	14.500	14.700	15.200	16.000

Table A6 Solubility

	Inlet air temperature (°C)	T1	T2	T3	T4	T5	T6
Solubility (%)	180	85.000	83.010	80.100	81.500	79.400	76.650
	185	84.120	81.802	79.900	81.300	79.400	76.650
	190	83.700	82.900	79.800	81.200	78.600	76.530

Table A7 Wettability

	Inlet air temperature (°C)	T1	T2	T3	T4	T5	T6
Wettability (s)	180	73.050	75.430	77.900	78.000	79.100	80.000
	185	74.100	76.000	77.900	78.060	79.760	80.040
	190	75.100	76.23	77.900	79.000	80.000	80.060

Table A8 Water solubility index (WSI)

	Inlet air temperature (°C)	T1	T2	T3	T4	T5	T6
WSI (%)	180	33.400	35.800	39.540	41.870	43.870	48.000
	185	35.210	37.120	39.760	42.140	44.870	55.100
	190	34.760	39.000	40.130	43.000	46.700	57.030

Table A9 Water absorption index (WAI)

	Inlet air temperature (°C)	T1	T2	T3	T4	T5	T6
WAI (%)	180	99.450	98.300	96.300	94.800	92.900	90.800
	185	98.500	97.400	95.840	93.400	92.400	90.540
	190	98.300	96.550	96.000	94.620	92.100	90.500

APPENDIX B

STORAGE STUDY OF SPRAY DRIED BANANA PSEUDOSTEM JUICE POWDER (Product-I)

Table B1 Changes in moisture content of Product-I during storage

Treatments	Moisture content (% w.b.)			
	Storage periods (months)			
	0	**2**	**4**	**6**
T6 (180°C)	3.240	3.287	3.320	3.470
T6 (185°C)	3.200	3.219	3.220	3.300
T6 (190°C)	3.100	3.100	3.150	3.290

Table B2 Changes in water activity of Product-I during storage

Treatments	Water activity			
	Storage periods (months)			
	0	**2**	**4**	**6**
T6 (180°C)	0.313	0.322	0.338	0.345
T6 (185°C)	0.300	0.320	0.332	0.339
T6 (190°C)	0.295	0.302	0.311	0.326

Table B3 Changes in tapped bulk density of Product-I during storage

Treatments	Tapped bulk density (g/ml)			
	Storage periods (months)			
	0	**2**	**4**	**6**
T6 (180°C)	0.431	0.431	0.432	0.443
T6 (185°C)	0.430	0.432	0.433	0.442
T6 (200°C)	0.412	0.413	0.417	0.420

Table B4 Changes in loose bulk density of Product-I during storage

Treatments	Loose bulk density (g/ml)			
	Storage periods (months)			
	0	**2**	**4**	**6**
T6 (180°C)	0.306	0.313	0.326	0.356
T6 (185°C)	0.304	0.308	0.314	0.316
T6 (190°C)	0.303	0.303	0.308	0.317

Table B5 Changes in solubility of Product-I during storage

Treatments	Solubility (%) Storage periods (months)			
	0	2	4	6
T6 (180°C)	79.400	78.970	78.320	77.541
T6 (185°C)	79.400	78.650	78.206	77.198
T6 (190°C)	78.600	78.423	78.223	77.127

Table B6 Changes in wettability of Product-I during storage

Treatments	Wettability (s) Storage periods (months)			
	0	2	4	6
T6 (180°C)	80.000	80.090	80.120	80.390
T6 (185°C)	80.040	80.160	80.390	80.500
T6 (190°C)	80.060	80.460	80.570	80.630

APPENDIX C

QUALITY PARAMETERS OF SPRAY DRIED BANANA PSEUDO STEM JUICE-HORSE GRAM EXTRACT BLEND POWDER (Product-II)

Table C1 Moisture content of Product-II

	Inlet air temperature (°C)	T1	T2	T3	T4	T5	T6
Moisture content (%)	180	4.523	4.510	4.230	4.350	4.333	4.210
	185	4.460	4.442	4.140	4.240	4.210	4.110
	190	4.231	4.211	4.040	4.160	4.100	3.930

Table C2 Water activity of Product-II

	Inlet air temperature (°C)	T1	T2	T3	T4	T5	T6

Water activity	180	0.407	0.401	0.387	0.387	0.364	0.352
	185	0.402	0.400	0.371	0.374	0.348	0.335
	190	0.372	0.363	0.353	0.354	0.324	0.314

Table C3 Tapped bulk density of Product-II

	Inlet air temperature (°C)	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**
Tapped bulk density (g/ml)	180	0.577	0.551	0.490	0.470	0.451	0.421
	185	0.567	0.539	0.480	0.464	0.451	0.419
	190	0.561	0.504	0.478	0.460	0.450	0.416

Table C4 Loose bulk density of Product-II

	Inlet air temperature (°C)	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**
Loose bulk density (g/ml)	180	0.474	0.432	0.413	0.453	0.421	0.420
	185	0.384	0.375	0.364	0.359	0.342	0.341
	190	0.338	0.332	0.327	0.326	0.322	0.316

Table C5 Total soluble solid of Product-II

	Inlet air temperature (°B)	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**

TSS	180	14.000	17.000	19.500	21.000	22.000	23.000
	185	16.150	18.200	20.000	22.000	22.000	24.000
	190	17.300	19.000	20.000	22.000	23.000	23.500

Table C6 Solubility of Product-II

	Inlet air temperature (°C)	T1	T2	T3	T4	T5	T6
Solubility (%)	180	99.200	98.910	98.690	98.910	97.840	97.770
	185	99.020	98.907	98.739	98.670	97.760	97.720
	190	98.900	98.250	98.200	97.980	97.540	97.480

Table C7 Wettability of Product-II

	Inlet air temperature (°C)	T1	T2	T3	T4	T5	T6
Wettability (s)	180	481.783	492.600	502.367	508.667	535.833	563.300
	185	481.897	492.767	503.350	515.833	539.967	564.027
	190	489.060	497.050	505.167	530.100	554.967	563.867

Table C8 Water solubility index of Product-II

	Inlet air temperature (°C)	T1	T2	T3	T4	T5	T6
Water solubility index (%)	180	32.810	43.833	46.007	49.640	52.467	54.853
	185	34.267	44.500	47.047	51.427	53.403	55.466
	190	42.427	45.037	48.377	51.933	53.910	60.467

Table C9 Water absorption index of Product-II

	Inlet air temperature (°C)	T1	T2	T3	T4	T5	T6
Water absorption index (%)	180	97.500	98.500	99.800	94.620	95.600	96.400
	185	98.300	99.390	100.000	94.800	96.210	96.550
	190	98.300	99.500	102.000	95.340	96.300	97.120

APPENDIX D

STORAGE STUDY OF SPRAY DRIED BANANA PSEUDO STEM JUICE-HORSE GRAM EXTRACT BLEND POWDER (Product-II)

