DEVELOPMENT AND QUALITY EVALUATION OF SPRAY DRIED PROBIOTIC FLAVOURED YOGHURT CONTAINING

Lactobacillus bulgaricus

by

SREEKUTTY SURESH V.

(2015-18-003)

THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"Development and quality evaluation of spray dried probiotic flavoured yoghurt containing *Lactobacillus bulgaricus*"** 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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Dedicated to

My Family & 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
Cfu ml^{-1}		Colony forming units per millilitre
CRD	:	Completely randomized design
df	:	Degree of freedom
etc.	:	etcetera
Fig.	:	Figure
g	:	gram
g ml^{-1}	:	Gram per mililitres
g cm^{-3}	:	Gram per centimetre cube
g mg^{-1}	:	Gram per milligram
h	:	Hour
NaOH	:	Sodium hydroxide
NaCl	:	Sodium chloride
KCAET	:	Kelappaji College of Agricultural Engineering and Technology
kg	:	kilogram

Kg cm^{-2}	:	Kilogram per square centimetre
KPa	:	Kilo pascal
L*	:	Lightness or darkness
MD	:	Maltodextrin
MC	:	Moisture content
mg	:	milli gram
min	:	minute
Ml	:	Millilitre
MT	:	Million tonnes
No.	:	Number
nm	:	Nano meter
p	:	probability
pH	:	percentage of H+ ions
rpm	:	revolution per minute
s	:	second
S	:	Significant
SEM	:	Scanning electron microscopy
Sl.	:	Serial
SD	:	Standard deviation
viz	:	namely
w.b.	:	wet basis
w/w	:	weight by weight
w/v	:	weight by volume
μm	:	micro metre

Introduction

CHAPTER I
INTRODUCTION

Dairy products are placed a significant position in the Indian food culture from the time immemorial. Every ceremony and ritual observances are marked by dairy sweets. Milk contains significant levels of required nutrients such as protein, fat, carbohydrate, minerals and several vitamins. Hence, it has been recognized as the most perfect single food available in nature for the maintenance of growth and health of living beings. World milk production is forecast to grow by 1.6 percent to 816 MT in 2016-17 (Anone., 2016). The Food and Agriculture Organization (FAO) has reported that a 3.1 per cent increase in world milk production from 765 MT in 2015 to 789 MT in 2016. Globally, India ranks first position in milk production, accounting for 18.5 per cent of world production, achieving an annual output of 146.3 MT during 2014-15 as compared to 137.69 MT during 2013-14 recording a growth of 6.26 per cent. The estimated per capita availability of milk during 2015-16 was 337 g day^{-1}, an increase of 4.7 per cent over the previous year. This increase in milk production is indeed a boon as there is an urgent need to increase the growth rate in milk production, to meet the growing domestic market for milk and milk products and ensure that India remains self-sufficient in milk.

Milk and dairy products have been consumed since the domestication of mammals. Domesticated goats, sheep and cattle have been used for milk production since 8000 BC. Though milk is a nutrient rich and well balanced food, it is very susceptible to microbial growth results in spoilage. To prevent this, various shelf stable dairy products have been developed *viz.,* cheese, milk powder, concentrated milk, fermented milk, butter, ice cream etc. Yoghurt and similar fermented milk products in particular are thought to originate from the Middle East. The first production of fermented milk products derived from the requirement to prolong the shelf life of milk instead of being disposed. Yoghurt manufacture was in the beginning based on knowledge and empirical processes without standard procedures or investigation of the steps that occur during the entire process. Only after the late 20^{th} century, when yoghurt became a profitable commercial good, its manufacture became industrialised and the processes were standardised. During the last 20 years, interest in yoghurt manufacture has increased tremendously for scientific and commercial reasons. Scientific findings have suggested that new fermented dairy products produced by inoculating probiotic cultures and fortification with bioactive compounds promote human health with improved textural and rheological characteristics. Thus, there has been an increased consumer demand for yoghurt and similar fermented dairy products (Tamime and Robinson, 2007).

Fermented milk consumption in India is reported way back since the *Vedic* era. Eastern India has a rich tradition of consuming caramelised sweet curd, known as "*Mistidahi*" or sweetened yoghurt, because of its pleasant aroma, slightly cooked flavor, and thick consistency (Raju and Pal, 2009). Yoghurt is one of the most popular fermented milk products worldwide and has gained widespread consumer acceptance as a healthy food. Yoghurt is a product of the lactic acid fermentation of milk by addition of a starter culture containing *Streptococcus thermophilus* and *Lactobacillus delbrueckii sp. Bulgaricus* (Tamime and Robinson, 2007). Fermenting the milk with numerous beneficial microbial cultures, a broad range of healthy products with different flavour, texture and consistency are produced.

Commercial production of yoghurt has not been able to prove its supremacy in market due to its shorter shelf life. The shelf life of yoghurt is short, i.e., one day under ambient condition (25-30°C) and around 5 days at 7°C which delays its commercialisation (Kurmann *et al.*, 1992). Yoghurt is maintained at 2-4°C throughout the distribution chain, which avoids the risk of spoilage from yeasts, moulds and also prevents further activity by starter culture. On the other hand, it adds to the cost of the product (Salji *et al.*, 1987). The shelf life of yoghurt can be improved by lowering its water content by drying *viz.,* freeze drying, spray drying or microwave drying or by draining of whey. The products obtained are in shelf stable powder form which can be stored at ambient temperature (Kumar and Mishra, 2004)

The main objective of drying the yoghurt is to preserve it in a shelf stable powder form of high quality, without a need for refrigeration. In order to improve the shelf life of yoghurt, some traditional processes such as removing of water by straining (strained yoghurt) or sun drying are followed. But these technologies have been unable to get wide spread acceptance from the consumers. At present, modern technologies *viz.,* spray drying, microwave drying, freeze drying etc are also employed to produce yoghurt powder. But none of the methods got commercialised till now. The quality of yoghurt powder is mainly disturbed by the viable yoghurt starter bacteria count. Even though the best method for drying the yoghurt is observed to be freeze drying in terms of survival of yoghurt starter bacteria; high cost of application is seen to be the main disadvantage of this method (Koc *et al.*, 2009).

Spray drying technique has recognised to be highly successful in improving the storage stability of food products. It is the most widely used methods for preservation of perishable liquid products. Spray drying of yoghurt is in ready to use form and also has a great market potential in our country and abroad (Peighambardoust *et al.*, 2011). Spray drying has advantages such as high moisture removal rate, decreased cost and short processing time, when compared to the other drying techniques. Yoghurt powder can be utilized as a part of dry dessert mixes, yoghurt drink mixes flavored with natural fruits, soup bases, instant drink mixes and as ingredients in bakery and confectionery industries. It can also be used in reconstituted form as fresh yoghurt.

Poor texture, gel structure and flavor of reconstituted yoghurt are the main problems of yoghurt powder technology and should be improved. Also, the spray drying process parameters need to be standardised. This study will provide a new dimension for preserving yoghurt. It not only increases the sales and meets the requirements of the consumer, but also helps to reduce the spoilage and increase the availability of nutrient rich food to the consumer at least cost. Considering the above cited facts, a study was undertaken to develop a process protocol for yoghurt powder with the following objectives:

1. To develop yoghurt powder by spray drying with maltodextrin and corn starch as carrier materials.
2. To standardise the process parameters for the development of spray dried yoghurt powder.
3. To conduct the storage studies of spray dried yoghurt powder .

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

This chapter presents a comprehensive review of the research work carried out in the recent past, on the spray drying of liquid food products. A brief account of principle and mechanism of spray drying and the storage of spray dried product are also discussed.

India ranks first in milk production, representing 18.5 per cent of world production, achieving an annual output of 158 MT during 2015-16 (Anone., 2016). Currently, the relevance of diet on healthy wellbeing has increased which results in the rising demand for food products that support health along with supply of adequate nutrition. One among these products is yoghurt, a milk based product. Yoghurts are commonly prepared by fermentation of milk with bacterial cultures (blend of *Streptococcus subsp. thermophiles* and *Lactobacillus delbrueckii subsp. bulgaricus*).

2.1 YOGHURT

"Yoghurt" has been derived from a Turkish verb, "Jugurt" that means "to be curdled or coagulated" (Tamime and Robinson, 1999). There is a proof of cultured milk products as far back as 5000 BC (Kosikowski, 1982). Yoghurt is a cultured dairy product that can be made from whole, low fat or skim milk and reconstituted skimmed milk powder. As per Code of Federal Regulations of the FDA (2013), yoghurt is a milk product made by culturing one or additional of the fundamental ingredients (cream, milk, partially skimmed milk, skim milk, or the reconstituted versions of those ingredients) and any of the dairy ingredients with a characterizing bacteria (live and active) culture that has the lactic acid-producing bacteria (*Lactobacillus bulgaricus* and *Streptococcus thermophilus*). It is made by inoculating starter culture, usually *Streptococcus thermophilus* and *Lactobacillus bulgaricus*, with milk. After the inoculation process, milk is incubated at 110°F ± 5°F till it firm; lactic acid produced by the bacteria during the time of incubation will coagulate the milk. Yoghurt might have further cultures, sweeteners, flavorings, color additives, stabilizers and emulsifiers and preservatives added to it. Yoghurt could also be heat treated after culturing to increase the shelf life.

Weerathilake *et al*. (2014) found that yoghurt must contain as a minimum 3.25% of milk fat and 8.25% of Milk Solids Non Fat (MSNF) with a titratable acidity of not less than 0.9%, expressed as lactic acid. Usually yoghurt is prepared from cow, water buffalo, goat and sheep milk. But in some of the regions in the world, milk from mare and camel is also used in yoghurt making.

2.1.1 Health Benefits of Yoghurt

Yoghurt are often considered as healthy food because of its high digestibility and bioavailability of nutrients and can also be suggested to the individuals with lactose intolerance, gastrointestinal disorders such as inflammatory bowel disease and irritable bowel disease, and aids in immune function and weight management (Mckinley, 2005). National Yoghurt Association (2013) reported that there is a growing trend for yoghurt and its drinks. According to them, yoghurt is a nutrient rich food that meets a good kind of nutritional needs for human beings. Yoghurt is high in protein and also an excellent source of calcium. It may contain up to 35 per cent of the recommended daily intake for calcium. Yoghurt is low in fat and high in minerals *viz*., phosphorus and potassium and vitamins, such as riboflavin B2, Vitamin B12 etc. (Anon., 2013). The active cultures indicate the living organisms *Lactobacillus bulgaricus* and *Streptococcus thermophiles* which convert pasteurized milk in to yoghurt during fermentation. At present, many research studies are progressing related to how live and active culture yoghurt may have a positive outcome on the immune system, the possibility to bring down cholesterol, and how it might contradict certain types of cancer causing compounds, particularly in the digestive tract.

In a recent review, Astrup (2014) reported that fermented yoghurt products can produce 4%-5% decrease in total and LDL-cholesterol, whereas an eight week randomized disciplined trial of overweight adults shown an 8.4% reduction in LDL-cholesterol after the intake of yoghurt fermented with *Enterococcus faecium* and *Streptococcus thermophilus*.

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Mckinley (2005) reported that lactose is the major carbohydrate in milk which is a disaccharide comprises of one molecule of glucose and galactose. Due to the action of the enzyme lactase inside the gut, lactose is broken down to its simple sugars. Insufficiency of lactase may permit undigested lactose into the large intestine which will be fermented by colonic microflora results gastrointestinal symptoms such as flatulence, diarrhea and abdominal pain. This phenomenon is called as lactose intolerance. Buchowski *et al.* (2002) stated that the lactose intolerance is related with low calcium intake and bone mineral density presumably excessive exclusion of milk and dairy products from the diet. So, it can be concluded that yoghurt is effective for the people with lactose intolerance to achieve all the aids of milk products without causing discomforts related with hypolactasia.

Ruxton and Phillips (2015) described that yoghurt consist of many of the nutrients required for optimum bone health *viz.,* calcium, protein, magnesium, zinc and phosphorus. The calcium existing in yoghurt is bioavailable because the low pH ionizes calcium, accelerating intestinal calcium uptake. High intake of yoghurt helps to control the blood pressure and can even help to avoid hypertension.

Ruxton and Phillips (2015) also reported that low-fat yoghurt has been a keystone of weight management guidance for decades. Evidence from large observational studies recommends that yoghurt is one of a group of foods constantly related with healthier weight variations. In a pooled adjusted analysis of dietary habits and weight alteration in over 120,000 healthy, non-obese Unites State adults, use of low-fat yoghurt was related with a reduction in weight (1.0 -2.0 kg) over a four-year period - a better effect than that seen for vegetables, fruit and whole grains and also found that yoghurt obviously contains less lactose than milk (3.4% compared with 6.0%), recommending that it may be better tolerated than milk in people with lactose intolerance, due to time consuming gastric emptying and gut transit.

2.1.2 Nutritional Profile of Yoghurt

Mckinley (2005) reported that yoghurt contains milk proteins, carbohydrate, minerals such as calcium and phosphorous, and vitamins such as riboflavin (B2), thiamine (B1), cobalamin (B12), folate (B9), niacin (B3) and vitamin A. Milk proteins existing in yoghurt is of high quality because of its great

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biological value and provide majority of essential amino acids required to maintain good health . Milk proteins in yoghurt have higher content of proline- and glycine-contain amino acids than whole milk. The fat content of low-fat yoghurt varies from 0.5-3.25 per cent.

Weerathilake *et al.* (2014) claimed that yoghurt is very nutritious and clearly digestible dairy product which contains in excess of ten essential nutrients in particular, certain minerals and vitamins. The nutritional composition of yoghurt relies upon the strains of starter culture utilized as a part of fermentation, type of milk used (whole, semi or skimmed milk), species that milk is obtained (bovine, goat, sheep), milk solids, solid non-fat, sweeteners and natural products included before fermentation along with the length of the fermentation process. The nutritional profile of yoghurt as per the Dairy Council (2013) is shown in Table 2.1.

Table 2.1 Nutritional profile of yoghurt

Component	WholeMilk yoghurt	Low Fat yoghurt	Non Fat yoghurt
Energy (kcal)	79	56	54
Protein (g)	5.7	4.8	5.4
Carbohydrate (g)	7.8	7.4	8.2
Fat (g)	3.0	1.0	0.2
Thiamin (mg)	0.06	0.12	0.04
Riboflavin (mg)	0.27	0.22	0.29
Niacin (mg)	0.2	0.1	0.1
Vitamin B6 (mg)	0.10	0.01	0.07
Potassium (mg)	280	228	247
Calcium (mg)	200	162	160
Phosphorus (mg)	170	143	151

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Weerathilake *et al.* (2014) cited by Mckinley (2005) reported that a 150 g serving of whole milk plain yoghurt and low-fat plain yoghurt will give 31 per cent and 30 per cent of a grown person's daily riboflavin respectively.

2.1.3 Manufacture of Yoghurt

Yoghurt production consists of modifying the original composition of milk, pasteurizing the yoghurt mix, fermentation at thermophilic temperatures (40-45ºC), cooling and addition of fruits and flavors (Lee and Lucey, 2010).

Standardization of milk

↓

Homogenization
55-65ºC and 15-20 MPa

↓

Pasteurization
80-85ºC for 30 min or 90-95ºC for 5 min

↓

Cooling to incubation temperature(42-45ºC)

↓

Inoculation of starter culture (2%V/V)

↓

Fermentation/incubation(42-45ºC)
Until pH reached to 4.6 (6 h)

↓

Cold storage

↓

Yoghurt

Figure 1.1 Manufacturing process of yoghurt

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2.1.4 Raw Materials for Yoghurt Manufacture

Tamime and Robinson (1999) reported that yoghurt is produced using a variety of ingredients like milk, sweeteners, stabilizers, fruits, flavors, and bacterial cultures. Milk is the main ingredient employed in yoghurt production. The type of milk to be used depends on the variety or type of the yoghurt that will be prepared. Whole milk is used for full fat/regular yoghurt, partially skimmed milk is used for low fat yoghurt and skimmed milk is used for nonfat yoghurt. Cream or butter fat is used to regulate the fat content however skim milk powder, whey protein concentrate are used to raise the total solid content of the yoghurt. Stabilizers are normally added to the mix to build up the body and texture leading to an increase in firmness, avoids whey separation, and helps in uniform distribution of constituents. Moreover, sweeteners are used to enhance the flavor and consumer appeal.

2.1.5 Starter Cultures for Yoghurt Production

2.1.5.1 Lactobacillus bulgaricus

Lactobacillus bulgaricus grows at reasonabliy low pH values (below pH 5.0) and has most favorable growing temperature of around 37°C. There are various nutritional benefits from these lactic acid bacteria, such as better absorption of lactose and control of intestinal infections, control of cancer cells, lowering of serum cholesterol levels etc (Gilliland, 1990) .

Sanders and Klaenhammer (2001) reported that *Lactobacillus bulgaricus* is a probiotic strain of human origin available commonly in usual foods such as milk, yoghurts, juice and dietary supplements. It is assumed that the strain is functionally essential to human because of their health favorable effects which have been built up to ease, prevent several diseases like colon cancer, diabetes, hay-fever, and lactose intolerance.

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Lactobacillus bulgaricus is a homofermentative species, fermenting sugars into lactic acid and known as Gram positive non-spore-forming rods with rounded ends that occur one by one and in short chain (Gopal, 2011).

Traditional yoghurt is produced from symbiotic growth of starter bacteria *Streptococcus thermophilus and Lactobacillus bulgaricus.* To get better health benefits, the current trend is to add *Lactobacillus acidophilus* to yoghurt (Ashraf and Shah, 2011).

2.1.5.2 Streptococcus thermophilus

Rasic and Kurmann (1978) stated that the growth temperature for *S. thermophilus* varied from 20°C to 50°C with an optimum of 40°C to 45°C. According to Carper (1998), yoghurt containing *S. thermophilus and L. bulgaricus* reduced the rate of lung cancer in mice.

It is a thermophilic lactic acid bacterium (LAB) commonly used in the production of yoghurt products and can be considered as the important industrial dairy starter after *L. lactis* (Hols *et.al.,* 2005).

Combinations of probiotic commodities containing *S. thermophilus* helped to increase gastrointestinal function, for example prevention of rotaviral diarrhea in infant and reduce the severity of Necrotizing Enterocolitis in neonates (Saavedra *et. al.*, 1994 ; Bin-Nun *et.al.*, 2005).

2.1.6 Carrier Materials for Spray Drying

For an economically and technically viable drying process, it is essential to include carrying agents, also known as drying aids. These materials help to build the glass transition temperature of the product to be atomized. Drying aids used should have a high molecular weight and also have a high glass transition temperature (Jaya and Das, 2009). Moreover, these added substances offer a better handling of the product and protecting the sensitive components of the foodstuff from undesirable environmental conditions. It additionally stays away from the adsorption of moisture from the environment and preserving the flavours,

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fragrances etc. It also decreases the unpredictability and reactivity and gives an extra engaging quality to foodstuff (Re, 1998).

The carrier agents used in spray drying can be carbohydrates (starch, maltodextrin, dextrans, sucrose, cellulose and derived), gums (Arabic gums, agar, carrageenan, etc.), lipids (wax, paraffin, diglycerides) and proteins (gluten, caseins, albumins, haemoglobin and peptides). Among these, the polymers of high molecular weight and high glass transition temperature (Tg) *viz.,* maltodextrin, Arabic gum and modified starch are commonly used (Cano-Chauca *et al.*, 2011).

2.1.6.1 Maltodextrin

Maltodextrin [($C_6H_{12}O_5$) nH_2O] is a saccharide non-sweet polymer, which contains D-glucose solidarities joined by α 1-4 chain. It is usually appear as a white powder and is made through the partial hydrolysis of corn starch with the activity of acids or enzymes. Maltodextrin is available in different dextrose equivalents (DE), which indicate the hydrolysis level of the starch polymer. The advantages of hydrolysate starch offer low relative cost (one third of modified starch) and low consistency in high concentration of solids, neutral smell and taste. Additionally, it offer greater protection against oxidation depending on the dextrose equivalent (Bemiller and Whistler, 1996). The principle advantage of maltodextrin are its low hygroscopicity, avoiding the agglomeration of particles, high solubility in cold water, also shows an anti-oxidative impact and good retention of volatile substances and low cost (Matioli and Rodriguez-Amaya, 2002; Tonon *et al.*, 2008).

2.1.6.2 Arabic gum

It is usually used in the encapsulated flavours by spray drying. It is easily dispersed in water in concentrations of up to 50% due to its because of its profoundly ramified structure (Sahini and Han, 1993). This gum has great solubility, low viscosity, good emulsifying properties, taste and high oxidative stability. Its emulsifying property offers a better capacity for protection or retention of volatile compounds during the drying process and also retaining more

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sensitive flavours. But, its use is difficult due to high cost (Gharsallaoui *et al.*, 2007).

2.1.6.3 Modified starch

The modified starches are regularly utilized as encapsulating agents because of the great maintenance of volatiles (over 93%), the adjustment of the emulsion and low viscosity. They offer low protection against oxidation during stocking, hence the significance of utilizing this material is related to maltodextrin (Silva et al., 2013). Starch is a generally available and low cost product. However, the viscosity of starch solutions is usually too high for the considerable part of the drying process. Reviews reveal that, on the encapsulation of the orange essential oil, the modified starch exhibited higher oil retention when compared to the arabic gum (Ascheri *et al.*, 2003). Soottitantawat *et al.* (2005) did encapsulation of limonene by spray drying, and the best stability was acquired by using modified starch as encapsulating agent, in comparison to Arabic gum and maltodextrin.

Cano-Chauca *et al.* (2005) observed the impact of the carriers on the microstructure of mango powder obtained by spray drying. In this work, maltodextrin, gum arabic and starch waxy at concentration 12% were used as the carrier materials. Analyses of microstructure, stickiness, hygroscopicity and solubility were performed on the acquired spray dried powder. The microstructure analyses revealed that the spray dried powder with carriers maltodextrin, gum arabic, starch waxy without the addition of cellulose offered amorphous surfaces. Results demonstrated that starch wax showed the best effect on microstructure of mango powder.

Krishnan *et al.* (2005) did research work on microencapsulation of cardamom oleoresin using the blends of gum arabic, maltodextrin and a modified starch as wall materials. The results indicated that gum arabic could be considered as a superior wall material for encapsulation of cardamom oleoresin when compared to the other wall materials and furthermore the stability of the cardamom oleoresins decreased with decrease in the quantity of gum arabic in its

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blend with maltodextrin. Gum arabic: maltodextrin: modified starch (4/6,1/6,1/6) blend showed to be more impact than the other blends even better than 100% gum arabic.

Tonon *et al.* (2010) studied about anthocyanin stability and antioxidant activity of spray-dried acai (*Euterpeoleracea Mart.*) juice produced with different carrier agents. In this work,spray drying was carried out using three types of carrier agents: maltodextrin, gum Arabic and tapioca starch. Anthocyanin stability and antioxidant activity of powdered açai juice was assessed throughout 120 days. Results showed that maltodextrin was the carrier agent that showed the best pigment protection and antioxidant activity, for all the conditions.

Nadeem *et al.* (2011) led an examination on spray drying of the mountain tea (*Sideritisstricta*) water extract by utilizing different hydrocolloid carriers. Here, the water extract of the mountain tea was spray dried by using distinctive sustenance hydrocolloids such as b-cyclodextrin (BCD), arabic gum (AG), and maltodextrins (MD19 and MD12). Powdered specimen were then subjected physico-chemical analyses to observe product yield, moisture content, water activity, bulk density, solubility, color and SEM particle microstructure analyses etc. Results found that the product yield increased with the addition of the carrier materials but decreased at higher drying temperature. Physicochemical properties of the spray-dried mountain tea samples were significantly influenced by the inlet air temperature and also the type and concentration of the carrier materials.

Pereira *et al.* (2014) used the spray dryer for dehydrating probiotic cashew apple juice which is sensitive to high temperatures by using Arabic gum as a carrying agent. Results showed that the temperature of 100°C with 5% Arabic gum produced more natural juices and maintained the viability of the probiotic cell. On the other hand, the use of temperature at 150°C increased the yielding of the process.

Ekpong *et al.* (2016) studied about the effects of maltodextrin as a drying aid and drying temperature on production of tamarind powder and consumer

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acceptance of the powder. In this study, tamarind pulp with different levels of included maltodextrin was foam-mat dried to enhance the stability of the tamarind and to analyse consumer acceptance. Tamarind foam-mats were made using hydroxypropyl methylcellulose (HPMC) as a foaming agent and maltodextrin at 0%, 5%, 10%, or 15% as a drying aid. Results showed that the increase in the maltodextrin content lead to decrease in colour, with a decrease in redness and yellowness. Also decrease in the total acidity and increase in pH was observed with addition of maltodextrin. Dispersibility of the tamarind powder was enriched by including maltodextrin.

2.2 SPRAY DRYING PROCESS

Masters (1991) observed that spray drying is the best way for the production of powder colorants with high storage stability, easier to handle for certain applications, and reduce the weight for transportation when compared to liquid concentrate.

Dolinsky *et al.* (2000) conducted studies on fruit drying and reported that 30 – 45 per cent maltodextrin must be added to the vegetable and fruit juices to obtain acceptable amount of powder. Addition to this, Adhikari *et al.* (2003) reported that the maltodextrin content considerably decrease the stickiness property of fructose solutions, indicating it to be a viable drying aid.

Cano-Chaucaa *et al.* (2005) learned about the effect of the carrier materials on the microstructure of spray dried mango powder. The investigations on microstructure revealed that the powders of the mango juices obtained through spray drying using the carrier materials *viz.,* maltodextrin, gum arabic, starch waxy offered amorphous surfaces.

Hernandez *et al.* (2005) observed the spray drying of Cactus pear juice (*Opuntia streptacantha*) and its effect on the physicochemical properties of powder. The results revealed that the reconstituted product showed a small change in total color (ΔE) when compared to natural juice.

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Chegini and Ghobadian (2007) conducted a study on spray drying of orange juice at 65% concentration. Parameters selected for the study were wall material, inlet and outlet temperature, feed flow rate and sticky point temperature. They found that product yield and wall deposition are influenced by inlet temperature and feed flow rate. Optimum drying conditions for the orange juice were feed flow rate of 15 ml /min , inlet and outlet air temperatures of 130°C and 85°C and sticky point temperature of 44°C for powder having 2 per cent moisture.

Quek *et al.* (2007) observed the physicochemical properties of spray dried watermelon powders. The dried powder were examined for, dissolution, moisture content, colour, water activity, lycopene and β-carotene. Results revealed that the moisture content and dissolution of the spray dried powder decreased with increased inlet temperature. On the other hand, there were no suggestive changes in the water activities of the spray dried powders for all inlet air temperatures.

Tonon *et al.* (2008) studied about the impact of process conditions on the physicochemical properties of spray dried acai (Euterpeoleraceae Mart.) powder. The results indicated that moisture content of spray dried powder and process yield were adversely influenced by feed flow rate and emphatically influenced by inlet air temperature which are specifically related to heat and mass transfer. As the maltodextrin concentration increased, powders hygroscopicity decreased due to the higher water concentration gradient between the surrounding air and the product. Due to high sensitivity, anthocyanin retention was only affected by temperature. In the case of morphology of powder, larger particles were obtained at higher temperature and they showed smooth surfaces.

Kima *et al.* (2009) investigated about surface composition spray dried milk powders and also the effects of spray drying conditions on the surface composition. The impact of various spray drying conditions (drying temperature, feed solids content, initial droplet size and degree of homogenization) on the surface composition of milk powders were examined. The surface composition of milk powders depends on combination of spray drying conditions. Based on the observations in this work and theoretical considerations, possible mechanisms behind the formation of the surface composition of spray dried milk powders were recommended.

Fazaeli *et al.* (2012) conducted a study on effect of spray drying conditions and feed composition on the physical properties of black mulberry juice powder.In this study, the effects of processing parameters on moisture content, water activity, drying yield, bulk density, solubility, glass transition temperature (Tg), and microstructure of spray dried black mulberry (*Morusnigra*) juice powders were examined. Maltodextrin and gum Arabic were used as carrier agent. Results showed that maltodextrin plays the best result on the properties of black mulberry juice powders. Drying yield varied from 45 to 82 per cent. The maximum drying yield (82%) and solubility (87%) indicate to the blend of maltodextrin and gum Arabic. The lowest moisture content powders (1.5%) obtained at the compressed air flow rate of 800 L/h. Minimum bulk density leads to higher solubility.

Samborska and Bienkowska (2013) conducted a study to characterise the physical and chemical properties of spray dried honey preparations and the changes in these properties during storage. Spray drying was accomplished at inlet air temperature 160 and 200°C, atomising disk speed 32,000 and 38,000 rpm. Dextrin and maltodextrin were used as two types of carriers. The results showed that the powders had the desirable physical properties such as low water content and water activity, complete solubility and low cohesiveness. Also found that the powders obtained with dextrin as carrier material had higher hygroscopicity and poorer solubility, and highest water absorption during storage. Powders produced with less atomisation speed were the most stable in terms of water absorption and hygroscopicity during storage. Solubility of all powders was constant during storage.

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

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temperatures of 200°C and 120°C were selected for the study. The result proved that physicochemical properties of powders varied with some process variables such as characteristics of liquid feed, drying air, and also the type of atomiser and carrier agents.

Avila *et al.* (2015) assessed the effect of maltodextrin (MD) on quality of spray dried sugarcane juice powder. The results were optimised by a central composite design with a response surface analysis. The product obtained at maltodextrin 20 per cent, inlet air temperature 130°C, Outlet air temperature-75°C, atomisation speed- 22,000 rpm showed the highest quality among the other treatments.

2.2.1 Spray Drying of Yoghurt

Kim and Bhowmik (1990) observed the survival of lactic acid bacteria during spray drying of plain yoghurt. It is reported that survival of *Streptococcus salivarius* var. *Thermophilus* and *Lactobacillus delbrueckii* var. *L. bulgaricus* was examined under several processing conditions used for spray drying of yoghurt and found that numbers of microorganisms reduced with increased inlet/outlet air temperature and atomizing air pressure. From the results, it has been concluded that outlet air temperature was an important parameter related to the number of survivors. The suitable processing conditions found in this study were- inlet air temperature 160°C, outlet air temperature 60°C, atomizing air pressure 98 kPa, hot air flow rate 0.28 m^3 min^{-1} and feed temperature of 30°C.

Bielecka and Majkowska (2000) described the effect of spray drying temperature of yoghurt on the survival of starter cultures, moisture content and sensory properties of yoghurt powder. A synergistic set of the strains *Lactobacillus delbrueckii subsp. bulgaricus* 151 and *Streptococcus thermophilus* MK-10 was treated with the process of spray drying. The outlet air temperatures selected in this study were in range of 60-80°C. It had been found that survival of yoghurt cultures was maximum at outlet air temperatures 60 and 65°C.

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Koc *et al.* (2010) conducted a study on spray drying of yoghurt. The independent parameters selected were inlet air temperature (150-180°C), outlet air temperatures (60-90°C) and feed temperature (4-30°C). The quality of the yoghurt powder was highest at air inlet temperature 171°C, air outlet temperature 60.5°C, and feed temperature 15°C.

Anjineyulu *et al.*, (2014) conducted a study on the effect of adding maltodextrin (MD) on spray drying of dahipowder. Curd was mixed with different maltodextrin levels of 5, 7.5, 10, and 12.5 per cent. Quality parameters of curd powder *viz.,* lightness, wettability, water solubility index, viscosity, bulk density, dispersibility and total solids improved with increase in maltodextrin content, but moisture content, acidity and hygroscopicity reduced with increase in maltodextrin (MD). The flavour of reconstituted dahi samples increased with increase in maltodextrin content. It may be due to the retention of acetaldehyde in the samples. Addition of maltodextrin (MD) also improved the sensory properties and overall acceptability of reconstituted spary dried dahi powder.

2.2.1.1 Quality improvement of yoghurt powder by addition of spices

Flavourings are added to foods to improve taste and aroma. There are several natural flavours which are originated from herbs and spices. Spices are plant parts used for flavoring or preserving food. Many spices have antimicrobial properties. Common used spices are ginger, pepper, cardamom, chilly, garlic etc. *Zingiber officinale Ros.* commonly called as ginger is a spice with wide range of medicinal uses. From earlier times, it was used for most of the digestive disorders. Moreover it has anti-inflammatory and chemo-protective effects (Malhotra and Singh, 2003). Ginger is used as a herb, flavor material and a spice. 2 g of ginger contains 1.6 calories, 0.7 mg of omega-3 fatty acids and 2.4 mg of omega-6 fatty acids. It also provides 0.1 mg of vitamin C and 0.2 mg of folate. Ginger also contains small amounts of minerals: calcium (0.3 mg), magnesium (0.9 mg), phosphorus (0.17 mg), potassium (8.3 mg) and sodium (0.3mg) (Catherine, 2010). The addition of flavor to spray dried products enhances the consumer acceptance and marketing.

Iheagwara (2013) conducted the effects of addition of ginger extracts on the stability and sensory quality of mackerel fish. Peroxide value, mould count *etc.,* were examined for over 20 days storage and concluded that samples with ginger extract has low mould count and samples with 5% ginger extract showed the best among the other treatments.

Ihemeje *et al.* (2015) conducted a study on production and quality evaluation of flavored yoghurts using carrot, pineapple, ginger and pepper fruit. The nutritional quality of the yoghurt was improved by the addition of spices and flavorings. The mineral content of the plain yoghurt were also increased. In this study, pepper flavored yoghurt was selected as the best combination among the other flavored samples.

Amal *et al* . (2016) studied about the chemical, functional and rheological properties of fruit flavored yoghurt. Yoghurt with different fruit pulp such as papaya and cactus pear was prepared and stored up to 10 days. The fruit were incorporated at the rate of 5%, 10% and 15%w/w. Results showed considerable differences between plain yoghurt and fruit yoghurt in the pH, moisture, ash, protein, carbohydrate content and titrable acidity during storage. Sensory evaluation results showed that the yoghurt containing papaya pulp had scored the highest overall acceptability as compare to other fruit yoghurt samples and also plain yoghurt.

2.3 RECONSTITUTION PROPERTIES OF SPRAY DRIED POWDER

Reconstitutability indicates the ease with which a powder can be dissolved in water (Singh and Aiqian, 2010). In case of spray dried powdered foods, several properties includes, solubility, wettability, dispersibility, particle properties such as bulk density, tapped density etc influence the overall reconstitution characteristics (Reddy *et al.*, 2014).

Yoghurt powder after reconstitution at 10- 40°C in water at powder to water ratio 1:5 had taste, flavor and nutritional composition like that of fresh yoghurt (Pan *et al.,* 1994).

Gavin (1968) suggested the ideal incubation condition as 40°C for 3 hours while Tamime and Robinson (1989) suggested that 20°C is the ideal incubation temperature for thermophilic LAB and *bifidobacteria.*

Fang *et al.* (2008) suggested that industrial milk powder manufacturers usually use solubility property as a criterion to point out the standard of milk powders. It helps to represent the complete occurrence of dairy powder reconstitution, comprising soluble components like lactose, undenatured whey protein, salts as well as dispersible components.

Silva *et al.* (2013) prepared propolis powder using spray drying technique and examined its properties *viz.,* water activity, particle size, hygroscopicity *etc.* They found that spray dried powder with particle size 15-24 μm got low hygroscopicity.

Koc *et al.* (2010) conducted a study on physical properties of yoghurt powder produced by spray drying and found that the bulk, tapped and particle densities of yoghurt powder were observed to be 538, 746 and 1177 kg m^{-3}, respectively. The porosity of yoghurt powder was estimated as 36.54 per cent. Yoghurt powders have moderate poor flowability because of their small particle size. The caking degree of the yoghurt powder was found as 30.32 per cent.

Patil *et al.* (2014) investigated the physical and nutritional properties of spray dried guava powder. They observed that the moisture content and bulk density of the spray dried product decreased with raise in inlet temperature. Maximum solubility was obtained at 185°C.

Sarabandi *et al.* (2014) studied the effect of spray drying conditions on physicochemical properties of grape syrup powder. The quality parameters of spray dried powder *viz.,* moisture content, water activity, bulk density, solubility, hygroscopicity, and wettability were estimated. It was found that moisture content, water activity, bulk density and hygroscopicity of the spray dried powder decreased with increase in inlet air temperature, whereas wettability and solubility values increased with increase in inlet temperature. Also bulk density, solubility, hygroscopicity and wettability were adversely influenced by maltodextrin concentration.

Seth *et al.* (2016) studied the functional and reconstitution properties of spray dried sweetened yoghurt powder. They found that the solubility varied within the range of 65 -72.5 per cent. The results showed that the solubility of yoghurt powder decreased with the increase of inlet air temperature. The higher inlet temperature led to protein denaturation and thus affected solubility. Powder with high solubility takes less time to wet their surface, which resulted in lower wetting time or wettability. The wetting time of yoghurt powder ranged from 132 to 378 s and also the dispersibility exhibited a variation in the range of 70.62 – 88.74%. It has been observed that dispersibility reduced with decrease in particle size. Hall and Hedrick (1975) conducted SEM analysis of yoghurt powder. They found out that yoghurt powder particles were spherical or crater in shape.

2.4 PACKAGING AND STORAGE STUDIES OF SPRAY DRIED PRODUCTS

The important considerations for the packaging of dry products are protection from moisture migration, loss of viable counts and loss of volatile flavoring compounds. Shelf life can be defined as the maximum time for which a food product can be stored under certain environmental condition without any significant deterioration in quality and acceptability. During storage, the product should be fit for human consumption. Environmental factors affecting food stability are relative humidity, oxygen concentration, toxic vapors, microbial contamination, light, temperature etc (Khanna and Peppas, 1982).