Table D1 Changes in moisture content of Product-II during storage

Treatments	Moisture content (% w.b.)			
	Storage periods (months)			
	0	2	4	6
T6 (180°C)	4.210	4.240	4.244	4.311
T6 (185°C)	4.110	4.209	4.220	4.319
T6 (190°C)	3.930	4.000	4.110	4.122

Table D2 Changes in water activity of Product-II during storage

Treatments	Moisture content (%)			
	Storage periods (months)			
	0	**2**	**4**	**6**
T6 (180°C)	0.352	0.352	0.353	0.355
T6 (185°C)	0.335	0.342	0.348	0.354
T6 (190°C)	0.314	0.319	0.322	0.324

Table D3 Changes in tapped bulk density of Product-II during storage

Treatments	Tapped bulk density (g/ml)			
	Storage periods (months)			
	0	**2**	**4**	**6**
T6 (180°C)	0.421	0.422	0.435	0.438
T6 (185°C)	0.419	0.421	0.425	0.436
T6 (190°C)	0.416	0.419	0.422	0.425

Table D4 Changes in loose bulk density of Product-II during storage

Treatments	Loose bulk density (g/ml)			
	Storage periods (months)			
	0	**2**	**4**	**6**
T6 (180°C)	0.420	0.422	0.424	0.429
T6 (185°C)	0.341	0.342	0.356	0.409
T6 (190°C)	0.316	0.317	0.335	0.347

APPENDIX E

QUALITY PARAMETERS OF MILK FORTIFIED BANANA PSEUDOSTEM JUICE POWDER (Product-III)

Table E1 Mosture content of Product-III

	Inlet air temperature (°C)	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
Moisture content (%)	185	4.500	4.480	4.363	4.481	4.463	4.222	4.475	4.320	4.183	4.450	4.300	3.960
	190	4.473	4.476	4.357	4.472	4.400	4.180	4.460	4.313	4.150	4.400	3.870	3.720
	200	4.473	4.452	4.440	4.455	4.000	3.880	4.400	4.110	3.880	3.750	3.711	3.643

Table E2 Water activity of Product-III

	Inlet air temperature (°C)	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
Water activity	185	0.376	0.360	0.287	0.354	0.344	0.275	0.345	0.340	0.267	0.332	0.312	0.263
	190	0.342	0.333	0.268	0.334	0.326	0.254	0.326	0.323	0.231	0.324	0.309	0.223
	200	0.309	0.284	0.264	0.299	0.276	0.254	0.287	0.260	0.243	0.280	0.257	0.221

Table E3 Tapped bulk density of Product-III

	Inlet air temperature (°C)	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
Tapped bulk density (g/ml)	185	0.426	0.467	0.512	0.427	0.471	0.522	0.432	0.475	0.532	0.432	0.476	0.543
	190	0.409	0.456	0.505	0.411	0.457	0.506	0.412	0.462	0.511	0.417	0.467	0.512
	200	0.387	0.436	0.477	0.395	0.457	0.486	0.399	0.439	0.489	0.404	0.444	0.501

Table E4 Loose bulk density of Product-III

	Inlet air temperature (°C)	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
Loose bulk density (g/ml)	185	0.345	0.467	0.512	0.357	0.399	0.428	0.365	0.403	0.426	0.365	0.406	0.431
	190	0.331	0.456	0.505	0.332	0.396	0.425	0.342	0.398	0.423	0.344	0.403	0.427
	200	0.309	0.457	0.477	0.321	0.369	0.412	0.325	0.385	0.415	0.331	0.385	0.421

Table E5 L^* values of Product-III

	Inlet air temperature (°C)	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
	185	85.460	87.540	88.600	86.460	87.890	88.980	86.850	88.010	89.990	87.430	88.240	90.030
L* values	190	84.540	85.460	84.990	84.650	85.870	85.870	84.760	85.680	86.560	85.440	86.900	88.000
	200	67.000	77.800	80.350	74.000	85.870	81.200	76.000	80.430	81.200	77.100	81.070	81.490

Table E6 b^* values of Product-III

	Inlet air temperature (°C)	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
	185	19.440	19.370	18.280	19.430	18.300	18.190	17.960	16.320	17.140	16.400	15.780	15.190
b* values	190	20.510	20.370	20.100	20.500	20.350	18.910	18.490	17.330	18.220	18.450	17.220	18.820
	200	24.710	21.550	20.480	21.650	20.540	19.450	21.640	19.530	19.440	20.620	19.440	18.820

Table E7 a^* values of Product-III

	Inlet air temperature (°C)	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
	185	7.510	7.220	7.090	7.300	7.200	6.160	6.830	7.010	5.240	5.430	5.170	4.940
a* values	190	7.540	7.260	7.090	6.860	7.140	7.130	6.470	6.950	5.710	6.350	6.300	5.500
	200	10.630	9.650	8.840	9.980	7.140	8.440	9.760	8.610	8.150	8.960	8.550	8.150

Table E8 Total soluble solids (TSS) in Product-III

	Inlet air temperature (°C)	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
	185	15.000	15.400	16.000	15.500	16.300	17.700	16.300	17.500	18.000	16.870	18.400	19.000
TSS (°B)	190	15.300	15.400	16.000	15.500	16.300	17.700	16.500	17.500	18.000	16.860	18.400	19.300
	200	15.000	15.400	16.400	15.500	16.300	17.700	16.400	18.000	18.000	16.860	18.300	19.300

Table E9 Solubility of Product-III

	Inlet air temperature	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12

	(°C)												
Solubility (%)	185	93.000	85.860	82.730	93.000	85.740	82.720	90.120	85.700	82.300	90.010	85.000	82.060
	190	89.500	78.940	74.961	89.000	78.510	74.670	88.770	78.010	72.610	88.520	75.750	70.000
	200	53.000	44.00	49.400	53.000	44.000	47.540	51.200	45.000	44.560	47.000	45.600	43.800

Table E10 Wettability of Product-III

	Inlet air temperature (°C)	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
Wettability (s)	185	348	388	400	457	460	512	466	466	558	475	501	603
	190	344	400	675	457	462	677	463	462	703	470	603	741
	200	995	1200	1260	1001	1223	1260	1001	1242	1278	1012	1246	1290

APPENDIX F

STORAGE STUDY OF MILK FORTIFIED BANANA PSEUDOSTEM JUICE POWDER (Product-III)

Table F1 Changes in moisture content of Product-III during storage

Treatments	Moisture content (%)			
	Storage periods (months)			
	0	**1**	**2**	**3**
T12 (185°C)	3.960	3.960	3.967	4.127
T12 (190°C)	3.720	3.827	3.847	3.977
T12 (200°C)	3.643	3.643	3.723	3.747

Table F2 Changes in water activity of Product-III during storage

Treatments	Water activity			
	Storage periods (months)			
	0	**1**	**2**	**3**
T12 (185°C)	0.263	0.263	0.267	0.309
T12 (190°C)	0.223	0.226	0.252	0.271
T12 (200°C)	0.221	0.223	0.235	0.253