Kumar and Mishra (2004) stated that packaging, handling and transportation of yoghurt powder was easier when compared with yoghurt due to less weight and volume of the dried product. Dry yoghurt was less subjected to spoilage by the action of unwanted bacteria and moulds. The shelf life of yoghurt powder kept at 21°C was better up to 6 months of storage when ascorbic acid and monosodium glutamate were added prior to spray drying . The dried products reconstituted quickly.

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Mary *et al.* (2007) conducted a study on the packaging and storage studies of spray dried ripe banana powder under ambient conditions. They found that banana powder could be effectively stored under ambient conditions for one year using nitrogen flushed aluminium foil laminated pouches. The changes in colour, flavour, texture, microbial load and organoleptic qualities were found to be less significant during the storage period.

Balkir *et al.* (2010) conducted a study on the storage stability of spary dried yoghurt powder. In this study the spray dried yoghurt powder was kept in glass jars and aluminium laminated polyethylene (ALPE) pouches and stored at 25°C and 50 per cent RH for 90 days. The storage stability of yoghurt powder in terms of quality parameters (MC, water activity, titrable acidity, pH, colour change, overall sensory acceptability) was studied. Results showed that moisture content, a_w, increased while microbial counts decreased during storage and also the change in color and overall sensory acceptability of powder was affected during storage.

Sagar and Kumar (2014) observed the impact of drying treatments and storage stability on quality characteristics of spray dried bael powder. Moisture content of the dried product was in the range of 4% - 5%. Powders were packed in 400 gauge and 200 gauge HDPE, 150 gauge PP and 200 gauge LDPE and kept for storage at low temperature (7°C) and ambient condition (18-35°C) for a period of 6 months. They found that 200 gauge HDPE was the best packaging material for storage at low temperature with least changes in stored product.

Wong and Lim (2016) conducted a study on storage stability of spray dried papaya (*Carica papaya L.*) powder packaged in aluminium laminated polyethylene (ALP) and polyethylene terephthalate (PET). The physiochemical characteristics and microbiological study of powder stored in ALP and PET at enhanced storage for 7 weeks were recorded. The moisture content of powder kept in PET was doubled (13.28%) of those kept in ALP (6.38%) by the end of 7 weeks. A bigger increment of hygroscopicity was recognized for powder

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packaged in PET compared to ALP. The flowability of powder was considerably diminished for both packaging materials upon storage. The degree of caking for powder stored in PET was more than ALP. Powder kept in ALP was microbiological safe. From the results, it was clear that the powder packaged in ALP was with acceptable qualities and stability.

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

This chapter deals with the materials used and methodology followed for the development and quality evaluation of spray dried yoghurt powder and are discussed under the following sections.

3.1 RAW MATERIALS

Double toned pasteurized homogenized milk (Milma) was procured from Thrissur dairy unit. The wall materials *viz.,* maltodextrin and corn starch were purchased from Vivekam Agencies Coimbatore. Lyophilised starter culture such as *Lactobacilllus bulgaricus* and *Streptococcus thermophilus* were purchased from IMTEC (Institute of Microbial Technology), Chandigarh and it was preserved under refrigerated condition.

3.2 PREPARATION OF YOGHURT

Yoghurt is a fermented milk product that contains microbial cultures *viz.*, *Lactobacilllus bulgaricus* and *Streptococcus thermophilus*. Double toned pasteurized homogenized milk, procured from market was heated to 90˚C for 3-5 min and then cooled to 42˚C. Cooled milk was then inoculated with two per cent (V/V) starter culture (*Lactobacilllus bulgaricus* and *Streptococcus thermophilus in 1:1 ratio*) and kept for incubation at 42˚C for 4-6 h.

3.3 DETERMINATION OF PHYSICO - CHEMICAL AND MICROBIOLOGICAL PROPERTIES OF FRESH YOGHURT

The physico-chemical and microbiological properties of freshly prepared yoghurt were conducted and are discussed under subsequent sections.

3.3.1 Physico-Chemical Properties of Fresh Yoghurt

3.3.1.1 Colour

The colour of the yoghurt was found using a Hunter lab colour flex meter (Hunter Association laboratory, Inc., Reston, Virgina, USA; model: Hunter Lab's Colour Flex EZ) which is shown in Plate 3.1. The Hunter lab's colour flex spectro calorimeter consists of measurement (sample) port, opaque cover and display unit. The principle of working is by measuring the energy reflected from the sample across the entire visible spectrum, done by focusing the light. 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 - 100 (green) to + 100 (red) and b* indicates the blue - yellow spectrum with a range from – 100 (blue) to + 100 (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. A transparent glass cup filled with sample was placed over the port of the instrument and an opaque cover which act as a light trap to exclude the interference of external light was placed over the cup. Colour was calibrated by fixing the definite colours like white and black tiles. After calibration, the sample was placed over the port and values of 'L*', 'a*' and 'b*' were recorded.

3.3.1.2 pH measurement

The pH of the freshly prepared yoghurt was determined using a digital pH meter (M/s. Systronics; Model MK VI) shown in Plate 3.2. Initially, the pH meter was standardised with distilled water of pH 7.0 and standards of pH 4.0, 7.0 and 9.0. Sample was taken in a beaker and the electrode of pH meter was immersed in the sample. The reading was directly recorded from the pH meter. This procedure was repeated thrice for precision and the average value was noted (AOAC, 1990).

3.3.1.3 Water activity

Water activity is used to predict the stability of the product with respect to microbial growth, chemical and biological reaction rates and physical properties during storage. Aqua Lab series 3 water activity meter (M/s Aqua lab, USA) was used to obtain the water activity of fresh yoghurt. Water activity is measured by equilibrating the liquid phase water in the sample with the vapour phase water in the headspace and measuring the relative humidity of the head space. The water activity of fresh yoghurt was carried out using Aqua lab water activity meter (M/s. Aqua Lab, U.S.A; model: Series 3TE) which is shown in Plate 3.3. The yoghurt was filled in the disposable cups of the water activity meter and the sample drawer knob is turned to OPEN position. The product was then placed in the sealed chamber and turned the knob to READ position. The water activity of the sample was recorded with respect to atmospheric temperature.

3.3.1.4 Viscosity

Viscosity was measured using a Brookfield DV-E Viscometer (Plate 3.4) as described by Denin *et al.* (2001). The viscometer works on the principle of rotation of a spindle inside a cup measuring the twisting power necessary to overcome the resistance offered by yoghurt during rotation. Before measuring the viscosity, the instrument was calibrated using auto test without sample, from 0 to 100 rpm. Spindle No 3 at 20 rpm was selected for yoghurt to obtain necessary torque force. The spindle was inserted in the centre of the sample at a constant depth of 2 cm from the top level of the sample. The viscosity values attained a steady state after 30 seconds and the values were recorded.

3.3.1.5 Total soluble solid

Total soluble solid (TSS) of freshly prepared yoghurt was measured using a hand refractometer (Erma inc, Tokyo) as shown in plate 3.5. 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).

3.3.1.6 Vitamin C

Vitamin C content of freshly prepared yoghurt was estimated by volumetric method (Sadasivam and Manickam, 1992). Dye solution was prepared using 42 mg of sodium bicarbonate and 52 mg of 2, 6, dichloro phenol indophenols dye in 200 ml of distilled water. About 100 mg of pure dry crystalline ascorbic acid was taken and made up to 100 ml using 4% oxalic acid to get the stock solution. The working standard solution (100 ml) was prepared by diluting 10 ml stock solution using 4% oxalic acid. Then 5 ml each of working standard solution and 4% oxalic acid was pipette into a conical flask and titrated against the dye solution. The result point was the appearance of pale pink colour which is observed for a few minutes. The titration was repeated for 3 times to get the concordant value. The amount of dye consumed (V_1) was equal to the amount of ascorbic acid present in the working standard solution. The sample was made into pulp and 10 ml pulp (Vs) was taken and made up to 100 ml with 4% oxalic acid solution. Then 5 ml of the made up solution was pipetted into a conical flask and is titrated against the dye (V_2).

The quantity of ascorbic acid (mg) present in 100 gm of sample was calculated as follows.

$$\text{Ascorbic acid (mg/100 g)} = \frac{0.5}{V_1} \times \frac{V_2}{5} \times \frac{100}{V_s} \times 100 \qquad \ldots\ldots 3.1$$

3.3.1.7 Titrable acidity

Nine gram of yoghurt sample was weighed and five drops of phenolphthalein was added to it as indicator solution. This mixture was titrated with 0.1 N NaOH until

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the color changed to slight pink and persists for 30 seconds. The volume of NaOH used was recorded.

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

Plate 3.1 Hunter Lab colorimeter

Plate 3.2 pH meter

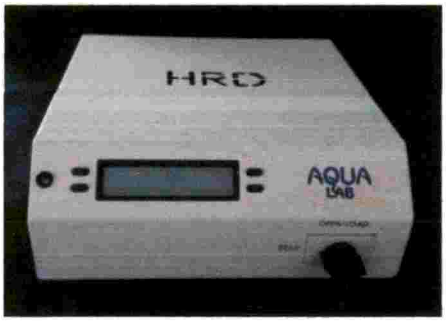

Plate 3.3 Water activity meter

Plate 3.4 Viscometer

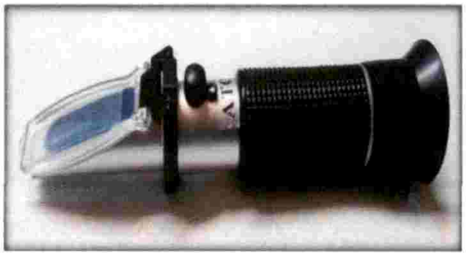

Plate 3.5 Hand refractometer

3.4 EXPERIMENTAL DESIGN

Based on the detailed review of literature and the preliminary studies conducted, the process parameters which form the independent variables were chosen. The quality characteristics which have keen influence on the efficiency of spray drying, stability and shelf life of the yoghurt powder were chosen as dependant variables.

3.4.1 Development of Spray Dried Yoghurt Powder

3.4.1.1 Independent Variables

- Carrier blend ratio (maltodextrin: corn starch)

  (a) B_1: Maltodextrin alone (4:0)

  (b) B_2: 3% Maltodextrin and 1% Corn starch

  (c) B_3: 1% Maltodextrin and 1% Corn starch

  (d) B_4: 1% Maltodextrin and 3% Corn starch

  (e) B_5 : Corn starch alone (0:4)

- Inlet air temperature

  a) T_1 : 160°C

  b) T_2 : 170°C

  c) T_3 : 180°C

- Feed rate

  a) F_1: 10 rpm (0.5 l/h)

  b) F_2 : 12 rpm (1.0 l/h)

  c) F_3 : 14 rpm (1.5 l/h)

3.4.1.2 Dependent variables

- Moisture content
- Colour
- Water activity
- Solubility
- Vitamin C
- Hygroscopicity
- pH
- TSS
- Titrable acidity
- Bulk density
- Wettability
- Probiotic viability

3.4.2 Quality Improvement of Spray Dried Yoghurt Powder Using Spice Extract

3.4.2.1 Independent variables

- White pepper extract
    - C_1 : 2.0% of feed solution
    - C_2 : 2.5% of feed solution
    - C_3 : 3.0% of feed solution
- Ginger extracts
    - G_1 : 3.0% of feed solution
    - G_2 : 3.5% of feed solution
    - G_3 : 4.0% of feed solution

3.4.2.2 Dependent variables

- Moisture content
- Colour
- Water activity
- Hygroscopicity
- Solubility
- Bulk density
- pH
- TSS
- Titrable acidity
- Wettability
- Vitamin C
- Average particle diameter
- SEM analysis
- Crystallinity

3.4.3 Shelf Life Studies of the Developed Flavoured Yoghurt Powder

3.4.3.1 Independent variables

- Aluminium laminated pouch (200 microns)

3.4.3.2 Dependent variables

- Moisture content
- Colour
- Water activity
- pH
- TSS
- Microbiological studies
- Titrable acidity
- Bulk density
- Solubility
- Wettability

3.5 DEVELOPMENT OF SPRAY DRIED YOGHURT POWDER

Spray drying is characterized as the conversion of liquid state feed into a dried particulate form. It can be accomplished by atomizing the fluid into a drying chamber, where the liquid droplets are passed through a hot air stream (Barbosa *et al.*, 2005; Masters, 1991).

A lab scale spray dryer (vertical co-current SMST tall type spray dryer) was used to conduct experiments. Spray drying of yoghurt was carried out using maltodextrin and corn starch as carrier materials in different proportions B_1, B_2, B_3, B_4 and B_5 (4:0, 3:1, 1:1, 1:3 and 0:4). The mixture was then spray dried at different operating parameters *viz.,* inlet air temperature T_1, T_2 and T_3 (160°C, 170°C and 180°C) and feed rate F_1, F_2 and F_3 (10 rpm, 12 rpm, 14 rpm). The process parameters were optimised based on the physico-chemical and microbiological properties of the developed yoghurt powder.

Table 3.1 Treatment combinations

Carrier blend ratio (maltodextrin: corn starch)	Inlet air temperature (^{0}C)	Feed rate (rpm)	Product Combination	Product Combination	Product Combination
	T_1	F_1	$B_1T_1F_1$	$B_1T_2F_1$	$B_1T_3F_1$
B_1	T_2	F_2	$B_1T_1F_2$	$B_1 T_2F_2$	$B_1T_3F_2$
	T_3	F_3	$B_1T_1F_3$	$B_1T_2F_3$	$B_1T_3F_3$
	T_1	F_1	$B_2T_1F_1$	$B_2T_2F_1$	$B_2T_3F_1$
B_2	T_2	F_2	$B_2T_1F_2$	$B_2 T_2F_2$	$B_2T_3F_2$
	T_3	F_3	$B_2T_1F_3$	$B_2T_2F_3$	$B_2T_3F_3$
	T_1	F_1	$B_3T_1F_1$	$B_3T_2F_1$	$B_3T_3F_1$
B_3	T_2	F_2	$B_3T_1F_2$	$B_3T_2F_2$	$B_3T_3F_2$
	T_3	F_3	$B_3T_1F_3$	$B_3T_2F_3$	$B_3T_3F_3$
	T_1	F_1	$B_4T_1F_1$	$B_4T_2F_1$	$B_4T_3F_1$
B_4	T_2	F_2	$B_4T_1F_2$	$B_4T_2F_2$	$B_4T_3F_2$
	T_3	F_3	$B_4T_1F_3$	$B_4T_2F_3$	$B_4T_3F_3$
	T_1	F_1	$B_5T_1F_1$	$B_5T_2F_1$	$B_5T_3F_1$
B_5	T_2	F_2	$B_5T_1F_2$	$B_5T_2F_2$	$B_5T_3F_2$
	T_3	F_3	$B_5T_1F_3$	$B_5T_2F_3$	$B_5T_3F_3$

3.5.1 Preparation of Feed Solution

Feed solution was prepared by blending freshly prepared yoghurt with equal amount of distilled water and wall materials such as maltodextrin and corn starch according to the various treatment combinations as given in Table 3.1. Different proportions of yoghurt and wall materials were chosen on the basis of trial and error method in accordance with review of literature. 1000 ml yoghurt with wall material solution was prepared and stored at refrigeration temperature (4°C) till the conduct of experiments.

3.5.2 Spray Drying of Yoghurt

Spray drying is a process in which a mixture in its liquid form is converted to powder. This process is done by removing the moisture component from the liquid solution. The solution (emulsion) along with hot air is sprayed through a nozzle. A lab model vertical co-current SMST tall type spray dryer (Plate 3.6) which is having an evaporation rate of 1000 ml h^{-1} was used for the drying process. It consists of hot air supply system, feed supply system, atomizer, powder recovery system, drying chamber and a control panel.

3.5.2.1 Hot air supply system

Hot air supply system consists of compressor, air filter and air heater. The compressed air generated from compressor is first filtered and heated using an air filter and heater. It is then introduced into the spray drying chamber using a twin fluid pressure nozzle atomizer. The compressed air disintegrates the feed emulsion into a fine mist. An air filter is essential to cease the entry of microorganism. The electrical air heating system consists of four electric heating coils (each having 1.6 kW) enclosed inside an insulated rectangular chamber. The maximum air temperature that can be achieved is 350°C.

3.5.2.2 Feed supply system

The feed supply system consists of a peristaltic pump and a feed source. Five hundred ml beaker with emulsion was considered as a feed source. The feed is pumped to the atomizer at the top of the spray drier by a peristaltic pump which consists of five rollers through which a hypalon natural rubber tube (6 mm diameter) passes. The rollers squeeze the tube with its contents in the forward direction and while doing so, a vacuum is created behind each roller which further sucks emulsion from the feed tank. The motorized peristaltic pump has variable speed arrangement to control the flow. The motor is DC operated and its rpm is controlled by a rotary knob.

3.5.2.3 Atomizer

Twin fluid pressure nozzle with rotary wheel atomizer was used for this experiment. It comprises of an atomizing wheel pivoting at a high speed on a shaft driven by electric motor (0.5 hp). Due to the rotation of the wheel, the feed is flung out at a high speed through radial channels in the wheel and as a result the feed is atomized into a very fine spray. Also, the kinetic energy of compressed air which is introduced into the twin fluid nozzle disperse the feed solution in the form of a fine mist. The atomizer has an ability to produce wide range of flow rate and droplet size. It produces a cone shaped spray pattern. The pressure of the compressed air was around 2 kg cm^{-2}. The feed coming from the peristaltic pump was brought into contact with the heated air after atomisation results in drying.

3.5.2.4 Drying chamber

The drying chamber of the spray drier is made up of SS 304 stainless steel and is cylindrical in shape and has a conical bottom with tapering to facilitate the easy flow of dried powder. Also to eliminate the accumulation of powders during process, the internal side of the drying chamber is polished to 180-200 grit fineness.The atomizer is placed at the top most portion of the drying chamber. Two inspection window glasses with light are provided at two sides of wall to see the operation inside the drying chamber. A glass bottle of 1000 ml is flanged at the bottom through teflon gaskets at the conical portion of the drying chamber for collecting the dried powder.

3.5.2.5 Powder recovery system

Fine powder particles along with the hot air enter into the cyclone separator in a tangential position trough a duct of 65 mm diameter. The fine particles, which are carried along with the exhaust air is separated in the cyclone. Air, along with particles, swirls in a spiral direction down the cyclone results in pressure depression where the particles are collected, following which, air leaves the cyclone due to the density difference.The fine powder separated from the cyclone separator is collected in glass bottle attached at the bottom of the cyclone through threaded flange with a teflon gasket.

3.5.2.6 Control panel

The blower speed, feed rate and inlet and outlet temperature were controlled through an electrical control panel with appropriate regulators, ON/OFF push buttons and indicators. In addition to this, an automatic and manual deblocking knob is also connected to solve the clogging of atomizer.

Plate 3.6 Spray dryer

Drying studies were carried out at different inlet air temperature and feed rates. In order to adjust the spray drying temperature, distilled water was pumped into the drying chamber about 30 min prior to feeding. After attaining the preset inlet temperature, the feed was introduced into the spray dryer through feed pipes.