Table F3 Changes in tapped bulk density of Product-III during storage

Treatments	Tapped bulk density (g/ml)			
	Storage periods (months)			
	0	**1**	**2**	**3**
T12 (185°C)	0.543	0.543	0.546	0.553
T12 (190°C)	0.512	0.515	0.517	0.523
T12 (200°C)	0.501	0.512	0.514	0.518

Table F4 Changes in loose bulk density of Product-III during storage

Treatments	Loose bulk density (g/ml)			
	Storage periods (months)			
	0	**1**	**2**	**3**
T12 (185°C)	0.431	0.433	0.436	0.450
T12 (190°C)	0.427	0.432	0.435	0.443
T12 (200°C)	0.421	0.423	0.424	0.430

Table F5 Changes in Solubility of Product-III during storage

Treatments	Solubility (%)			
	Storage periods (months)			
	0	**1**	**2**	**3**
T12 (185°C)	82.060	82.060	82.000	81.758
T12 (190°C)	70.000	70.000	69.463	68.417
T12 (200°C)	43.800	43.806	43.577	43.466

Table F6 Changes in wettability of Product-III during storage

Treatments	Wettability (s)			
	Storage periods (months)			
	0	**1**	**2**	**3**
T12 (185°C)	603.000	603.000	603.100	603.151
T12 (190°C)	741.000	741.000	741.053	741.110
T12 (200°C)	1290.000	1290.000	1300.000	1300.000

APPENDIX G

MICROBIAL ANALYSIS OF SPRAY DRIED PSEUDOSTEM JUICE POWDERS

Table G1 Microbial load of Product-I

Treatments	Microbial load (cfu/g)		
	10^1	10^2	10^4
T6 (180°C)	0	0	0
T6 (185°C)	0	0	0
T6 (190°C)	0	0	0

Table G2 Microbial load of Product-II

Treatments	Microbial load (cfu/g)		
	10^1	10^2	10^4
T6 (180°C)	0	0	0
T6 (185°C)	0	0	0
T6 (190°C)	0	0	0

Table G3 Microbial load of Product-III

Treatments	Microbial load (cfu/g)		
	10^1	10^2	10^4
T12 (185°C)	0	0	0
T12 (190°C)	0	0	0
T12 (200°C)	0	0	0

Table G4 Microbial load of Product-I during storage

Treatments	Microbial load (cfu/g)	Storage periods (months)			
		0	2	4	6
T6 (180°C)	10^1	0	0	0	1
T6 (185°C)		0	0	0	0
T6 (190°C)		0	0	0	0
T6 (180°C)	10^2	0	0	0	0
T6 (185°C)		0	0	0	0
T6 (190°C)		0	0	0	0
T6 (180°C)	10^4	0	0	0	0
T6 (185°C)		0	0	0	0
T6 (190°C)		0	0	0	0

Table G5 Microbial load of Product-II during storage

Treatments	Microbial load (cfu/g)	Storage periods (months)

		0	2	4	6
T6 (180°C)		0	0	2	2
T6 (185°C)	10^1	0	0	0	3
T6 (190°C)		0	0	0	2
T6 (180°C)		0	0	2	1
T6 (185°C)	10^2	0	0	0	2
T6 (190°C)		0	0	0	1
T6 (180°C)		0	0	1	0
T6 (185°C)	10^4	0	0	0	0
T6 (190°C)		0	0	0	0

Table G6 Microbial load of Product-III during storage

Treatments	**Microbial load (cfu/g)**	**Storage periods (months)**			
		0	**1**	**2**	**3**
T12 (185°C)		0	0	0	3
T12 (190°C)	10^1	0	0	0	2
T12 (200°C)		0	0	0	0
T12 (185°C)		0	0	0	1
T12 (190°C)	10^2	0	0	0	1
T12 (200°C)		0	0	0	0
T12 (185°C)		0	0	0	0
T12 (190°C)	10^4	0	0	0	0
T12 (200°C)		0	0	0	0

APPENDIX H

SENSORY EVALUATION OF BANANA PSEUDOSTEM BASED POWDERS

SENSORY SCORE CARD FOR PSEUDOSTEM BASED POWDERS

Date:

Name of judge:

You are requested to assess the product in terms of general acceptability on a 9 point hedonic scale

Score system:

Like extremely 9
Like very much 8
Like moderately 7
Like slightly 6
Neither like nor dislike 5
Dislike slightly 4
Dislike moderately 3
Dislike very much 2
Dislike extremely 1

Characteristics	Sample code					
	A	B	C	D	E	F
Colour & appearance						
Flavor						
Taste						
Overall acceptability						

Comments if any: Signature

APPENDIX I

ANOVA FOR SPRAY DRIED BANANA PSEUDOSTEM JUICE POWDER (Product-I)

Factor –A: Inlet air temperature (°C)

Factor –B: Maltodextrin concentration (%)

Factor –C: Sugar concentration (%)

Table I1 Moisture content (% w.b.)

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	8.03	5	1.61	42.35	<0.0001	0.19	5.57
Factor –A	0.40	2	0.20	5.22	0.0089		
Factor –B	6.51	2	3.26	85.88	<0.0001		
Factor –C	1.12	1	1.12	29.58	<0.0001		
Pure error	0.83	36	0.023				
Cor total	9.85	53			Significant		

Table I2 Water activity

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	0.077	5	0.015	5.12	0.0008	0.055	15.73
Factor –A	3.299E-003	2	1.649E-003	0.55	0.5808		
Factor –B	0.064	2	0.024	50.63	0.0002		
Factor –C	9.699E-003	1	9.439E-003	3.23	0.0785		
Pure error	0.14	36	2.585E-003				
Cor total	0.22	53			Significant		

Table I3 Tapped bulk density (g/ml)

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	0.056	5	0.011	3.65	0.0071	0.05	12.29

						6	
Factor –A	2.903E-003	2	1.451E-003	0.47	0.0282		
Factor –B	0.051	2	0.026	8.32	0.0008		
Factor –C	2.022E-003	1	2.022E-003	0.65	0.4227		
Pure error	0.15	36	4.090E-003				
Cor total	0.20	53			Significant		

Table I4 Loose bulk density (g/ml)

Source	Sum of squares	df	Mean square	F value	p-value Prob > F	Std. Dev.	C.V. (%)
Model	0.059	5	0.012	5.48	0.0005	0.047	19.98
Factor –A	1.42E-003	2	7.146E-004	0.33	0.7203		
Factor –B	0.048	2	0.024	11.18	0.0001		
Factor –C	9.439E-003	2	9.439E-003	4.36	0.0420		
Pure error	0.093	36	2.585E-003				
Cor total	0.16	53			Significant		

Table I5 L^* value

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	1321.55	5	264.31	57.37	<0.0001	2.15	2.53
Factor –A	27.87	2	13.94	3.02	0.0579		

Factor –B	17.60	2	587.17	127.44	<0.0001		
Factor –C	119.35	1	119.35	25.90	<0.0001		
Pure error	186.62	36	5.18				
Cor total	1542.71	53			Significant		

Table I6 a^* value

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	113.33	5	22.67	10.65	<0.0001	1.46	115.38
Factor –A	7.89	2	3.94	1.85	0.1678		
Factor –B	75.84	2	37.92	17.82	<0.0001		
Factor –C	29.60	1	29.60	13.91	0.0005		
Pure error	8.82	36	0.24				
Cor total	215.50	53			Significant		

Table I7 b^* value

Source	**Sum of squares**	**df**	**Mean square**	**F value**	**p-value Prob > F**	**Std. Dev.**	**C.V. (%)**
Model	38.95	5	7.79	5.96	<0.0001	1.14	19.50

Factor –A	21.34	2	10.67	8.16	0.1678
Factor –B	17.60	2	8.80	6.74	<0.0001
Factor –C	8.817E-003	1	8.8E-003	6.748E-003	0.0005
Pure error	22.41	36	0.62		
Cor total	101.67	53			Significant

Table I8 Solubility (%)

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	372.84	5	74.57	12.78	<0.0001	2.42	2.98
Factor –A	18.35	2	9.17	1.57	0.2181		
Factor –B	350.56	2	175.28	30.03	<0.0001		
Factor –C	3.93	1	3.93	0.67	0.4159		
Pure error	152.43	36	4.23				
Cor total	652.96	53			Significant		

Table I9 Wettability (s)

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	182.89	5	36.56	13.79	<0.0001	1.63	2.10
Factor –A	15.60	2	7.80	2.94	0.625		
Factor –B	149.06	2	74.53	28.09	<0.0001		
Factor –C	18.24	1	18.24	6.87	0.0117		
Pure error	112.18	36	3.12				
Cor total	310.22	53			Significant		

Table I10 Product yield (%)

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	3579.95	5	715.99	70.85	<0.0001	3.18	8.18
Factor –A	49.45	2	24.72	2.45	0.0973		
Factor –B	2790.04	2	1395.02	138.04	<0.0001		
Factor –C	740.46	1	740.46	73.27	<0.0001		
Pure error	35.59	36	0.99				
Cor total	4065.03	53			Significant		

APPENDIX J

ANOVA FOR SPRAY DRIED BANANA PSEUDOSTEM JUICE POWDER DURING STORAGE (Product-I)

Factor –A: Storage period (months)

Factor –B: Treatment temperature (°C)

Table J1 Moisture content of product during storage

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	0.32	5	0.063	5.71	0.0008	0.11	3.25
Factor –A	0.17	3	0.056	5.02	0.0061		
Factor –B	0.15	2	0.075	6.74	0.0038		
Pure error	0.31	24	0.013				
Cor total	0.65	35			Significant		

Table J2 Water activity of product during storage

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	9.369E-003	5	1.874E-003	15.41	<0.0001	0.11	3.46
Factor –A	6.020E-003	3	2.007E-003	16.51	<0.0001		
Factor –B	3.349E-003	2	1.675E-003	13.78	<0.0001		
Pure error	3.276E-003	24	1.365E-004				
Cor total	0.013	35			Significant		

Table J3 Tapped bulk density of product during storage

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	3.521E-003	5	7.042E-004	10.08	<0.0001	8.358E-003	1.95
Factor –A	6.371E-003	3	2.124E-004	3.04	0.0442		
Factor –B	2.884E-003	2	1.442E-004	20.64	<0.0001		
Pure error	2.030E-003	24	8.459E-005				
Cor total	5.616E-003	35				Significant	

Table J4 Loose bulk density of product during storage

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	0.013	5	2.647E-003	6.87	0.0002	0.020	6.56
Factor –A	9.237E-003	3	3.079E-003	7.99	0.0005		
Factor –B	3.998E-003	2	1.999E-003	5.19	0.0116		
Pure error	4.932E-003	24	2.055E-004				
Cor total	0.025	35				Significant	

Table J5 L* value of product during storage

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	1.68	5	0.34	1.99	0.1090	0.41	0.45
Factor –A	0.017	3	5.641E-003	0.033	0.9916		
Factor –B	1.66	2	0.83	4.92	0.0142		
Pure error	5.06	24	1.077E-003				
Cor total	6.74	35			Not significant		

Table J6 a* value of product during storage

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	1.605E-003	5	3.210E-004	17.98	<0.0001	4.226E-003	1.36
Factor –A	1.313E-004	3	4.375E-005	2.45	0.0828		
Factor –B	1.474E-003	2	7.370E-004	41.27	<0.0001		
Pure error	3.720E-004	24	1.550E-005				
Cor total	2.141E-003	35			Significant		

Table J7 b* value of product during storage

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	0.029	5	5.779E-003	11.52	<0.0001	0.022	0.42
Factor –A	1.032E-004	3	3.439E-005	0.069	0.9762		
Factor –B	0.029	2	0.014	28.70	<0.0001		
Pure error	5.060.015	24	6.120E-004				
Cor total	0.044	35			Significant		

Table J8 Solubility of product during storage

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	902.32	5	180.46	1.32	0.2842	11.71	15.76
Factor –A	644.94	3	214.98	1.57	0.2179		
Factor –B	257.39	2	128.69	0.94	0.4026		
Pure error	3287.74	24	136.99				
Cor total	5018.69	35			Not significant		

Table J9 Wettability of product during storage

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	14.84	5	2.97	66.10	<0.0001	0.21	0.26
Factor –A	12.98	3	4.33	96.38	<0.0001		
Factor –B	1.86	2	0.93	20.68	<0.0001		
Pure error	0.38	24	0.016				
Cor total	16.19	35			Not significant		

APPENDIX K

ANOVA FOR SPRAY DRIED BANANA PSEUDOSTEM JUICE-HORSE GRAM EXTRACT BLEND POWDER (Product-II)

Factor –A: Inlet air temperature (°C)

Factor –B: Maltodextrin (%)

Factor –C: Horse gram extract (%)

Table K1 Moisture content (% w.b)

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	1.13	3	0.38	5.56	0.0023	0.26	6.18
Factor –A	0.52	1	0.52	7.60	0.0081		
Factor –B	0.50	1	0.50	7.37	0.0091		
Factor –C	0.12	1	0.12	1.72	0.1963		
Pure error	2.17	36	0.060				
Cor total	4.53	53			Significant		

Table K2 Water activity

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	0.035	6	5.857E-003	197.43	<0.0001	5.447E-003	1.49
Factor –A	0.012	1	0.012	391.96	<0.0001		
Factor –B	0.015	1	0.015	502.26	<0.0001		
Factor –C	8.070E-003	1	8.070E-003	272.03	<0.0001		
AB	1.469E-005	1	1.469E-005	0.50	0.4850		
AC	8.167E-006	1	8.167E-006	0.28	0.6023		
BC	5.214E-004	1	5.214E-004	17.57	0.0001		
Pure error	2.860E-004	36	7.944E-006				
Cor total	0.037	53			Significant		