3.5.3 Standardisation of Spray Dryer Parameters

The experiments were conducted with different process parameters *viz.*, carrier blend ratio, inlet air temperature and feed rate. The process parameters were optimised based on the yield, external appearance and quality of the powder. With the help of detailed review of literature, spray dryer parameters like main blower rpm, outlet temperature and atomizing air pressure were kept constant. The main blower rpm, outlet temperature and pressure in the drying chamber was kept as 2100 rpm, 60-65°C and 2 kg cm^{-2}, respectively. All these were done based on the previous studies on yoghurt and milk powders.

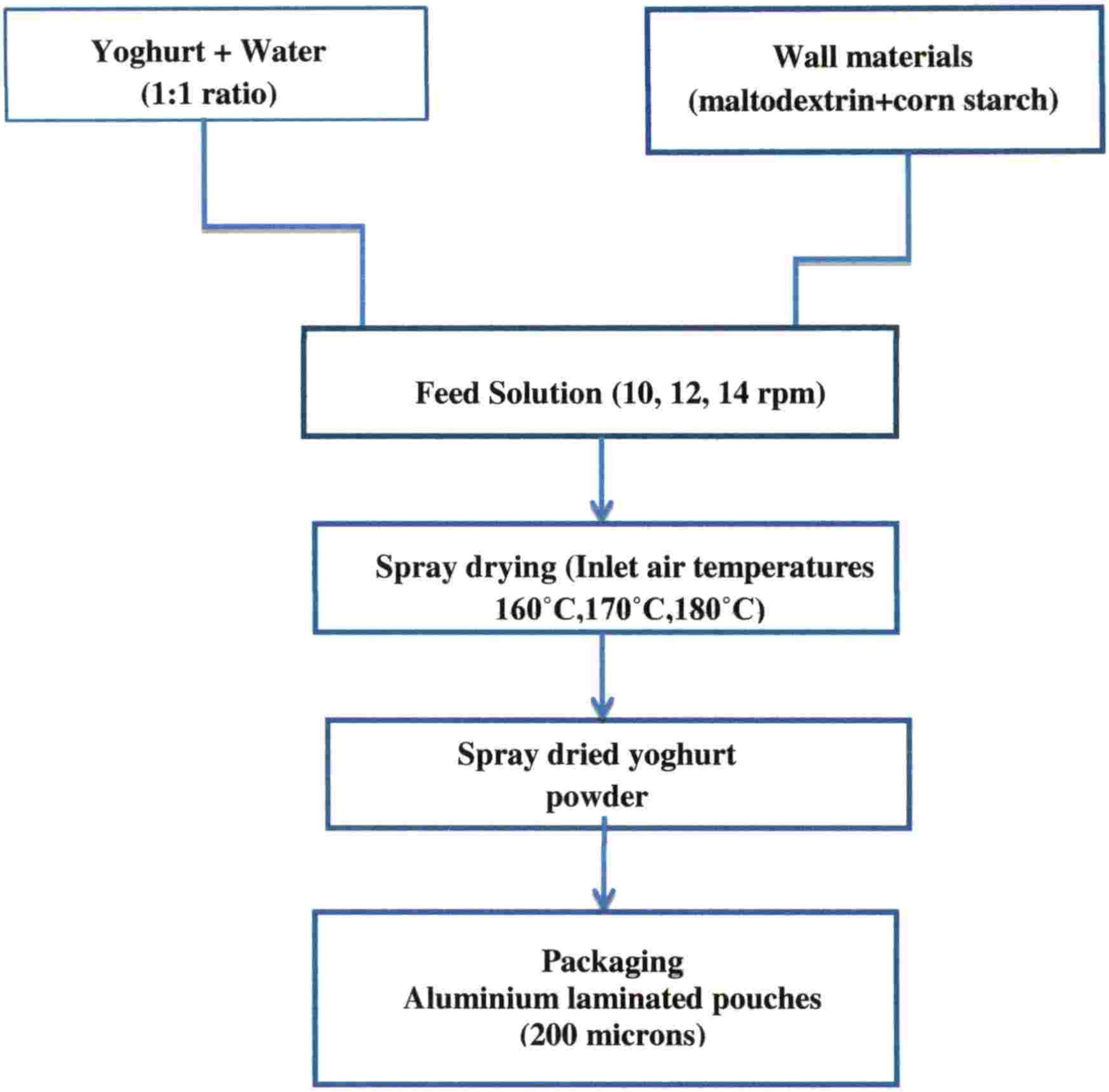

Figure 3.1 Flow chart –preparation of yoghurt powder

The prepared feed solution was pumped into the drying chamber of the spray drier through twin fluid pressure nozzle. The feed pump was adjusted to 10 rpm and the air pressure for the twin fluid pressure nozzle was altered to 2 kg cm^{-2}. The inlet air temperature was varied from 160°C to 180°C as per the technical programme and the blower speed was adjusted to 2100 rpm. The hot air and the fine mist of solution will mix closely in the drying chamber resulting in the heat and mass transfer which will produce the powder product. The dried powder was then collected from glass bottles of both drying chamber and cyclone separator which are then mixed thoroughly and packed in aluminium foil pouches, sealed air tight using a hand sealer and stored at room temperature (25-30°C) for further analysis. Preparation of spray dried yoghurt powder is shown in Fig. 3.1.

3.6 QUALITY ANALYSIS OF SPRAY DRIED YOGHURT POWDER

3.6.1 Moisture Content

Moisture content was estimated by hot air oven method (No. 990.20; AOAC, 2005). About one g sample was weighed accurately and dried in a hot air oven at 100°C. The drying was continued till a constant weight was obtained. The moisture content was expressed as percentage. This procedure was replicated thrice and the average value was noted.

$$\text{Moisture content}\ (\%) = \frac{W_1 - W_2}{W_1} \times 100 \qquad .....3.3$$

Where,

W1 (g) = Initial weight of sample

W2 (g) = Final weight of sample

3.6.2 Colour Characteristics

The instrument used for colour measurement was Hunter lab colour flex meter (Hunter Association laboratory, Inc., Reston, Virgina, USA). Colour of the sample was measured by measuring 'L*', 'a*' and 'b*' values as described in 3.3.1.1. The spray dried yoghurt powder samples were placed over the colour measuring port of the flex meter and 'L*', 'a*', 'b*' values were recorded.

3.6.3 Water Activity

The water activity of spray dried yoghurt powder was carried out using Aqua lab water activity meter (M/s. Aqua Lab, U.S.A; model: Series 3TE). The yoghurt powder was filled in the disposable cups of the water activity meter and the measurement procedure was repeated as described in session 3.3.1.3.

3.6.4 Hygroscopicity

Hygroscopicity was resolved by the method proposed by Cai and Corke (2000). One gram of powdered samples were kept at 25°C in a container with NaCl saturated solution (75% RH). Samples were weighed following one week and hygroscopicity was expressed as g of moisture adsorbed per 100 g dry solids (g/100 g).

3.6.5 Total Soluble Solids

Total soluble solid (TSS) of yoghurt powder was measured using a hand refractometer (Erma inc, Tokyo). Spray dried yoghurt powder (5 g) was mixed with few drops of water and allowed 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).

3.6.6 pH

The pH of the reconstituted yoghurt powder was measured using a digital pH meter (M/s. Systonics, Naroda) available at KCAET, Tavanur. The electrode of pH meter was immersed in the sample to obtain pH. The reading was directly recorded in the pH meter. The procedure was repeated thrice and the average value was noted (AOAC, 1990).

3.6.7 Titrable Acidity

Acidity of powder sample was determined by titration method (No. 947.05 AOAC 2005). 10 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. This solution was titrated against 0.1N NaOH until the point that light pink end point showed up. Volume of 0.1N NaOH used was recorded. This procedure was carried out three times and the average value was considered as acidity of the sample. The acidity of yoghurt powder was calculated as per eqn.3.2.

3.6.8 Bulk Density

The bulk density of spray dried powder was measured by the methodology portrayed by Gong et al. (2008) and Lebrun *et al.* (2012). One g 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. Experiment was repeated for accuracy and average values were considered as loose bulk density of samples. It was computed using the following equation;

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

3.6.9 Reconstitution Properties of Spray Dried Yoghurt Powder

Reconstituted properties of food powders are important for its consumer acceptability and market quality. As per the specification provided, the milk powder should have the same chemical composition to that of milk from which it is prepared there fore the spray dried yoghurt powder are reconstituted, so that they contains the same total solids as fresh yoghurt. Reconstituted yoghurt was prepared using lukewarm distilled water (40°C -50°C). The water : powder ratio was kept as 1: 0.4 inorder to get the required consistency. Reconstitution properties such as solubility, wettability of spray dried yoghurt powder were determined using standard methods as described below.

3.6.9.1 Wettability

Wettability is the time in seconds expected to accomplish finish wetting of the spray dried yoghurt powder. For this, a glass funnel held on a stand and it was set over the beaker containing 100 ml of distilled water at room temperature. A glass rod was kept inside the funnel to obstruct its lower opening. To this setup, one gram sample was placed around the glass rod and after that the glass rod was lifted. The time taken for complete wetting of powder particles were noted using a stop watch. Determination of wettability was found out thrice for spray dried powder and the average value was considered as wettability of powder (Jinapong *et al.*, 2008, Falade and Omojola, 2010).

3.6.9.2 Solubility

Solubility of powder was measured by the methodology depicted by Chauca *et al.* (2005). One g of powder was blend with 100 ml of water at room temperature for 30 min. A 10 ml aliquot of the supernatant solution was placed to a 15 ml centrifuge tube and centrifuged for 30 min at 3000 rpm. The aliquot of the supernatant was then taken in a pre measured aluminum moisture dish, evaporated on a steam bath and dried in an oven at 105°C for 4h. The solubility was calculated as per equation

$$\text{Solubility}\ (\%) = \frac{10 \times \text{Solid in supernatant (g)}}{\text{sample weight (g)}} \times 100 \qquad \ldots..3.5$$

3.6.9.3 Vitamin C

The vitamin C content of the yoghurt powder was found out by the procedure as explained in section 3.3.1.6.

3.6.10 Statistical Analysis

Statistical analysis was carried out using completely randomised design (CRD) by Design expert software 7.0 was used to analyse the data. After appropriate analysis, data were suited in the tables according to the necessities of objectives for elucidation of results. Every trials in the investigation were led in triplicate and mean values were recorded. Statistical significance was examined by analysis of variance (ANOVA) for every response. The p-values were utilised as a tool to check the significance of each of the coefficients, which is important to understand the pattern of the mutual interactions between the test variables. Based on this, the best combination of product variables was standardised.

3.6.11 Physico-Chemical and Microbiological Properties of Optimised Yoghurt Powder

The physico-chemical properties of the optimised yoghurt powder was estimated as per the standard procedures as described in above section 3.6.

3.6.11.1 Average particle size

The average particle size of optimised product was done using particle size analyzer. A Zetasizer nano range of instrument, Horiba SZ 100, Japan which was available at Nano science and technology department, TNAU, Coimbatore was used to measure the mean diameter of the particles. The range of particles that can be resolved through this instrument is 0.6 nm – 6 μm. One milligram of sample was suspended in 10 ml of ethanol (99.5%) and the suspension was sonicated for 5 minutes in order to break powder agglomerates. Particle size distribution was observed during each measurement until the point that five progressive readings have turned out to be steady.

3.6.11.2 Microbiological analysis

The analysis was done for the determination of probiotic viability. MRS agar (De Man, Rogosa and Sharpe agar – M1926) and nutrient agar media were used for the microbial analysis. First is the sterilisation process in which agar media and glass wares were autoclaved at 121°C for 15 min to make them sterile.

To get 10^{-1} dilution, one gram of the powder sample was taken and added to 10 ml of sterile water blank. Suspension was shaken well for 10 to 15 min to get 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^{-7} dilutions with the sterile water blank. One ml aliquots from all dilutions were relocated to the sterile Petri dishes with respective agar media 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 a flat surface to have a uniform distribution. Plates were kept undisturbed until the agar gets solidify. After solidification, the plates were inverted and incubated at 42°C for 24 h. The colonies were counted after the incubation period and the number of colony forming units per milliliter of sample and survival rates were calculated by applying the following formulas:

$$\text{CFU / ml} = \frac{\text{Mean number of CFU's} \times \text{Dilution factor}}{\text{Volume of sample plated (ml)}} \qquad .....3.6$$

$$\text{Survival rate of bacteria (\%)} = \frac{\text{CFU/ml after spray drying}}{\text{CFU/ml before spray drying}} \qquad ......3.7$$

3.7 QUALITY IMPROVEMENT OF STANDARDISED YOGHURT POWDER USING SPICE EXTRACT

The flavoure of the yoghurt powder was improved by incorporating dried white pepper extract (C_1- 2%, C_2-2.5 % and C_3- 3%) and ginger extract (G_1-2%, G_2-3% and G_3-4%) at different combinations. The spices incorporated yoghurt product was spray dried at optimised operating parameters from the above processes.

Table 3.2 Product combination for flavor addition

White pepper extract (C)	Ginger extract (G)	Product Combination
C_1 (2.0%)	G_1 (2%)	C_1G_1
	G_2 (3%)	C_1G_2
	G_3 (4%)	C_1G_3
C_2 (2.5%)	G_1 (2%)	C_2G_1
	G_2 (3%)	C_2G_2
	G_3 (4%)	C_2G_3
C_3 (3.0%)	G_1 (2%)	C_3G_1
	G_2 (3%)	C_3G_2
	G_3 (4%)	C_3G_4

3.7.1 Physico-Chemical Characteristics of Flavoured Yoghurt Powder

The quality parameters like moisture content, water activity, colour, hygroscopicity, TSS, pH, titrable acidity, bulk density, wettability, solubility and vitamin C was determined as per the procedure explained under 3.6.

3.7.1 .1 Scanning electron microscopy (SEM)

Scanning electron microscopy (SEM) was used to determine the morphology of powder. 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, Quanta 250 scanning electron microscope which was available at TNAU. Powder sample was spread on double sided conductive carbon tap fixed on the stub and then placed the sample chamber of Low Vacuum or ESEM (Environmental Scanning Electron Microscope). The samples were observed under magnification of 2000x ,4000x and also 8000x by SEM. It was performed at an accelerating voltage of 10 kV, a working distance of 9.3 mm.

3.7.1.2 Crystallinity

X-ray diffraction is a typical method used to confirm the crystalline–amorphous state of dried products in a powder form. The measurement was carried out with the X-ray diffraction meter (DMAX-2AX Rigaku, Japan). Powder samples were set into sample holder for the powder X-ray diffraction and the surface was smoothened with glass slide.Three trials were done and the average value was considered as the actual state of spray dried powder.

3.7.1.3 Average particle size

The average particle size of optimisssed powder sample was carried out by the procedure as explained in the section 3.6.11.1.

3.7.2 Sensory Analysis of Flavoured Yoghurt Powder

The yoghurt prepared from powder was considered for their sensory attributes like appearance, flavour, and overall acceptability by a 9-point Hedonic scale test. Optimised yoghurt powders developed by spray drying method were reconstituted with normal water at 1:4 ratio during sensory analysis. The prepared products were evaluated for sensory characteristics by a panel of 12 judges. Freshly prepared yoghurt which was made prior to drying was kept as control for comparison. (Neto et al., 2015).

3.7.3 Statistical Analysis

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. Based on this and sensory evaluation, the final product was optimized.

3.8 SHELF LIFE STUDY OF THE DEVELOPED FLAVOURED YOGHURT POWDER

Flavoured yoghurt powder was packed in aluminium laminated pouches having 200 micron thickness and sealed using a hand sealing machine and subjected to storage studies . Sealed pouches were stored at both ambient (25 -30°C) and refrigerated conditions (4°C) for a period of three months. The effect of physical, chemical and microbiological characteristics during storage was studied. Samples were analysed at every 25 days interval and the best treatment was selected based on physicochemical properties and probiotic viability.

3.8.1 Quality Attributes for the Storage Study

Quality parameters like moisture content, water activity, colour, TSS, pH, titrable acidity, bulk density, wettability and solubility were determined by the procedure as explained in 3.6.

3.8.1.1 Determination of total bacterial count, E.Coli and fungi in the optimised yoghurt powder

Total bacteria count was determined by the procedure as described in section 3.6.11.2.

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a) Determination of E.coli

The analysis was done to observe the presence of *E.coli* in the optimised product of yoghurt powder. Tergitol 7 agar (T7 himedia – M616) media was used for the enumeration of *E.coli*. Serial dilution method was followed up to 10^{-3} dilution. T7 agar of 3.12 g was suspended in 100 ml distilled water and melted in a water bath. Sterilisation was done by autoclaving at 1.5 kg cm^{-2} pressure (121°C) for 15 min, then cooled to 45-50°C. Triphenyl Tetrazolium Chloride (TTC) solution (0.25ml of 1% TTC) was added into it and this media was poured into sterile Petri plates. Diluted sample of 0.1 ml from particular dilution was pipetted out into T7 agar plates and was spread uniformly using a sterilized 'L' rod. The plates were kept in an upright position for few minutes and incubated at 37°C for 18-24 hours. *E.coli* colonies are lime yellow in colour, occasionally with rust brown center and an yellow zone around (Anon., 1962).

E. coli/g = (Average count x dilution factor) / Volume plated (ml)

Confirmation of E.coli

Eosine –Methylene Blue (EMB) agar was liquefied, cooled to 50°C, filled into Petri dishes and permitted to solidify. The plates were dried at 56°C for 45 min, and cooled to room temperature. Distinctive yellow colonies from T7 plates were picked and streaked on to EMB plates by the streak technique. These plates were incubated at 37°C for 18-24 h. Well isolated colonies, 2-3 mm diameter with a greenish metallic sheen by reflected light and dark purple center by transmitted light was picked and sub cultured on TGA slants and incubated at 37°C for 18 -24 h. Green metallic sheen was caused by the precipitation of methylene blue in acid pH produced because of lactose fermentation by *E.coli* .

b) Determination of Fungi

The analysis was done to observe the presence of fungi in the optimised yoghurt powder sample. Potato dextrose agar (PDA – M096) media was used for the analysis of fungi. Serial dilution method was done up to 10^{-1} dilution. PDA agar of 3.9 g was suspended in 100 ml distilled water. The medium was heated to dissolve completely. Sterilization was done by autoclaving at 121°C (1.5 kg cm^{-2} pressure) for 15 min. Cooled media was filled into sterile Petri plates. Diluted sample (0.1 ml) from particular dilution was pipetted out into PDA agar plates and was spread uniformly using a sterilised 'L' rod. The plates were kept in an upright position for few minutes and incubated at 37°C for 24- 48 h.

3.9 COST ECONOMICS

Considering the fixed and variable costs, the cost of production of flavoured yoghurt powder was estimated. The fixed cost was calculated by using the following equation described by Palanisami *et al.*, 1997.