Table K3 Tapped bulk density (g/ml)

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	0.14	6	0.023	477.04	<0.0001	6.918E-003	1.42
Factor –A	1.845E-003	1	1.845E-003	38.54	<0.0001		
Factor –B	0.092	1	0.092	1920.74	<0.0001		
Factor –C	0.039	1	0.039	806.79	<0.0001		
AB	9.724E-004	1	9.724E-004	20.32	<0.0001		
AC	7.315E-005	1	7.315E-005	1.53	0.2225		
BC	3.556E-003	1	3.556E-003	74.30	<0.0001		
Pure error	1.448E-004	36	4.021E-006				
Cor total	0.14	53			Significant		

Table K4 Loose bulk density (g/ml)

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	0.14	6	0.023	54.52	< 0.0001	0.020	5.40
Factor-A	0.13	1	0.13	311.12	< 0.0001		
Factor-B	4.178E-003	1	4.178E-003	10.08	0.0026		
Factor-C	9.818E-004	1	9.818E-004	2.37	0.1306		
AB	1.190E-003	1	1.190E-003	2.87	0.0968		
AC	9.375E-006	1	9.375E-006	0.023	0.8811		
BC	2.668E-004	1	2.668E-004	0.64	0.4265		
Pure Error	2.349E-003	36	6.526E-005				
Cor Total	0.16	53			significant		

Table K5 L* value of Product-II

Source	Sum of squares	df	Mean square	F value	p-value Prob > F	Std. Dev.	C.V. (%)
Model	112.58	6	18.76	0.96	0.4606	4.41	5.01
Factor-A	0.55	1	0.55	0.028	0.8671		
Factor-B	11.36	1	11.36	0.58	0.4491		
C	14.03	1	14.03	0.72	0.4004		
AB	0.71	1	0.71	0.037	0.8492		
AC	67.18	1	67.18	3.45	0.0696		
BC	18.74	1	18.74	0.96	0.3317		
Pure Error	656.62	36	18.24				
Cor Total	1028.46	53			Not significant		

Table K6 a* values

Source	Sum of squares	df	Mean square	F value	p-value Prob > F	Std. Dev.	C.V. (%)
Model	2.61	6	0.44	1.54	0.1876	0.53	71.38
Factor-A	0.089	1	0.089	0.32	0.5772		
Factor-B	0.33	1	0.33	1.17	0.2854		
Factor-C	0.10	1	0.10	0.35	0.5544		
AB	0.078	1	0.078	0.28	0.6020		
AC	1.93	1	1.93	6.80	0.0122		
BC	0.085	1	0.085	0.30	0.5871		
Pure Error	9.88	36	0.27				
Cor Total	15.93	53			Not significant		

Table K7 b* value

Source	Sum of squares	df	Mean square	F value	p-value Prob > F	Std. Dev.	C.V. (%)
Model	25.00	6	4.17	0.78	0.5911	2.31	34.11
Factor-A	7.51	1	7.51	1.40	0.2423		
Factor-B	4.72	1	4.72	0.88	0.3524		
Factor-C	1.18	1	1.18	0.22	0.6403		
AB	6.32	1	6.32	1.18	0.2829		
AC	0.015	1	0.015	2.709E-003	0.9587		
BC	5.25	1	5.25	0.98	0.3270		
Pure Error	186.02	36	5.17				
Cor Total	276.61	53			Not significant		

Table K8 Solubility

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	14.79	6	2.47	51.43	<0.0001	0.22	0.22
Factor-A	2.03	1	2.03	42.38	<0.0001		
Factor-B	8.10	1	8.10	168.9 2	<0.0001		
Factor-C	4.29	1	4.29	89.46	<0.0001		
AB	9.404E-004	1	9.404E-004	0.020	0.8892		
AC	0.10	1	0.10	2.10	0.1538		
BC	0.27	1	0.27	5.71	0.0209		
Pure Error	0.49	36	0.014				
Cor Total	17.05	53			Significant		

Table K9 Wettability

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	42930.46	6	7155.08	877.52	<0.0001	2.86	0.55
Factor-A	792.68	1	792.68	97.22	<0.0001		
Factor-B	30634.57	1	30634.57	3757.13	<0.0001		
Factor-C	9532.45	1	9532.45	1169.09	<0.0001		
AB	165.02	1	165.02	20.24	<0.0001		
AC	238.10	1	238.10	20.20	<0.0001		
BC	1567.65	1	1567.65	192.26	<0.0001		
Pure Error	22.93	36	0,64				
Cor Total	43313.69	53			Significant		

Table K10 Product yield

Source	Sum of squares	df	Mean square	F value	p-value Prob > F	Std. Dev.	C.V. (%)
Model	528.98	6	88.16	1.08	0.3861	9.02	15.04
Factor-A	17.57	1	17.57	0.22	0.6444		
Factor-B	31.93	1	31.93	0.39	0.5341		
Factor-C	109.13	1	109.13	1.34	0.2527		
AB	102.56	1	102.56	1.26	0.2673		
AC	254.31	1	254.31	3.13	0.0836		
BC	13.47	1	13.47	0.17	0.6860		
Pure Error	2981.66	36	82.82	0.93			
Cor Total	4353.78	53			Not ignificant		

APPENDIX L

ANOVA FOR SPRAY DRIED BANANA PSEUDOSTEM JUICE-HORSE GRAM EXTRACT BLEND POWDER DURING STORAGE (Product-II)

Factor –A: Storage period (months)

Factor –B: Treatment temperature (°C)

Table L1 Moisture content of product during storage

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	0.43	5	0.087	15.61	<0.0001	0.075	1.79
Factor –A	0.13	3	0.044	7.95	0.0005		
Factor –B	0.30	2	0.15	27.10	<0.0001		
Pure error	0.15	24	6.066E-003				
Cor total		35			Significant		

Table L2 Water activity of product during storage

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	7.747E-003	5	1.549E-003	19.99	< 0.0001	8.803E-003	2.59
Factor –A	5.821E-004	3	1.940E-004	2.50	0.0782		
Factor –B	7.165E-003	2	3.583E-003	46.23	< 0.0001		
Pure error	2.107E-003	24	8.778E-005				
Cor total	0.010	35			Significant		

Table L3 Tapped bulk density of product during storage

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	0.064	5	0.013	28.74	< 0.0001	0.021	5.67
Factor –A	7.390E-003	3	2.463E-003	5.56	0.0037		
Factor –B	0.056	2	0.028	63.52	< 0.0001		
Pure error	9.254E-003	24	4.434E-004				
Cor total	0.077	35	3.856E-004		Significant		

Table L4 Loose bulk density of product during storage

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	0.064	5	0.013	28.74	< 0.0001	0.021	5.67
Factor –A	7.390E-003	3	2.463E-003	5.56	0.0037		
Factor –B	0.056	2	0.028	63.52	< 0.0001		
Pure error	9.254E-003	24	3.856E-004				
Cor total	0.077	35			Significant		

Table L5 L* value of product during storage

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	6.10	5	1.22	5.93	0.0006	0.45	0.48
Factor –A	0.28	3	0.094	0.46	0.7130		
Factor –B	5.82	2	2.91	14.14	< 0.0001		
Pure error	5.02	24	0.21				
Cor total	12.27	35			Significant		

Table L6 a* value of product during storage

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	0.017	5	3.364E-003	1823.74	< 0.0001	1.358E-003	0.35
Factor –A	1.342E-005	3	4.472E-006	2.42	0.0851		
Factor –B	0.017	2	8.403E-003	4555.72	< 0.0001		
Pure error	3.800E-005	24	1.583E-006				
Cor total	0.017	35			Significant		

Table L7 b* value of product during storage

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	11.63	5	2.33	74.30	< 0.0001	0.18	2.89
Factor –A	0.36	3	0.12	3.87	0.0189		
Factor –B	11.26	2	5.63	179.95	< 0.0001		
Pure error	0.78	24	0.033				
Cor total	12.57	35			Significant		

Table L8 Solubility of product during storage

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	0.86	5	0.17	23.47	< 0.0001	0.085	0.087
Factor –A	0.18	3	0.061	8.34	0.0003		
Factor –B	0.67	2	0.34	46.17	< 0.0001		
Pure error	0.16	24	6.502E-003				
Cor total	1.07	35			Significant		

Table L9 Wettability of product during storage

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	3.57	5	0.71	12.61	< 0.0001	0.24	0.042
Factor –A	3.52	3	1.17	20.72	< 0.0001		
Factor –B	0.051	2	0.025	0.45	0.6438		
Pure error	0.48	24	0.057				
Cor total	5.26	35	0.020		Significant		

APPENDIX M

ANOVA FOR MILK FORTIFIED BANANA PSEUDOSTEM JUICE POWDER DURING STORAGE (Product-III)

Factor –A: Storage period (months)

Factor –B: Milk (%)

Factor –C: Horse gram extract (%)

Table M1 Moisture content

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	24.96	9	2.77	96.87	< 0.0001	0.17	6.00
Factor –A	0.74	1	0.74	25.81	< 0.0001		
Factor –B	2.00	1	2.00	69.97	< 0.0001		
Factor –C	20.33	1	20.33	710.24	< 0.0001		
AB	0.035	1	0.035	1.22	0.2727		
AC	0.043	1	0.043	1.48	0.2259		
BC	0.67	1	0.67	23.48	< 0.0001		
A^2	5.316E-003	1	5.316E-003	0.19	0.6675		
B^2	0.43	1	0.43	15.08	0.0002		
C^2	0.29	1	0.29	10.25	0.0018		
Pure error	0.64	72	8.851E-003				
Cor total	27.76	107			Significant		

Table M2 Water activity

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	0.18	9	0.020	121.15	< 0.0001	0.013	4.51
Factor –A	5.580E-004	1	5.580E-004	3.34	0.0709		
Factor –B	6.685E-003	1	6.685E-003	39.96	< 0.0001		
Factor –C	0.16	1	0.16	971.58	< 0.0001		
AB	2.318E-004	1	2.318E-004	1.39	0.2420		
AC	8.143E-005	1	8.143E-005	0.49	0.4870		
BC	2.716E-003	1	2.716E-003	16.24	0.0001		
A^2	8.792E-005	1	8.792E-005	0.53	0.4702		
B^2	3.359E-005	1	3.359E-005	0.20	0.6551		
C^2	7.782E-003	1	7.782E-003	46.52	< 0.0001		
Pure error	6.900E-003	72	1.673E-004				
Cor total	0.20	107	9.583E-005		Significant		

Table M3 Tapped bulk density (g/ml)

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	0.19	9	0.021	27.54	< 0.0001	0.028	5.80
Factor –A	5.827E-004	1	5.827E-004	0.75	0.3872		
Factor –B	0.014	1	0.014	17.88	< 0.0001		
Factor –C	0.15	1	0.15	195.41	< 0.0001		
AB	1.763E-004	1	1.763E-004	0.23	0.6339		
AC	8.976E-004	1	8.976E-004	1.16	0.2836		
BC	2.237E-003	1	2.237E-003	2.90	0.0919		
A^2	1.239E-004	1	1.239E-004	0.16	0.6896		
B^2	0.017	1	0.017	21.92	< 0.0001		
C^2	3.082E-004	1	3.082E-004	0.40	0.5291		
Pure error	7.328E-003	72	1.018E-004				
Cor total	0.27	107			Significant		

Table M4 Loose bulk density (g/ml)

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	0.013	9	1.483E-003	6.65	< 0.0001	0.015	4.37
Factor –A	4.004E-006	1	4.004E-006	0.018	0.8937		
Factor –B	2.142E-003	1	2.142E-003	9.61	0.0025		
Factor –C	5.273E-005	1	5.273E-005	0.24	0.6279		
AB	3.577E-006	1	3.577E-006	0.016	0.8995		
AC	4.353E-004	1	4.353E-004	1.95	0.1656		
BC	2.777E-005	1	2.777E-005	0.12	0.725		
A^2	3.934E-004	1	3.934E-004	1.76	0.1872		
B^2	3.875E-003	1	3.875E-003	17.37	< 0.0001		
C^2	5.099E-003	1	5.099E-003	22.86	< 0.0001		
Pure error	7.187E-003	72	9.982E-005				
Cor total	0.035	107			Significant		

Table M5 L* value

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	1623.47	9	180.48	144.29	< 0.0001	1.12	1.33
Factor –A	145.18	1	143.09	114.40	< 0.0001		
Factor –B	101.99	1	101.22	80.92	< 0.0001		
Factor –C	1247.14	1	1247.14	997.02	< 0.0001		
AB	0.036	1	1247.14	0.029	0.8648		
AC	37.89	1	37.89	30.29	< 0.0001		
BC	23.99	1	23.99	19.18	< 0.0001		
A^2	0.43	1	0.43	0.35	0.5568		
B^2	0.46	1	0.46	0.36	0.5478		
C^2	6.588E-003	1	6.588E-003	5.267E-003	0.9423		
Pure error	33.49	72	0.47				
Cor total	1746.95	107			Significant		

Table M6 a* value

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	3.76	9	0.42	4.20	0.0001	0.32	12.67
Factor –A	0.095	1	0.095	0.96	0.3295		
Factor –B	0.34	1	0.34	3.40	0.0682		
Factor –C	0.69	1	0.69	6.93	0.0098		
AB	0.42	1	0.42	4.27	0.0413		
AC	0.96	1	0.96	9.70	0.0024		
BC	0.28	1	0.28	2.85	0.0947		
A^2	0.21	1	0.21	2.10	0.1500		
B^2	0.029	1	0.029	0.29	0.5889		
C^2	0.026	1	0.026	0.27	0.6069		
Pure error	7.17	72	0.100				
Cor total	13.48	107			Significant		