Fixed cost of unit/year = Initial cost of equipment x capital recovery factor ---- (3.8)

$$\text{Capital Recovery Factor (CRF)} = \frac{Ri \times (1+Ri)^n}{(1+Ri)^n - 1} \qquad \text{---- (3.9)}$$

Where,

R_i = rate of interest

n = life period of the equipment, years

The variable cost of unit was calculated by considering electricity charges, repairs and maintenance, raw materials and cost of labour.

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

This chapter deals with the results of various experiments conducted on flavoured yoghurt. The effect of various process parameters on the quality of the yoghurt powder was studied for optimisation. Storage studies of the developed yoghurt powder were also studied. The results are tabulated, analysed statistically and discussed in this chapter.

4.1 DETERMINATION OF PHYSICO-CHEMICAL PROPERTIES OF FRESH YOGHURT

The physico-chemical properties of fresh yoghurt relevant to this study were found and the results are presented in Table 4.1.

Table 4.1 Physico-chemical properties of fresh yoghurt

Properties	**Values ± SD**
Moisture (% wb)	82% ±2.01
Titrable Acidity (%)	0.87%± 0.03
Vitamin C (mg/g)	0.085±0.002
Water Activity	0.863±0.1
Colour	L^* = 90.95, a^*= -1.11 , b^*= 11.69
pH	4.5±1
TSS (°B)	6.5±1
Viscosity	223 cP

According to Koc *et al.* (2010), freshly prepared yoghurt contains 83± 1.03 (%wb) moisture content. Titrable acidity in the range of 0.97 to 1.32, pH variation within 3.85- 4.59 and vitamin C was observed as 0.088 mg. Viscosity of the yoghurt was observed as 250 cP. Water activity of prepared yoghurt was noted as 0.876.

4.2 STANDARDISATION OF PROCESS PARAMETERS FOR THE DEVELOPMENT OF SPRAY DRIED YOGHURT POWDER

Plate 4.1 Spray dried yoghurt powder

The spray drying study was conducted using a laboratory scale spray dryer (lab model vertical co-current SMST tall type spray dryer) under different processing conditions as per the experimental design. The experiment was done using maltodextrin and corn starch as carrier materials in different proportions and different operating parameters *viz.,* inlet air temperatures and feed rates as described in section 3.5. The main blower rpm of dryer was kept constant at 2100 rpm throughout the study. The outlet temperature and pressure in the drying chamber was kept as 60-65°C and 2 kg cm^{-2}, respectively. The process parameters were optimised based on the physico-chemical and microbiological properties of the developed yoghurt powder. The results of raw material combinations and spray drying parameters were statistically analysed using analysis of variance (ANOVA) for optimisation.

The effect of processing conditions *viz.*, carrier blend ratio, inlet air temperature and feed rate on physico-chemical properties, reconstitution properties and microbial analysis of spray dried yoghurt powder were studied and are described in following sections.

4.2.1 Physico-Chemical Properties of Spray Dried Yoghurt Powder

4.2.1.1 Effect of spray drying parameters on moisture content

The effects of spray drying parameters on moisture content of spray dried yoghurt powder are displayed in Fig. 4.1, 4.2 and 4.3. The moisture content values for each treatment were found to be significant. From Fig. 4.1, it was observed that the moisture content of the powder decreased considerably with increase in inlet air temperature. The moisture content varied from 6.41 to 9.10 per cent (wb). The moisture content of yoghurt powder made from carrier blend ratio B_1, feed rate 10 rpm and inlet air temperatures 160°C, 170°C, 180°C were 8.57, 7.69 and 6.46 per cent respectively. Similarly, the moisture content of yoghurt powder made from carrier blend ratio B_2, B_3, B_4 and B_5 at corresponding feed rate and inlet air temperatures were 8.27, 7.28 and 6.41 per cent; 8.32, 7.60 and 6.54 per cent; 8.87, 7.69 and 6.47 per cent and 9.10, 8.18 and 6.86 per cent, respectively. Yoghurt powder made from carrier blend ratio B_2 (3:1), feed rate 10 rpm (F_1) and inlet air temperature 180°C (T_3) showed the minimum moisture content (6.41%). Highest moisture content of 9.10 per cent was observed for sample made from B_5 at 160°C (Table 1-Appendix I).

Similar trend in moisture content was observed in tomato pulp powder (Gaoula and Adamapoulos, 2010) and whey powder (Chegini and Taheri, 2014). The moisture content was found to decreased with increase in maltodextrin concentration in the wall material blend (Anjineyulu *et al.,* 2014). Decrease in the moisture content with the increase in maltodextrin concentration was also observed in spray dried pineapple, it could be due to an increase in total solids in the feed and decreased availability of free water for evaporation (Abadio, *et al.,* 2004).

Similar trend was observed for feed rates at 12rpm (F_2) and 14rpm (F_3) (Fig. 4.2 and 4.3). From Fig. 4.2, it was observed that, yoghurt powder made from carrier blend ratio B_2 (3:1), feed rate 12 rpm (F_2) and inlet air temperature 180˚C (T_3) showed the minimum moisture content of 6.42 per cent. Highest moisture content of 9.24 per cent was observed for sample made from B_5 at T_1 treatment. Similarly, the minimum and maximum moisture content obtained for sample made at feed rate 14 rpm (F_3) were 6.43 per cent and 9.83 per cent, respectively (Fig. 4.3). Above results shows that moisture content increased significantly with increase in feed rate. However, a reverse effect was observed with inlet air temperature. According to Kha *et al.* (2010), the increase in feed rate will increase the flow of atomised liquid into the drying chamber producing larger liquid droplets. Larger droplets increase the space so that the moisture should travel from the center of the droplets to the surface, which leading to higher moisture content.

The effect of spray drying parameters on moisture content of spray dried yoghurt powder were statistically analysed and shown in Table 1 (Appendix II). Statistical analysis indicated that various spray drying parameters and carrier blend ratios showed significant effect ($p < 0.0001$) on moisture content.

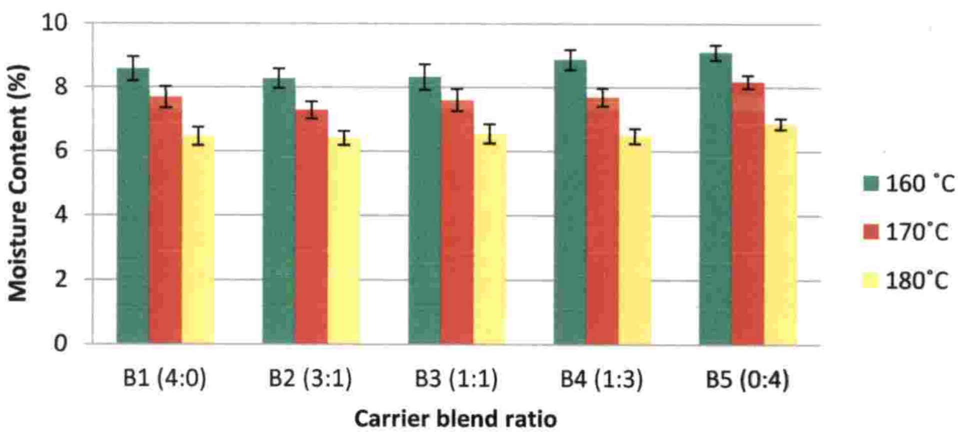

Figure 4.1 Moisture content of yoghurt powder at 10 rpm

70

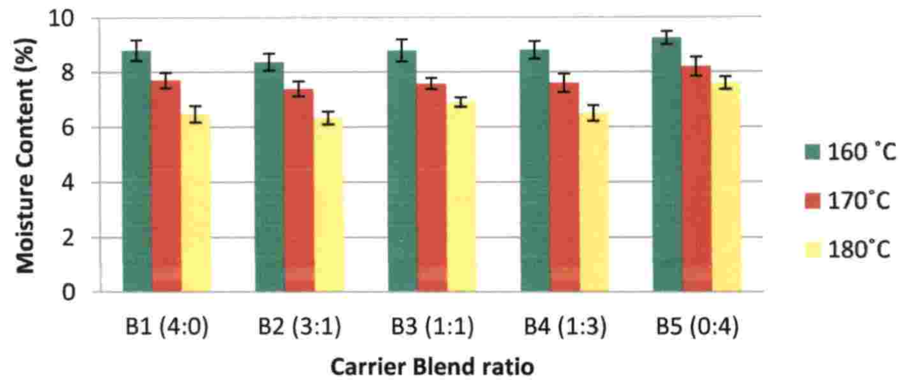

Figure 4.2 Moisture content of yoghurt powder at 12rpm

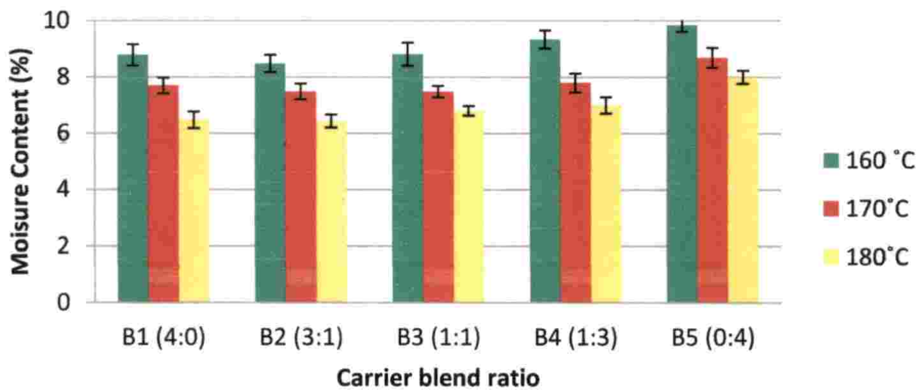

Figure 4.3 Moisture content of yoghurt powder at 14 rpm

4.2.2.2 Effect of spray drying parameters on water activity

Moisture content and water activity plays an essential role in all parts of general handling and storage of food powder. The products from industrial spray dryers had water activity about 0.2 - 0.29 (Adhikari *et al.*, 2003).

The impact of spray drying parameters of yoghurt powder on water activity is shown in Fig. 4.4, 4.5 and 4.6. From the figures, it is cleared that water activity values improved significantly with an increase in feed rate. But it decreased with increase in inlet air temperature. The highest water activity of 0.558 was observed at

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an air inlet temperature 160°C for carrier blend ratio B_5 at feed rate of 14 rpm. Similarly, the lowest water activity value of 0.247 was found at air temperature 180°C for blend ratio B_2 (3:1) at feed rate of 10 rpm . Fig. 4.4 shows that the water activity values of yoghurt powder ranges from 0.247 to 0.499 (Table 2- Appendix I).

According to Demertzis *et al.* (1989), as temperature increases the kinetic energy of the water molecules also increases and water absorbance at a given water activity will be low. Similar results were found in yoghurt powder experiment which was done by Koc *et al.* (2010). In this study, a minimum water activity value (0.096) was observed at the outlet air temperature of 84°C, inlet air temperature of 174°C and a maximum value of water activity (0.166) was noted at the outlet and inlet air temperatures of 66°C, 150°C, respectively.

The water activity of maltodextrin and corn starch was observed as 0.301 and 0.339, respectively (Sariga, 2015). Similar trend of results were observed in other feed rates, 12 rpm (F_2) and 14 rpm (F_3) and are presented as Table 2 (Appendix I). From Fig. 4.5, it was observed that, yoghurt powder made from carrier blend ratio B_2 (3:1), feed rate 12 rpm (F_2) and inlet air temperature 180°C (T_3) showed the minimum water activity of 0.253. Highest water activity of 0.517 was observed for sample made from B_5 at T_1 treatment. Similarly, the minimum and maximum water activity obtained for sample made at feed rate 14 rpm were 0.264 and 0.558, respectively (Fig. 4.6).

Lower water activity is achieved by increase in maltodextrin, in inlet air temperature and by decreasing the feed flow rate. Similar trend was observed by Fang and Bhandari (2011) in bayberry juice powder, Coralia *et al.* (2011) in guava powder, Fazaeli *et al.* (2012) in black mulberry juice powder.

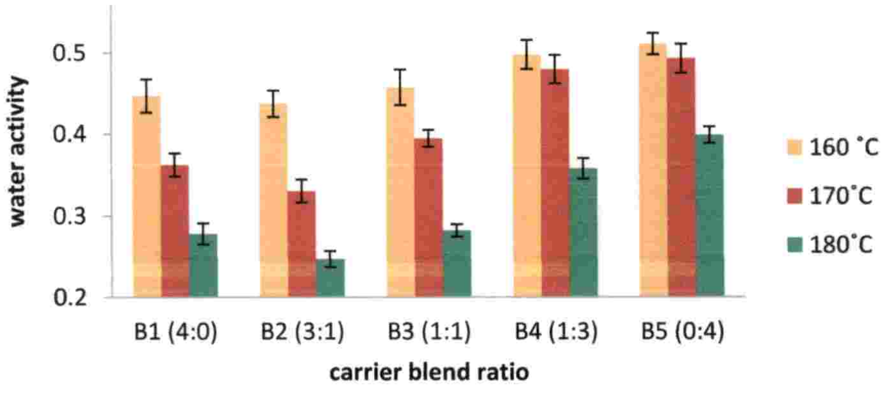

Figure 4.4 Water activity of yoghurt powder at 10 rpm

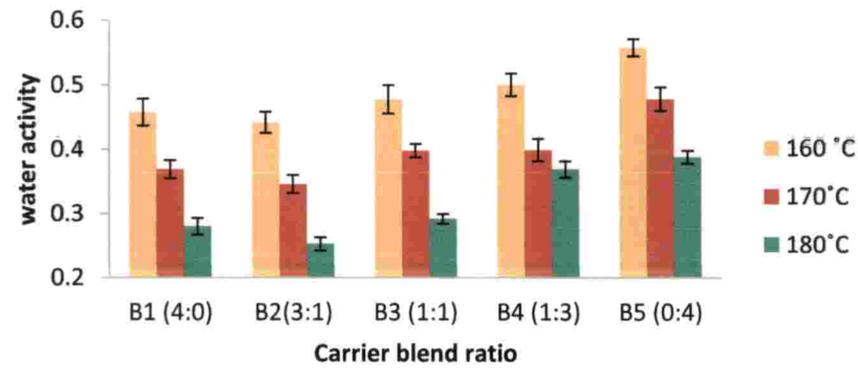

Figure 4.5 Water activity of yoghurt powder at 12 rpm

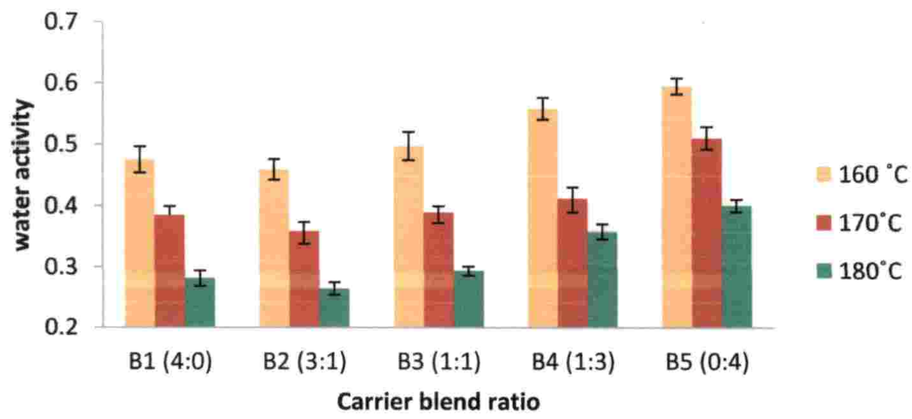

Figure 4.6 Water activity of yoghurt powder at 14 rpm

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The results were statistically analysed and presented in Appendix II as Table 2. Water activity values of yoghurt powder for each treatment were found to be highly significant ($p<0.001$).

4.2.2.3 Effect of spray drying parameters on hygroscopicity

Hygroscopicity is defined as the ability of food powder to absorb moisture from high relative humidity environment. It is an important property in case of powders, as stickiness is the main phenomenon normally faced during production, processing and storage of dried powders. The effect of spray drying parameters of yoghurt powder on hygroscopicity is shown in Table 3 (Appendix I).

Figure 4.7 shows the hygroscopicity at feed rate of 10 rpm. It is seen from the graph that hygroscopicity of powder increased with increase in inlet temperature. Minimum value of 14.66 g/100 g was observed for the carrier blend ratio B_2 at inlet air temperature 160°C and maximum value of 18.23 g/100 g for B_3 at 180°C followed by B_1. From the result, it is understood that the hygroscopic value has a reverse effect with product moisture content. The hygroscopicity of yoghurt powder made from carrier blend ratio B_1, feed rate 10 rpm and inlet air temperatures 160°C, 170°C, 180°C were 14.97, 16.87 and 18.2 g/100 g, respectively. Similarly, the water hygroscopicity of yoghurt powder made from carrier blend ratio B_2, B_3, B_4 and B_5 at corresponding feed rate and inlet air temperatures were 14.66, 16.65, 17.90 g/100 g ; 14.79, 18.23, 17.89 g/100 g ; 14.73, 16.87, 17.91 g/100 g and 14.75, 16.88, and 17.92 g/100 g, respectively.