Table M7 b* value

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	74.03	9	8.23	12.10	< 0.0001	0.82	7.66
Factor –A	56.12	1	56.12	82.58	< 0.0001		
Factor –B	0.20	1	0.20	0.29	0.5918		
Factor –C	0.86	1	0.86	1.27	0.2632		
AB	1.49	1	1.49	2.19	0.1417		
AC	3.90	1	3.90	5.73	0.0185		
BC	2.30	1	2.30	3.38	0.0690		
A^2	2.58	1	2.58	3.79	0.0544		
B^2	2.11	1	2.11	3.10	0.0813		
C^2	1.92	1	1.92	2.83	0.0958		
Pure error	36.99	72	0.51				
Cor total	140.63	107			Significant		

Table M8 Solubility

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	574.03	9	63.78	59.91	< 0.0001	1.03	1.08
Factor –A	30.97	1	30.97	29.09	< 0.0001		
Factor –B	62.28	1	62.28	58.49	< 0.0001		
Factor –C	448.01	1	448.01	420.80	< 0.0001		
AB	0.062	1	0.062	0.058	0.8102		
AC	0.37	1	0.37	0.35	0.5580		
BC	54.50	1	54.50	51.19	< 0.0001		
A^2	0.26	1	0.26	0.24	0.6244		
B^2	3.30	1	3.30	3.10	0.0816		
C^2	2.40	1	2.40	2.25	0.1367		
Pure error	18.57	72	0.26				
Cor total	678.37	107			Significant		

Table M9 Wettability

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	4.431E+005	9	49232.48	29.97	< 0.0001	40.53	8.50
Factor –A	19.91	1	19.91	0.012	0.9126		
Factor –B	20213.76	1	20213.76	12.31	0.0007		
Factor –C	2.433E+005	1	2.433E+005	148.10	< 0.0001		
AB	460.12	1	460.12	0.28	0.5978		
AC	56578.57	1	56578.57	34.45	< 0.0001		
BC	43704.94	1	43704.94	26.61	< 0.0001		
A^2	1530.65	1	1530.65	0.93	0.3368		
B^2	4923.91	1	4923.91	3.00	0.0865		
C^2	71232.24	1	71232.24	43.37	< 0.0001		
Pure error	64615.46	72	3705.90				
Cor total	6.041E+005	107			Significant		

Table M10 Product yield

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	4312.35	9	479.15	94.98	< 0.0001	2.25	3.95
Factor –A	119.75	1	119.75	23.74	< 0.0001		
Factor –B	307.28	1	307.28	60.91	< 0.0001		
Factor –C	3592.78	1	3592.78	712.17	< 0.0001		
AB	4.41	1	4.41	0.87	0.3523		
AC	9.03	1	9.03	1.79	0.1841		
BC	104.47	1	104.47	20.71	< 0.0001		
A^2	33.58	1	33.58	6.66	0.0114		
B^2	86.15	1	86.15	17.08	< 0.0001		
C^2	121.58	1	121.58	24.10	< 0.0001		
Pure error	63.38	72	0.88				
Cor total	4806.75	107			Significant		

APPENDIX N

ANOVA FOR MILK FORTIFIED BANANA PSEUDOSTEM JUICE POWDER DURING STORAGE (Product-III)

Factor –A: Storage period (months)

Factor –B: Treatment temperature (°C)

Table N1 Moisture content of product during storage

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	0.76	5	0.15	112.60	< 0.0001	0.037	0.96
Factor –A	0.16	3	0.053	39.54	< 0.0001		
Factor –B	0.60	2	0.30	222.19	< 0.0001		
Pure error	9.719E-003	24	1.350E-003				
Cor total	0.80		4.049E-004		Significant		

Table N2 Water activity of product during storage

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	0.022	5	4.391E-003	56.28	< 0.0001	8.833E-003	3.53
Factor –A	0.010	3	3.423E-003	43.87	< 0.0001		
Factor –B	0.012	2	5.843E-003	74.89	< 0.0001		
Pure error	1.418E-003	24	5.908E-005				
Cor total					Significant		

0.024

Table N3 Tapped bulk density of product during storage

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	9.180E-003	5	1.836E-003	193.18	< 0.0001	3.083E-003	0.59
Factor –A	6.990E-004	3	2.330E-004	24.52	< 0.0001		
Factor –B	8.481E-003	2	4.240E-003	446.18	< 0.0001		
Pure error	1.573E-004	24	6.556E-006				
Cor total	9.465E-003				Significant		

Table N4 Loose bulk density of product during storage

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	2.098E-003	5	4.196E-004	44.18	< 0.0001	3.082E-003	0.71
Factor –A	1.027E-003	3	3.423E-004	36.04	< 0.0001		
Factor –B	1.071E-003	2	5.355E-004	56.38	< 0.0001		
Pure error	1.633E-004	24	6.806E-006				
Cor total	2.383E-003				Significant		

Table N5 L* value of product during storage

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	450.45	5	90.09	44.28	< 0.0001	1.43	1.65
Factor –A	2.96	3	0.99	0.49	0.6950		
Factor –B	447.49	2	223.74	109.97	< 0.0001		
Pure error	51.46	24	2.03				
Cor total	511.49		2.14		Significant		

Table N6 a* value of product during storage

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	83.04	5	16.61	397.47	< 0.0001	0.20	3.28
Factor –A	0.44	3	0.15	3.55	0.0261		
Factor –B	82.59	2	41.30	988.34	< 0.0001		
Pure error	1.04	24	0.043				
Cor total	84.29				Significant		

Table N7 b* value of product during storage

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	2013.67	5	402.73	0.77	0.5757	22.80	105.79
Factor –A	1546.90	3	515.63	0.99	0.4100		
Factor –B	466.77	2	233.38	0.45	0.6426		
Pure error	12485.53	24	520.23				
Cor total	17611.29				Not significant		

Table N8 Solubility of product during storage

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model	9163.07	5	1832.61	1536.12	< 0.0001	1.09	1.68
Factor –A	3.31	3	1.10	0.92	0.4410		
Factor –B	9159.76	2	4579.88	3838.91	< 0.0001		
Pure error	33.64	24	1.40				
Cor total	9198.86				Not significant		

Table N9 Wettability of product during storage

Source	Sum of squares	df	Mean square	F value	p- value Prob > F	Std. Dev.	C.V. (%)
Model							
	3.219E+006	5	6.438E+005	81000.43	< 0.0001	2.82	0.32
Factor –A							
	104.20	3	34.73	4.37	0.0115		
Factor –B							
	3.219E+006	2	1.609E+006	2.025E+005	< 0.0001		
Pure error			7.95				
	42.55						
		24					
Cor total					Not significant		
	3.219E+006		1.77				

APPENDIX O

COST ESTIMATION OF SPRAY DRIED BANANA PSEUDOSTEM JUICE BASED POWDERS

Fixed cost

Machinery cost		
Cost of spray dryer	=	Rs 15,00,000/-
Cost of steam blancher	=	Rs 68,681/-
Cost of slicer	=	Rs 25,000/-
Cost of juicer cum filter	=	Rs 10,000/-
Cost of electric balance	=	Rs 10,000/-
Cost of hand sealing machine	=	Rs 1500/-
Total cost of machineries	=	Rs 1,615,181/-