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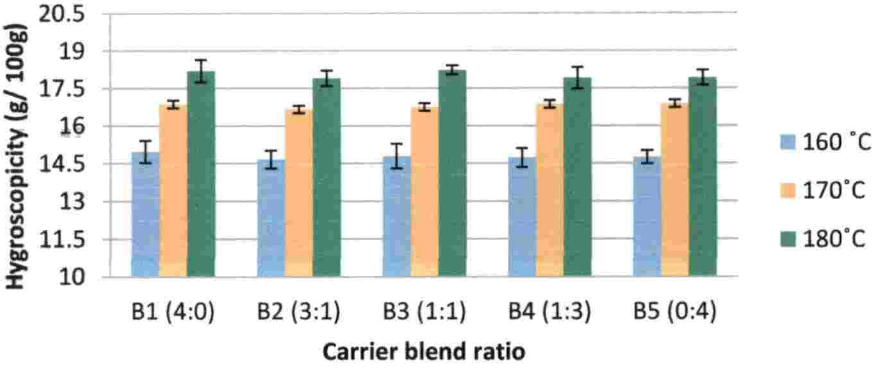

Figure 4.7 Hygroscopicity of yoghurt powder at 10 rpm

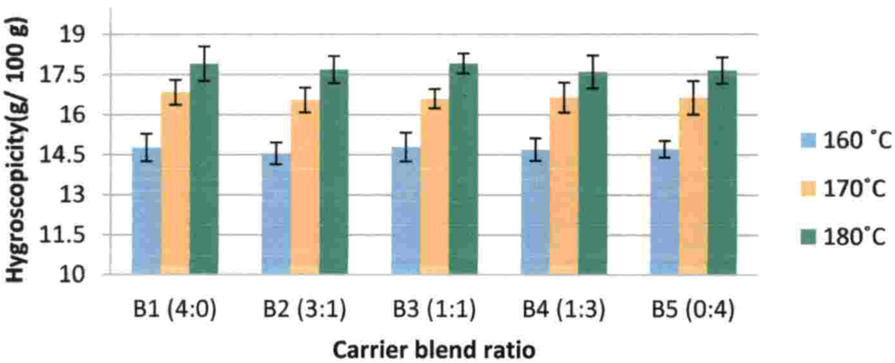

Figure 4. 8 Hygroscopicity of yoghurt powder at 12 rpm

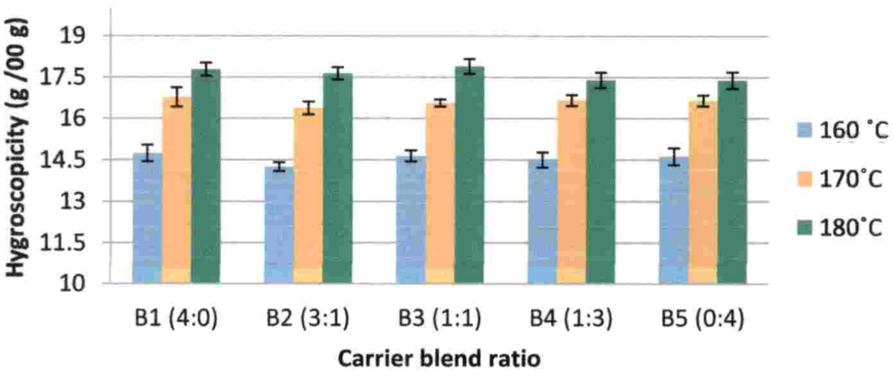

Figure 4.9 Hygroscopicity of yoghurt powder at 14 rpm

Fig. 4.8 and Fig. 4.9 shows the hygroscopicity at feed rates 12 rpm and 14 rpm, respectively. From Fig 4.8, it was observed that, yoghurt powder made from carrier blend ratio B_2 (3:1) and inlet air temperature 160°C (T_1) showed the minimum hygroscopicity of 14.55 g/100 g . Highest value 17.91 g/100 g was observed for sample made from B_3 at T_3 treatment. Similarly, the maximum and minimum hygroscopicity obtained for sample made at feed rate 14 rpm were 17.83 g/100 g and 14.25 g/100 g, respectively (Fig. 4.9). The powder which is having more maltodextrin showed less hygroscopicity than others. Similar trend of decrease in hygroscopicity with increase in maltodextrin concentration were also pointed out in spray dried acai powder by Tonon *et al.* (2008). Work done by Gaoula *et al.* (2010) on tomato powder also observed that the powder hygroscopicity increased in reverse with powder moisture content.

According to Tee *et al.* (2012) stated that the spray dried powder with less moisture content had improved capacity to absorb ambient moisture. Lower the powder moisture content, there will be more water concentration gradient between the powder and the surrounding water which supports the powder hygroscopicity.

Statistical results revealed a significant effect of different process parameters on hygroscopicity ($p<0.0001$) and are presented in Table 3 (Appendix II) .

4.2.2.4 Effect of spray drying parameters on bulk density

Bulk density values of developed yoghurt powders with various carrier blend ratios at various spray drying parameters were investigated and the results obtained were presented in Table 4 (Appendix I). Bulk density of spray dried yoghurt powder varies within the range of 0.45 - 0.72 g cm^{-3}.

The effect of drying parameters on bulk density at feed rate of 10 rpm is shown in Fig.4.10. From the figure, bulk density decreased with an increase in inlet air temperature. Yoghurt powder made from carrier blend ratio B_5 (0:1), feed rate 10 rpm (F_1) and inlet air temperature 180°C (T_3) showed the minimum bulk density of 0.45g cm^{-3}. Maximum bulk density of 0.68 g cm^{-3} was observed for sample made from B_3 at 160°C . The bulk density of yoghurt powder made from carrier blend ratio B_1, feed rate 10 rpm and inlet air temperatures 160°C, 170°C, 180°C were 0.67, 0.59 and 0.48 g cm^{-3}, respectively. from carrier blend ratio B_2, B_3, B_4 and B_5 at corresponding feed rate and inlet air temperatures were 0.66, 0.58 and 0.49 g cm^{-3}; 0.68, 0.53 and 0.46 g cm^{-3}; 0.65, 0.52 and 0.45 g cm^{-3}; 0.64, 0.50 and 0.45 g cm^{-3}, respectively.

Figure 4.11 and 4.12 shows the effect of drying parameters of yoghurt powder on bulk density at feed rates 12 and 14 rpm, respectively. From Figure 4.11, it was observed that, yoghurt powder made from carrier blend ratio B_5 (0:1) with inlet air temperature 180°C (T_3) showed the minimum bulk density of 0.47 g cm^{-3}. Highest value of 0.70 g cm^{-3} was observed for sample made from carrier blend ratio B_3 at 160°C . Similarly, the minimum and maximum bulk density obtained for sample made at feed rate 14 rpm were 0.48 g cm^{-3} and 0.72 g cm^{-3}, respectively (Fig. 4.12). Increase in bulk density values were observed with increased feed rate. Highest bulk density values were recorded for the feed rate of 14 rpm (F_3).

Since the bulk density of corn starch is less than maltrodextrin, minimum values were observed for corn starch rich carrier blend ratios (Sariga, 2015). Increase in bulk density with increase in maltodextrin was noted in case of spray dried pineapple juice powder because of the lower moisture content of the products and less void spaces (Abadio *et al.*, 2004). Similar result had been reported in spray dried dahi powder (Anjineyulu *et al.*, 2014).

Saranya (2016) observed that the bulk densities of spray dried banana pseudostem juice powder reduced 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 190°C. Thus at elevated temperature micro particles become hollowed and results in low bulk density

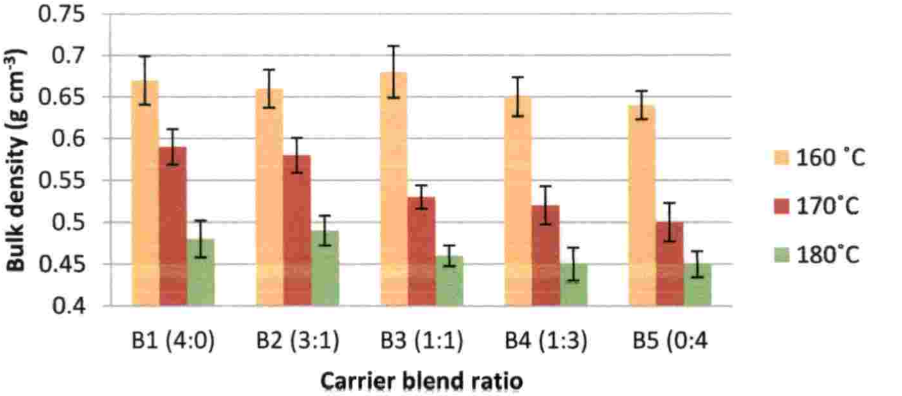

Figure 4.10 Bulk density of yoghurt powder at 10 rpm

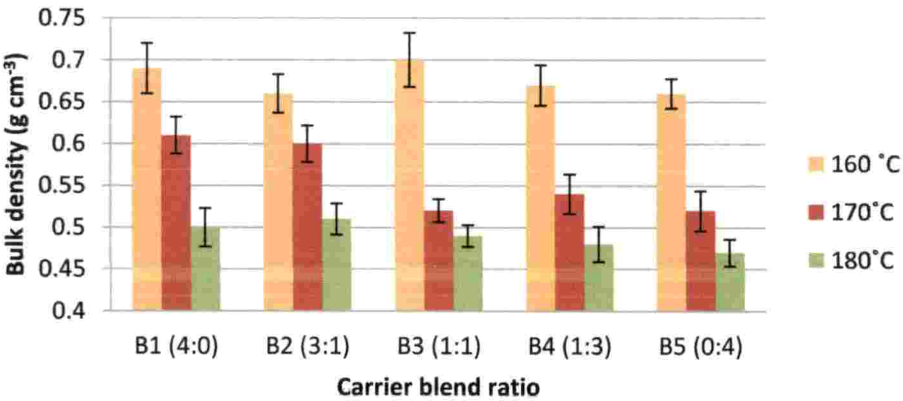

Figure 4.11 Bulk density of yoghurt powder at 12 rpm

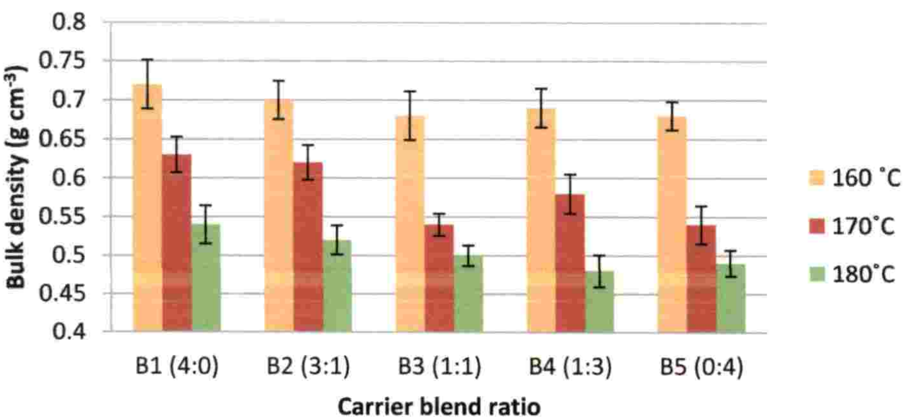

Figure 4. 12 Bulk density of yoghurt powder at 14 rpm

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The results from statistical analysis showed that the spray drying parameters had a significant effect on bulk density ($p<0.001$). But the interaction among the process variables showed less significance on bulk density. The ANOVA related with completely randomised design was executed and presented in Table 4 (Appendix II).

4.2.2.5 Effect of spray drying parameters on Color

Colour of a product is an important quality parameter in terms of acceptance. The effect of process parameters of yoghurt powder on colour is shown in Fig. 4.13, 4.14 and 4.15. From the figures, it was observed that the Hunter 'L*' values varied from 91.08 to 95.33; 91.50 to 94.64 and 91.06 to 94.18 at feed rates 10 ,12 and 14 rpm, respectively. The corresponding 'a*' and 'b*' values for these feed rates were -0.71 to 0.56; -0.89 to 0.56 and -0.89 to -0.24; 7.9 to 10.71; 7.90 to 10.71 and 8.52 to 10.71, respectively (Table 5, 6 and 7 in Appendix I). Yoghurt powder made from carrier blend ratio B_5, and inlet air temperature 160°C showed the maximum 'L*' value of 95.08 at 10 rpm. Minimum 'L*' value of 91.08 was observed for sample made from B_3 at 180°C . From the figures, it is observed that 'L*' values decreased with an increase in inlet air temperature. It showed almost similar variation for all feed rates. ΔE values of different carrier blend ratios were calculated and the sample with least ΔE value (1.866494) was observed as B_2 at 10 rpm (Table 8- Appendix I).

Anjineyulu *et al.* (2014) had conducted study on spray dried dahi powder. A gradual decrease in 'L*' values was observed in the case of inlet air temperatures (160°C -180°C). The least value of 91.05 was noted at inlet temperature of 180°C. Similar observation was reported by Falade and Omojola (2010). They found that at higher temperature, the emulsions are subjected to high intensity heat that may lead to burning, structural changes and increase in retention rates resulted in the lowering of 'L' values.

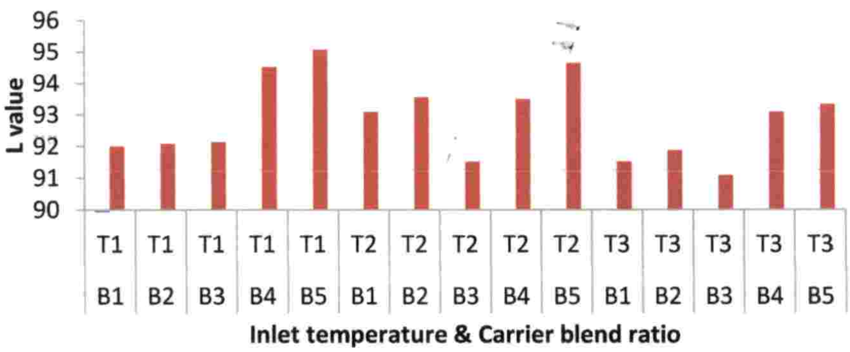

Figure 4.13 Hunter 'L' values of yoghurt powder at 10 rpm

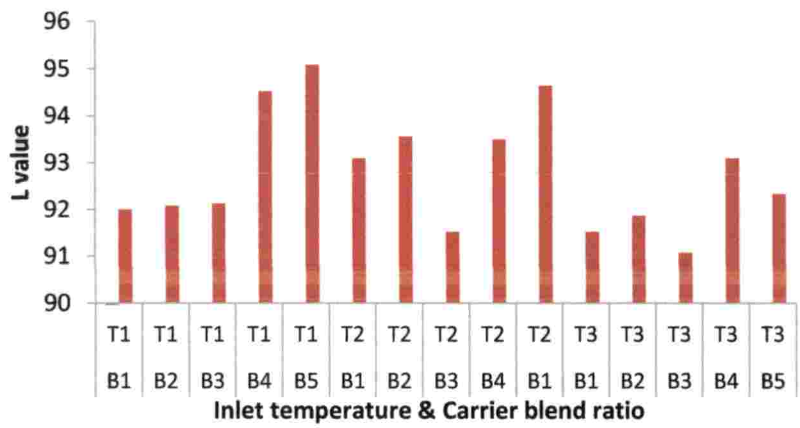

Figure 4.14 Hunter 'L' values of yoghurt powder at 12 rpm

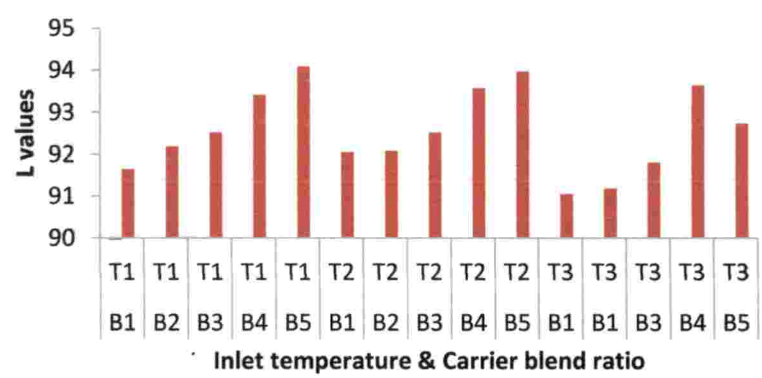

Figure 4.15 Hunter 'L' values of yoghurt powder at 14 rpm

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The results of colour values ('L*', 'a*' and 'b*') of spray dried yoghurt powder were statistically analysed and presented in Table 5, Table 6 and Table 7 (Appendix II), respectively. ANOVA result table indicates that all variables had significant effect ($p<0.0001$) on color of yoghurt powder.

4.2.2.6 Effect of spray drying parameters on pH and titrable acidity

Powders were reconstituted with distilled water for measuring pH. It was observed that the pH of the reconstituted solutions were significantly higher than the fresh yoghurt. The pH and titrable acidity values of yoghurt powder with respect to the spray drying parameters are given in Table 4.2 and 4.3. Table 4.3

Maximum pH value of 4.70 was recorded at 160°C for carrier blend ratio B_1 (4:0) at feed rate 10 rpm and the minimum value 3.58 was recorded at 180°C for blend ratio B_5 (0:4) at feed rate 14 rpm. The titrable acidity of yoghurt powder was in the range of 0.99 and 1.29 per cent. Maximum titrable acidity value was recorded at 180°C for blend ratio B_2 (3:1) at feed rate 14 rpm and the minimum value was recorded at 160°C for carrier blend ratio B_1 (4:0) at feed rate 10rpm. From the results, it is observed that pH of yoghurt powder decreased with an increase in feed rate and inlet air temperature. However, a reverse effect was observed with titrable acidity. Similar observations were found out by Koc *et al.* (2010) on optimisation study of spray dried yoghurt.

4.2.2.7 Effect of spray drying parameters on Total soluble solids (TSS)

The TSS of reconstituted powder solution was found in the range of 8 - 9° B. Result shows that there is no significant change in TSS among the variables. TSS of raw yoghurt was within the range of 6.5 -7°B. The increase in TSS value may due to the addition of carrier materials. Nithya *et al.* (2014) suggested that increase in TSS of pseudostem juice powder was because of the addition of maltodextrin.

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Table 4.2 pH values of yoghurt powder

Carrier Blend ratio	Feed rate (10 rpm)			Feed rate (12 rpm)			Feed rate (14 rpm)		
	160°C	170°C	180°C	160°C	170°C	180°C	160°C	170°C	180°C
B_1(4:0)	4.70	4.48	4.39	4.39	4.35	4.30	4.23	3.97	3.89
B_2(3:1)	4.44	4.61	4.40	4.38	4.31	4.31	4.22	4.04	3.89
B_3(1:1)	4.68	4.49	4.36	4.32	4.30	4.30	4.24	3.95	3.87
B_4(1:3)	4.61	4.46	4.37	4.37	4.34	4.29	4.26	3.92	3.84
B_5(0:4)	4.63	4.48	4.31	4.32	4.30	4.25	3.91	4.12	3.58

Table 4.3 Titrable acidity values of yoghurt powder

Carrier Blend ratio	Feed rate (10 rpm)			Feed rate (12 rpm)			Feed rate (14 rpm)		
	160°C	170°C	180°C	160°C	170°C	180°C	160°C	170°C	180°C
B1(4:0)	1.03	1.06	1.12	1.19	1.14	1.23	1.23	1.24	1.25
B2(3:1)	1.02	1.03	1.1	1.06	1.17	1.17	1.24	1.2	1.29
B3(1:1)	1.09	1.09	1.15	1.03	1.19	1.18	1.23	1.21	1.27
B4(1:3)	1.07	1.06	1.11	1.15	1.12	1.14	1.21	1.2	1.25
B5(0:4)	0.99	1.05	1.12	1.06	1.12	1.21	1.21	1.24	1.22

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4.2.2.8 Effect of spray drying parameters on Vitamin C

Vitamin C content of freshly prepared yoghurt was reported as 0.085-0.091 mg. The reconstituted yoghurt powder solution contains 0.076-0.084 mg of vitamin C (Table 4.4). No significant increase or decrease was observed for vitamin C in all cases.

The impact of spray drying parameters on vitamin C content of yoghurt powder were statistically analysed and presented in Table 10 (Appendix II) .Statistical analysis shows insignificant effect on various spray drying parameters.