Building cost	=	Rs 72,00,000/-
Furniture cost	=	Rs 1,00,000/-
Water charge per annum	=	Rs 3,60,000/-
Installation charge	=	Rs 50,000/-
Assumptions		
Working hours per shift	=	8 h
No. of shifts per day	=	2
Total capacity of unit/day	=	250 kg/day
Life span of unit (L)	=	15 Years
Annual working hours (H)	=	300 days (per day 16 h)
	=	4800 h
Interest on initial cost (i)	=	11% annually
Repair and maintenance	=	2% of initial cost
Fixed cost	=	$\frac{i(i+1)^n}{(i+1)^n+1} \times C$
Where, C	=	Total cost of (machineries +building + furniture + installation)
	=	1615181+7200000+100000 +50000
	=	Rs 8965181/-
Hence, Fixed cost	=	$\frac{0.11(0.11+1)^{15}}{(0.11+1)^{15}+1} \times (8965181$
	=	Rs 814,935/-
Total fixed cost	=	Total fixed cost of (machinery + building cost + furniture + installation+ water charge)
	=	814935+360000
	=	Rs 1174935/-
Fixed cost /h	=	$\frac{1174935}{4800}$
	=	Rs 245/-

Variable cost

a) Repair and maintenance charge of (equipments + furnitures + building)	=	2% of initial cost
	=	$\frac{2}{100 \times 4800} \times 8915181$
	=	Rs 37.14/h
b) Cost of energy		
i) Energy requirement (motor and heating coil)	=	131.57 KWh/16h
ii) Energy required for steam blancher	=	30 KWh/16 h
iii) Energy required for slicer and juicer cum filter	=	11.2 KWh/16h
iv) Energy requirement for electric balance and sealer	=	7.2 KWh/16h
v) Energy requirement 2 Fan = 80 KWh 3 Lights = 120 KWh 2 Exhaust = 80 KWh	=	2.24 KWh/16h
Total energy requirement	=	i + ii + iii + iv + v
	=	182.21 KWh/16 h
Electric charges	=	Rs 7.5 /KWh
Electric consumption charges	=	Power × duration × cost for 1 unit
	=	182.21×16×7.5
	=	Rs 21865.200/h
c) Labour charges		
Three women labour @ Rs 300/shift	=	Rs. 900/-
Two men labour @ Rs 500/shift	=	Rs 1000/-
Labour charge /day	=	Rs 3800/-

d) Cost of raw material required per day

Product-I

Raw materials	Quantity (kg)	Unit rate (per kg)	Total amount (Rs)
Banana pseudostem	1000	3	3000
Maltodextrin	250	40	10000
Sugar	150	35	5250
Ginger	4	80	320
Total cost of raw materials			Rs 18570.00/-

Product-II

Raw materials	Quantity (kg)	Unit rate (per kg)	Total amount (Rs)
Banana pseudostem	820	3	2460
Maltodextrin	250	40	10000
Horse gram	150	60	9000
Ginger	4	80	320
Total cost of raw materials			Rs 21780.00 /-

Product-III

Raw materials	Quantity (kg)	Unit rate (per kg)	Total amount (Rs)
Banana pseudostem	200	3	1200
Milk	500	40	20000
Horse gram	150	60	9000
Cardamom	0.5	600	300
Total cost of raw materials			Rs 30500/-

e) Packaging cost

Total quantity required/day	=	4 kg
Unit rate	=	Rs. 150
Total amount	=	Rs 600/-

Total variable cost	=	a + b+ c + d + e
Product-I	=	Rs 44872.340/-
Product-II	=	Rs 48082.340/-
Product-III	=	Rs 56802.340/-
Total cost of production of 250 kg powder (m)	=	Total fixed cost + Total variable cost
Product-I	=	Rs 48712.340/-
Product-II	=	Rs 52002.340/-
Product-III	=	Rs 60722.34/-
Cost of production of 1 Kg of powder/year	=	$\frac{m}{250}$
Product-I	=	Rs 195/kg
Product-II	=	Rs 208/kg
Product-III	=	Rs 243/kg
Cost of 50 g packet		
Product-I	=	Rs. 9.75/-
Product-II	=	Rs 10.40/-
Product-III	=	Rs. 12.15/-
Expected selling cost		
Product-I	=	Rs 400/kg
Product-II	=	Rs 450/kg
Product-III	=	Rs 550/kg
Benefit cost ratio		
Product-I	=	$\frac{400}{195} = 2.05$

Product-II $= \frac{450}{208} = 2.16$

Product-III $= \frac{550}{243} = 2.26$

Therefore the total production cost of 1kg of micro encapsulated banana pseudostem based powders (Product-I, II and III) was estimated as Rs. 195/-, Rs 208/- and Rs 243 respectively and the benefit cost ratio of the production was found to be 2.05:1, 2.16:1 and 2.26:1 respectively.

Abstract

Banana pseudostem, often discarded after the harvest of bunch is very good for health. Its disposal in the field lead to unhygienic surroundings and environmental pollution. Juice from banana stem is a well-known remedy for urinary disorders. But the major problem associated with the pseudostem juice is its perishability and immediate browning reactions which lead to reduction of its acceptability by consumers. Considering these facts, a study was undertaken to obtain powdered products from pseudostem juice. The intention of the study was to develop a process protocol for microencapsulated banana pseudostem juice powder, standardisation of the spray drying parameters, and quality analysis of developed product. Three powder based products were developed from banana pseudostem juice by spray drying technology. Product-I comprised of pseudostem juice-sugar combination with ginger as flavourant. Product-II consists of a blend of banana pseudostem and horse gram with ginger extract. However, the third product from banana pseudostem juice was fortified with milk, horse gram extract and cardamom flavour. The process parameters were optimised as inlet temperature of 180ºC and outlet temperature of 65-68ºC for product-I & II, whereas inlet air temperature of 185°C and outlet temperature of 74-92°C were chosen for Product-III. The feed pump rpm of 15 and main blower rpm of 1800 were kept constant for developing all three products. The physicochemical characteristics, reconstitution and flow properties were determined. Standardised products were stored in aluminium pouches and quality parameters of product-I and II were analysed up to six months at an interval of two months and Product-III was stored up to three months for verifying its stability during storage. Based on quality analysis and sensory evaluation, best samples were selected from product-I, II and III *i.e.,* T6-180°C (15% sugar + 25% maltodextrin + 56% pseudostem juice), T6-180°C (25% maltodextrin + 30% horse gram extract + 43% pseudostem juice), and T12-185°C (50% milk + 30% horse gram extract + 20% pseudostem juice), respectively. Cost analysis of the products was done and cost of production of one kilo gram was estimated as Rs.195/-, Rs.208/- and Rs.243/- for product I, II and III, respectively.