Table 4.4 Vitamin C content of yoghurt powder

Carrier Blend ratio	Feed rate (10 rpm)			Feed rate (12 rpm)			Feed rate (14 rpm)		
	160^{0}C	170°C	180°C	160^{0}C	170°C	180°C	160^{0}C	170°C	180°C
B1(1:0)	0.084	0.083	0.078	0.084	0.083	0.078	0.084	0.083	0.078
B2(3:1)	0.085	0.080	0.077	0.085	0.078	0.077	0.085	0.078	0.077
B3(1:1)	0.084	0.081	0.076	0.084	0.081	0.072	0.084	0.081	0.072
B4(1:3)	0.084	0.075	0.073	0.084	0.075	0.073	0.084	0.075	0.073
B5(0:1)	0.08	0.078	0.072	0.08	0.078	0.072	0.08	0.078	0.072

4.2.3 Reconstitution Properties of Spray Dried Yoghurt Powder

4.2.3.1 Effect of spray drying parameters on Solubility

The effect of spray drying parameters on solubility is shown in Fig. 4.16, 4.17 and 4.18. From the figures, it is observed that solubility of yoghurt powder reduced with improved inlet air temperature for all feed rates. But, a reverse effect was observed with feed rate. Figure 4.16 shows the solubility of yoghurt powder at 10

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rpm feed rate. Highest solubility value of 71.32 per cent was acquired from carrier blend ratio B_2 at 160°C and lowest value of 67.87 per cent was obtained from carrier blend ratio B_3 at 180°C (Table 9 – Appendix I). Koc *et al.* (2014) observed that the solubility of powder sample considerably decreased with the increase in inlet air temperature. It might be because of the high degree of protein denaturation at high inlet temperature.

Fig. 4.17 and 4.18 show the effect of variables on solubility at feed rates 12 and 14 rpm. From Fig. 4.17, it was observed that, yoghurt powder made from carrier blend ratio B_2 (3:1), feed rate 12 rpm (F_2) and inlet air temperature 160°C (T_1) showed the maximum solubility of 71.42 per cent and minimum solubility value of 68.66 per cent was observed for sample made from carrier blend ratio B_1 at temperature 180°C. Similarly, the minimum and maximum solubility obtained for sample made at feed rate 14 rpm were 68.71 per cent and 71.62 per cent, respectively for B_3 (Fig. 4.12).

According to Chegini and Ghobadian (2007), the decreasing trend of solubility with increase in inlet temperature could be due the result of inlet air temperature on particle size. Elevated air temperature helps in forming larger particle size that expanded the dissolving time of the powder. This was due to the formation of a rigid surface film just above the powder particles. Similar findings were detected on spray dried watermelon powder by

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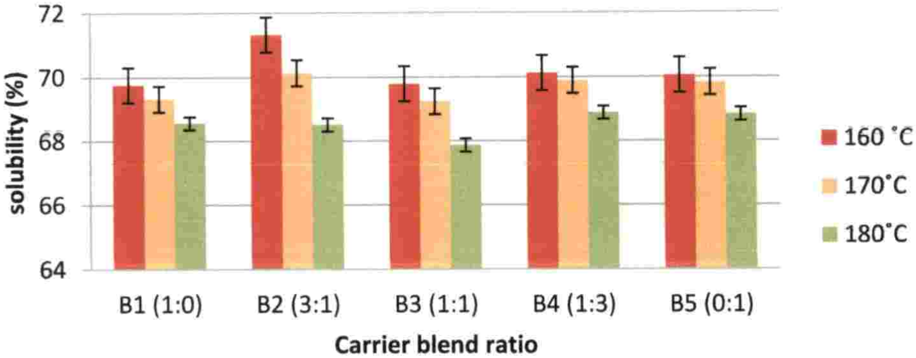

Figure 4.16 Solubility of spray dried yoghurt powder at 10 rpm

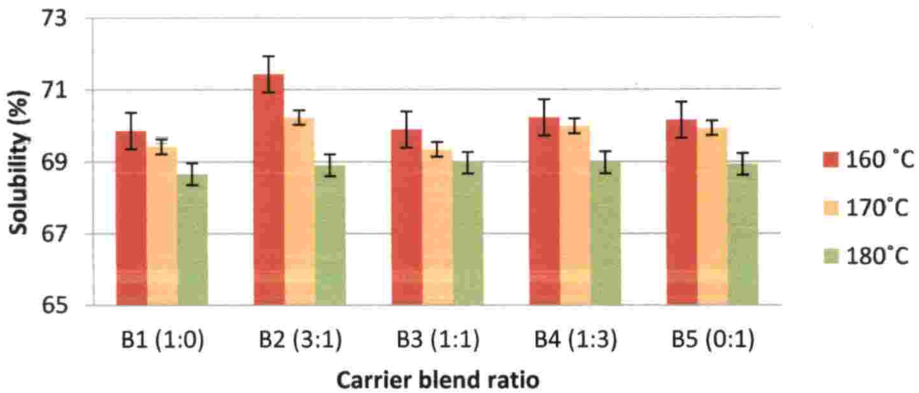

Figure 4.17 Solubility of spray dried yoghurt powder at 12 rpm

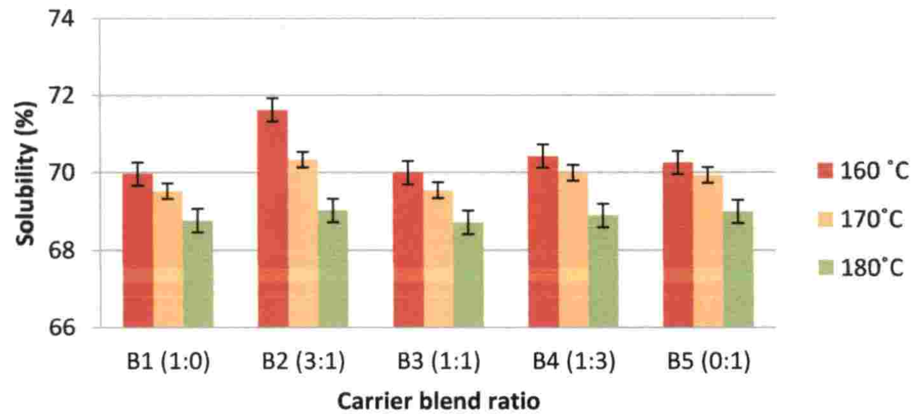

Figure 4.18 Solubility of spray dried yoghurt powder at 14 rpm

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Quek *et al.* (2007). They described it by the higher tendency of agglomeration at lower inlet temperatures, resulted in more reconstitution of the powders.Statistical analysis was done for verifying the significance of independent variables on solubility in all feed rates. The ANOVA for the solubility parameters are presented in Table 11 (Appendix II).

4.2.3.2 Effect of spray drying parameters on wettability

Wettability is the time required to achieve complete wetting of spray dried powder. The wettability of yoghurt powder at feed rates 10, 12 and 14 rpm are shown in Fig. 4.19, 4.20 and 4.21 (Table 10 – Appendix I).

From the figure, it is shown that the wettability increased with an increase in inlet air temperatures, concentration of maltodextrin and feed rates. The maximum and minimum wettability values at different feed rates were 611 and 335 s, respectively. Fig. 4.19 shows the wettability values of yoghurt powder at feed rate 10 rpm. Highest value of 580 s was observed at 180°C having carrier blend ratio B_3 and lowest value of 335 s was noted for the carrier blend ratio B_2 at 160°C. Similar trend was recorded for feed rates of 12 rpm and 14 rpm (Figure 4.20 and Figure 4.21). Maximum wetting time of 595 s and minimum wetting time of 347 s were observed at 12 rpm (F_2). At 14 rpm (F_3), 357 s to 611 s variation was observed.

. Fang *et al.* (2008) stated that moisture content variation in powder and lower dissolution property of maltodextrin were the cause for increased wettability. Marabi *et al.* (2007) and Millqvist-Fureby *et al.* (2001) reported that the poorer wettability is due to the lower dissolution rates and it could be connected to the reduced solubility of the denatured protein. Statistically analyse was done using analysis of variance (ANOVA). The parameters viz., inlet air temperature and feed rate had a high significant effect on wettability. The ANOVA table is presented in Table 12 (Appendix II).

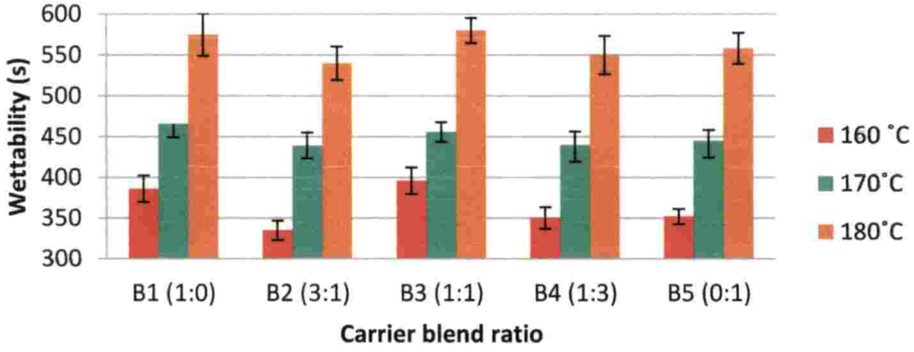

Figure 4.19 Wettability of spray dried yoghurt powder at 10 rpm

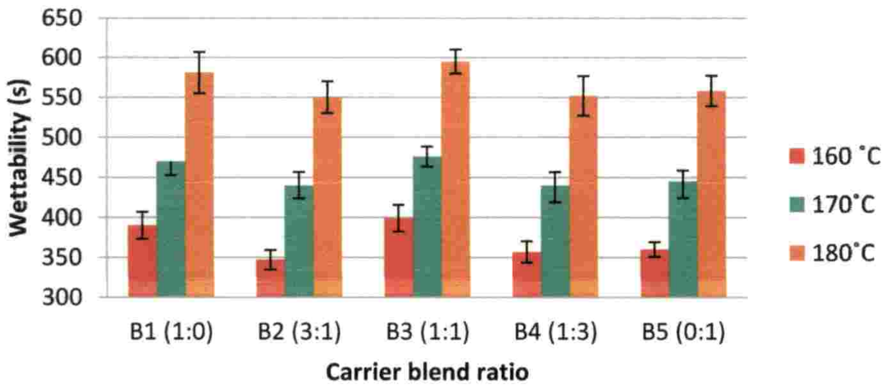

Figure 4.20 Wettability of spray dried yoghurt powder at 12 rpm

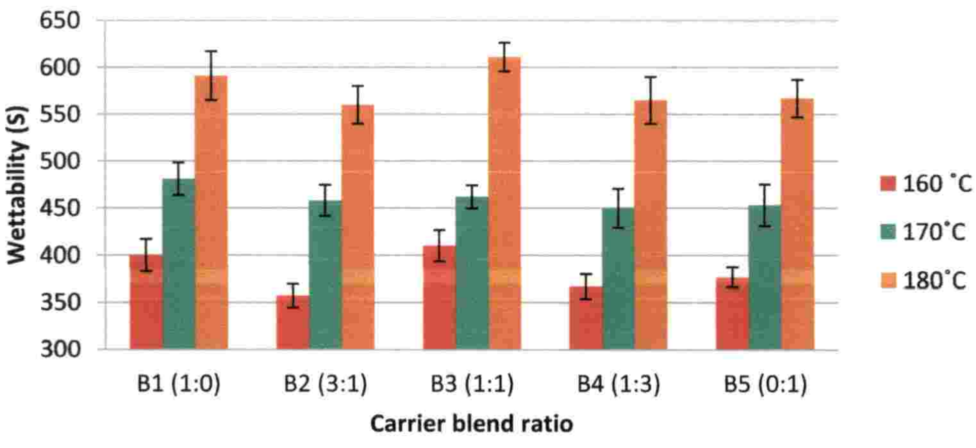

Figure 4.21 Wettability of spray dried yoghurt powder at 14 rpm

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4.3 OPTIMISATION OF PROCESS PARAMETERS

Yoghurt powder was prepared by spray drying technique following which the various process parameters which could influence the quality characteristics of the powder were studied as per the experimental design. The effect of the carrier blend ratio (maltodextrin and corn starch), inlet air temperature and feed rate on the quality attributes were determined and discussed in section 4.2.

Table 4.5 Standardised spray drying parameters for yoghurt powder

Properties	Desirability	Carrier blend ratio	Feed rate	Inlet air temperature
Moisture content	Minimize	B_2	10 rpm	180°C
Water activity	Minimize	B_2	10 rpm	180°C
Colour	Maximize	B_5	10 rpm	160°C
Solubility	Maximize	B_2	14 rpm	170°C
Vitamin C	Maximize	B_2	10 rpm	170°C
Hygroscopicity	Minimize	B_2	14 rpm	160°C
pH	In range	B_1	10 rpm	160°C
Titrable acidity	In range	B_5	10 rpm	170°C
Bulk density	Minimize	B_5	10 rpm	180°C
Wettability	Minimize	B_2	10 rpm	160°C

Based on the results and the related discussion, and the evaluation result obtained from the design expert software (Table 4.5), the process parameters responsible for yielding optimum product quality were found out with desirability of 0.734 during statistical analysis and are presented in Table 4.6.

Table 4.6 Optimised spray drying parameters for yoghurt powder

Process parameters	**Optimised Conditions**
Carrier blend ratio	B_2 (3:1)
Inlet air temperature (°C)	170°C
Feed flow rate	10 rpm

4.3.1 Probiotic Viability

The optimised product was then subjected to microbiological analysis to ensure the viability of bacteria after spray drying as described in chapter III.

Table 4.7 Probiotic viability of optimised sample at different inlet temperatures

	Temperature (°C)	Probiotic Viability (*L. bulgaricus and Streptococcus thermophilus)* (cfu ml^{-1})	Survival rate (%)
Yoghurt	Room Temperature	1.86×10^7	
Yoghurt Powder	160	4.09×10^6	21.83
	170	3.5×10^6	18.81
	180	4.01×10^5	2.15

The viability of total lactic acid bacteria and their survival rates at various inlet air temperatures are presented in Table 4.. The total viable cell counts of *Lactobacillus bulgaricus* and *Streptococcus thermophilus* before the spray drying process was observed as 1.86×10^7 cfu ml^{-1}. After the drying process it reduced to 4.09×10^6 cfu ml^{-1}, 3.5×10^6 cfu ml^{-1} , 4.01×10^5 cfu ml^{-1} at an inlet temperature of 160, 170, 180°C, respectively with survival ratio of 0.219, 0.188 and 0.021 per cent. From this, it could be concluded that survival rate decreases with increase in inlet air temperature. Similar observation was reported by Kim and Bhowmik (2000) on

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spraying of dairy products. According to them, number of *L. bulgaricus* decreased with increased inlet air temperature and atomising air pressure during the spray drying process.

The short residence time of spray drying shows that the air should enter at a high temperature in order to attain the required heat for water evaporation. The survival rate of microbes is related to the air dryer's outlet , inlet temperatures and the initial number of surviving yoghurt bacteria before drying. The survival proportion of lactic acid bacteria reduced with increasing outlet and inlet air temperatures, basically because of the thermal degradation of microorganism. This result agrees with the study of Riveros *et al.* (2009) who related the viability of a probiotic strain of *Lactobacillus acidophilus* to the spray dryer air outlet temperature. They set the spray dryer operating conditions close to or below 60°C at the air outlet point to get a product with good viability.

In this study, by considering the survival rate of bacteria, other quality parameters of yoghurt powder and also on the basis of thorough review, the inlet air temperature for the spray drying process was optimised as 170°C .

4.3.2 Average Particle Size

Spray dried products are commonly nonhomogeneous. For nonhomogeneous systems, with particle size distribution, the voids between big particles are occupied with smaller particles, which cause an expansion of the bulk density (Schubert, 1987). Figure 4.29 Particle size of flavoured yoghurt powder. It could be seen that the yoghurt powder had a narrower particle size vary with a relatively uniform distribution. The particle size of the developed yoghurt powder differed from 78.4 nm to 419.6 nm. These results showed that spray drying did not contain large particles. The lower the particle size, the lower the solubility and flowability of the spray dried powder (Kurozawa *et al.,* 2009).

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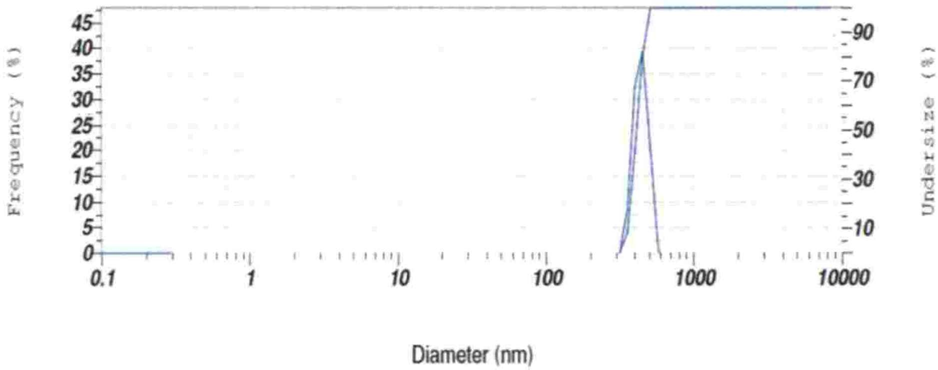

Figure 4.22 Average particle diameter

4.4 Quality Improvement of Spray Dried Yoghurt Powder Using Spices

The flavoured yoghurt powder was prepared by incorporating dried white pepper extract (C_1- 2%, C_2-2.5 % and C_3- 3%) and ginger extract (G_1-2%, G_2-3% and G_3-4%) at different combinations. The spices incorporated yoghurt product was spray dried at optimised operating parameters (Carrier blend ratio; B_2 (3:1), inlet air temperature; 170°C and feed rate; 10 rpm). The physico-chemical properties, reconstitution properties, microbial analysis of spray dried flavoured yoghurt powder were determined and are discussed in following sections.

4.4.2 Physico-Chemical Properties of Spray Dried Flavoured Yoghurt Powder

4.4.2.1 Moisture content

Only a little variation was recorded with the addition of spices. Variation ranges in between 6.90 to 7.03 per cent (wb) which is shown in Table 4.7. Minimum moisture content of 6.90 per cent was observed for the spice combination C_3G_3 and maximum of 7.03 per cent was for C_1G_1 (2% white pepper extract and 2% ginger extract).

The low moisture content of flavoured yoghurt may due to the increase in TSS value of the product. Dahi powder without addition of maltodextrin contains 8.2% of the moisture and then it has been reduced to 3.2% when maltodextrin

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concentration was raised to 12.5% due to the increase in solid concentration in the feed solution (Anjineyulu *et al.*,2014). As the total solid content in feed increased, the available water for evaporation gets decreased which led to the reduction in moisture content.

Saranya (2016) found that moisture of the fortified pseudostem powder was found to be in the range of 3.64- 4.5% (w.b). Feed with 30% horse gram extract and 50% milk exhibited the lowest moisture value of 3.64%, ie, TSS value of this feed is more than that of other combinations. As the total solid content increases, moisture content decreases.

Statistical studies showed that moisture content of flavoured yoghurt powder for each treatment were found to be insignificant (Table 1- Appendix IV).

4.4.2.2 Water activity

The water activity values ranged from 0.331 to 0.435 (Table 4.7). Maximum water activity was obtained for C_1G_1 treatment and minimum for C_3G_3. Water activity variation was observed similar to moisture content. The low water activity may due to the increase in TSS content of the product. Abadio *et al.* (2004) stated that an increase in the maltodextrin concentration resulted decrease in the moisture content and water activity, mostly due to an improvement in total solids in the feed and decreased amount of free water for evaporation.

Statistical analysis showed that water activity values had an insignificant effect on each variable and the ANOVA table is presented in Table 2 (Appendix IV).

4.4.2.3 Bulk density

The bulk density values showed only a little variation (Table 4.7). Minimum value of 0.58 g cm^{-3} was observed for both C_1G_1 and C_3G_2 and maximum of 0.63 g cm^{-3} was for C_3G_3. Chegini and Ghobadian (2007) and Kha *et al.* (2010) revealed that an increase in feed concentration leads to a decrease in particle volume, thus

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increase in bulk density. Anjineyulu *et al.* (2014) showed that density of dahi powder without addition of maltodextrin was 0.444 g cm^{-3} and was increased to 0.714 g cm^{-3} in sample containing 12.5% maltodextrin. Saranya (2016) conducted a study on development and quality evaluation of microencapsulated banana pseudostem juice powder and she described that milk fortified banana pseudostem juice powder having high concentration of horse gram extract and milk (30% horse gram extract and 50% milk) showed the highest bulk density values of 0.431 and 0.543 g ml^{-1} . Sarabandi *et al.* (2014) found that bulk density of spray dried grape increased with increased feed concentration because of the formation of heavy, solid spheres with high density.

Statistical analysis of product exhibited insignificant variation with each variables and the ANOVA table related with the bulk density values are presented in Appendix IV as Table 3.

4.4.2.4 Hygroscopicity

Table 4. shows the effect of flavor concentration on hygroscopicity of flavored yoghurt powder. The minimum hygroscopicity value of 14.84 g/100 g was obtained for C_2G_2 (2.5% white pepper extract and 3% ginger extract) and maximum of 15.86 g/100 g was observed for C_3G_2 (3% white pepper extract and 3% ginger extract). In this case also little changes were observed. From the result, it is understood that hygroscopicity increased with a decrease in spice concentration. Decrease in hygroscopicity of fruit powder with increase in maltodextrin concentration were found in acai (*Euterpeoleraceae*) powder produced by spray drying (Tonon, *et al.*, 2008). The drying aids decreased the powder hygroscopicity, especially cashew tree gumwas found out by Germano *et al.* (2009).

Statistical analysis of product exhibited insignificant variation with each variables and the ANOVA table related with the hygroscopicity values are presented in Appendix IV as Table

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Table 4.8 Moisture content, Water activity, Hygroscopicity and Bulk density values of flavoured yoghurt powder

Spice combination	MC (%)	Water activity	Hygroscopicity (g/100 g)	Bulk Density (g cm^{-3})
C_1G_1	7.03	0.435	15.6	0.58
C_2G_1	7.00	0.434	15.63	0.61
$C_3 G_1$	6.99	0.361	15.65	0.59
C_1G_2	7.01	0.369	15.81	0.62
C_2G_2	6.98	0.356	14.84	0.60
C_3G_2	6.95	0.344	15.86	0.58
C_1G_3	6.94	0.344	14.88	0.59
C_2G_3	6.91	0.332	15.00	0.60
C_3G_3	6.90	0.331	15.02	0.63
Control Sample (plain yoghurt powder)	7.38	0.39	16.86	0.58

4.4.2.5 Colour characteristics

The L* values of flavoured yoghurt powder is shown in Table 4.9. Only an insignificant difference was observed in the case of 'L*' values. The maximum L* value was observed for the spice combination C_1G_2 (2% white pepper extract and 3% ginger extract). Corresponding a* and b* values were observed as 0.03, 15.29 respectively. Minimum L* value was observed for highest spice concentration. Combination C_3G_3 (3% white pepper extract and 4% ginger extract) showed minimum values of L*, a* and b* (83.26, 1.21, 15.71).

Statistical analysis of product exhibited insignificance and the ANOVA table related with the colour values are presented in Appendix IV as Table 4, Table 5. Only b* values exhibited significant effect with spice concentrations (Table 6). 94

Table 4.9 Colour values of flavoured yoghurt powder

Spice combination	L*	a*	b*
C_1G_1 (2:2)	87.53	0.24	15.27
C_2G_1(2.5:2)	87.56	-0.15	18.18
C_3 G_1(3:2)	87.55	-0.34	14.82
C_1G_2 (2:3)	87.71	0.03	15.29
C_2G_2(2.5:3)	87.62	-0.61	16.87
C_3G_2(3:3)	87.69	-0.66	15.08
C_1G_3(2:4)	83.69	-0.51	12.32
C_3G_3(2.5:4)	83.45	-0.14	16.36
C_3G_3(3:4)	83.26	1.21	15.71
Control Sample	91.56	-0.34	9.81

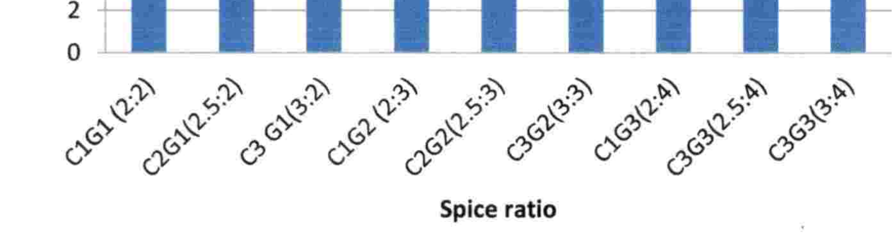

Figure 4. 23 ΔE values of flavoured yoghurt powder

Fig. 4.23 shows the total colour differene (ΔE) of flavoued yoghurt powder. Results showed that the ΔE values were increased with respect to the increased spice concentration. ΔE values varied from 7.378923 to 11.69557 when compared with the ΔE value of spray dried plain yoghurt powder . Highest ΔE value was obtained for C_3G_3 with 11.69557 and lowest variation was for C_2G_2 (2.5 % white pepper extract and 3% ginger extract).

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4.4.2.6 Vitamin C

Figure 4.24 Vitamin C of flavoured yoghurt powder . A considerable increase in vitamin C was observed with increased spice concentration. highest value of 0.099 mg was observed for C_3G_3 (3% white pepper extract and 4% ginger extract) and lowest value of 0.085 mg was for C_1G_1 (2% white pepper extract and 2% ginger extract), which is having less spice ratios. Ihemeje *et al.* (2015) observed that addition of pepper fruit, carrot, ginger to the plain yoghurt caused increase in vitamin A, vitamin C, riboflavin, thiamin and niacin contents. Similar trend of rise in vitamin content of flavoured yoghurts was noted by Iheagwara (2008).

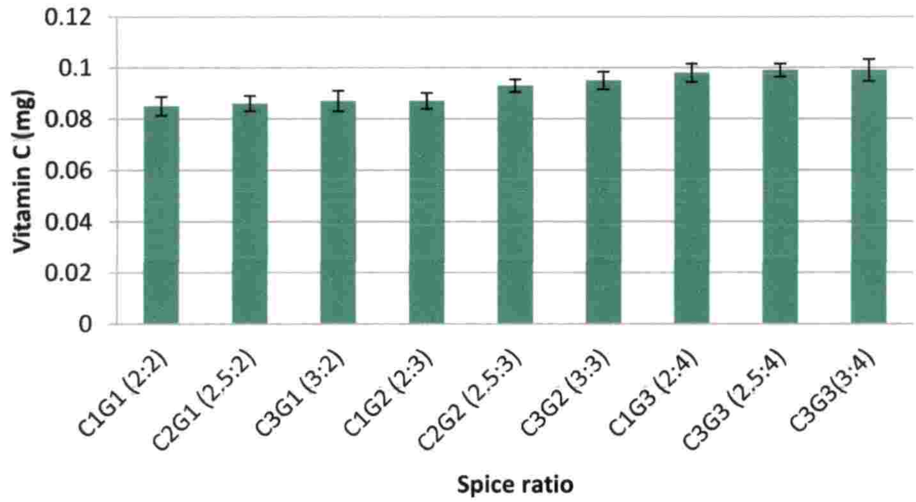

Figure 4.24 Vitamin C of flavoured yoghurt powder

Statistical analysis of product exhibited significant effect and the ANOVA table related with the vitamin C is presented in Appendix IV as Table 8

4.4.2.7 pH , Titrable acidity and TSS

TSS of reconstituted flavoured yoghurt powder was tested by using a digital hand refractometer. TSS of the flavoured yoghurt powder varied from 9 - 11°B. Sample with 3 per cent white pepper extract and 4 per cent ginger extract showed the maximum value of 11°B. TSS increased with increase in spice concentration. This might be due to the increased solid content in sample. Similar result was observed by Saranya (2015) in the case of microencapsulated banana pseudostem juice powder.

A little reduction in pH and increase titrable acidity was observed in the case of flavoured yoghurt powder when compared with plain yoghurt powder. Ihemeje *et al.* (2015) conducted a study on quality evaluation of flavoured yoghurts using carrot, pineapple, and spiced yoghurts using pepper fruit and ginger and they found that pH and titrable values remains same after the treatments with flavouring agents. Similar result was observed in this study also. pH values varied with the range of 4.61 – 4.84 and titrable acidity in the range of 1.08 – 1.12 (

Table 4.10).

Table 4.10 pH, Titrable acidity, TSS values of flavoured yoghurt powder

Spice Combination	pH	Titrable acidity (%)	TSS (^{0}B)
C_1G_1 (2:2)	4.61	1.10	9
C_2G_1 (2.5:2)	4.65	1.09	9.5
C_3G_1 (3:2)	4.69	1.11	10
C_1G_2 (2:3)	4.69	1.12	10
C_2G_2 (2.5:3)	4.72	1.08	10.5
C_3G_2 (3:3)	4.73	1.10	10.5
C_1G_3 (2:4)	4.74	1.12	10
C_3G_3 (2.5:4)	4.83	1.09	10.5
C_3G_3(3:4)	4.84	1.10	11
Control Sample (plain yoghurt powder)	4.71	1.03	9

4.4.3 Reconstitution Properties of flavoured yoghurt

4.4.3.1 Solubility

Solubility is the main parameter to be evaluated for declaring the quality of final powder. The solubility of flavoured yoghurt powder under different spray drying conditions was investigated. From Fig. 4.25, it was observed that the solubility decreased with increase in spice concentration. The solubility value of flavoured yoghurt powder was found to be in the range of 68.11 to 69.01 per cent. Feed concentration with 3% white pepper extract and 4% ginger extract (C_3G_3) scored the minimum solubility value and 2 per cent white pepper extract and 2% ginger extract (C_1G_1) scored the maximum solubility value (Fig 4.22). Statistically the sloubility values were insignificant among the process parameters and presented in Table 9 (Appendix IV).

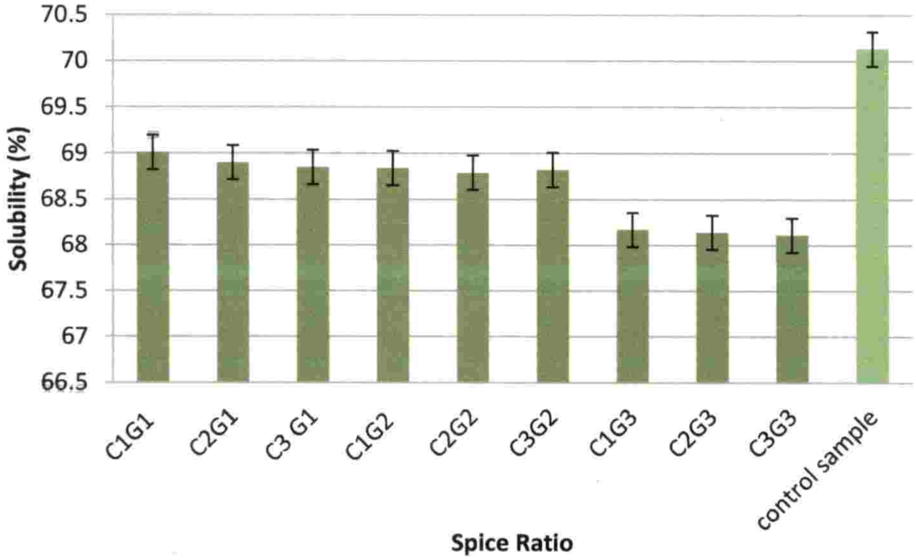

Figure 4.25 Solubility of flavoured yoghurt powder

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4.4.3.2 Wettability

The effect of spice concentration on wettability of flavoured yoghurt powder is shown in Fig. 4.26. From figure, it is observed that, wettability increased significantly with an increase in spice concentration. Maximum and minimum wettability of 387 s and 389 s was obtained for C_3G_3 (3% white pepper extract and 4% ginger extract) and C_1G_1 (2% white pepper extract and 2% ginger extract), respectively.

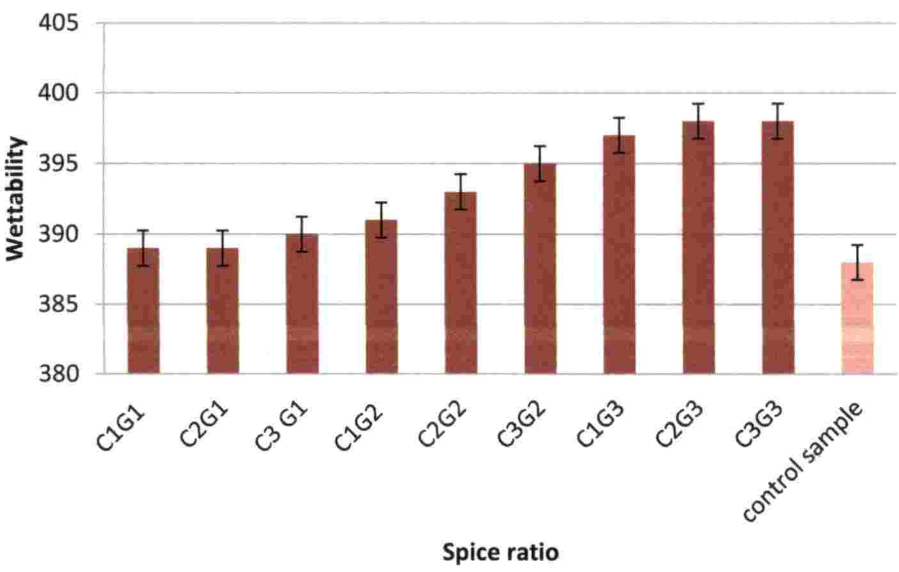

Figure 4.26 Wettability of flavoured yoghurt powder

The results were statistically analysed and presented in Table 10 (Appendix IV). Wettability values of flavoured yoghurt powder for each treatment were found to be insignificant.

4.4.4 Sensory Attributes of Reconstituted Flavoured Yoghurt Powder

The products were analysed by 12 semi trained sensory panelists. The flavoured yoghurt samples were reconstituted using lukewarm water (40-42°C) as 99 explained by koc *et al.* (2010). Sensory properties of reconstituted yoghurt samples were carried out on 9 point Hedonic scale (Appendix V). Out of nine samples, only seven samples which are having considerable sensory properties were kept for sensory analysis (except C_3G_1, C_1G_3 and C_2G_3 which are having no considerable taste difference with other samples).The fresh yoghurt with white pepper extract and ginger extract was taken as control. The results of the sensory evaluation are shown in Fig. 4.27.

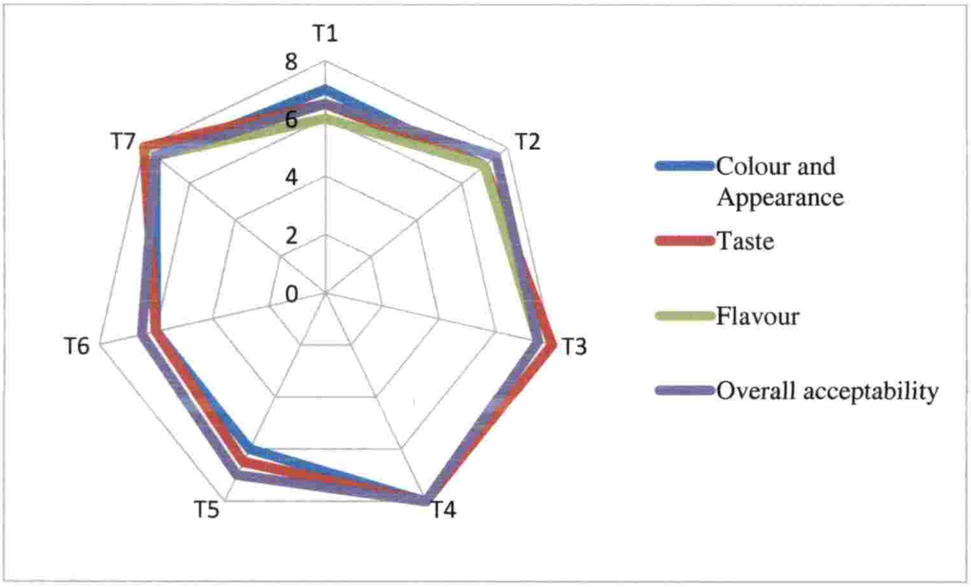

Figure 4.27 Sensory evaluation of flavoured yoghurt powder

Control sample scored the best score of 8. Sample T4 (C_2G_2) scored the highest value of 7.5 for overall acceptability among the spray dried samples. Sample T4 (C_2G_2) maintained almost similar sensory quality as control sample.

4.5 OPTIMISATION OF PROCESS PARAMETERS

Optimisation of process variables were performed using the General composite design. Final product standardisation was done by considering the results obtained from statistical models and sensory evaluation results. The result obtained from general composite design is shown in Table 4.11.

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Table 4.11 Standardised treatment combination for flavoured yoghurt powder

Properties	Desirability	Treatment
Moisture content	Minimize	C_3G_3
Water activity	Minimize	C_3G_3
Colour	Maximize	C_2G_2
Solubility	Maximize	C_1G_1
Vitamin C	Maximize	C_3G_3
Hygroscopicity	Minimize	C_2G_2
pH	In range	C_2G_2
Titrable acidity	In range	C_2G_2
Bulk density	Minimize	C_1G_1
Wettability	Minimize	C_1G_1

The flavoured yoghurt powder sample with 2.5 per cent white pepper extract and 3 per cent ginger extract (C_2G_2) was selected as the optimised sample with desirability of 0.719 during statistical analysis.

4.5.1 Morophology by SEM

The morphology of yoghurt powder, produced at the optimum spray drying conditions, are shown in Fig. 4.28 (a) image with 4000X magnification, (b) with a level of 8000X. Majority of particles displayed the spherical shape with smooth surface and in different sizes. Some depressions and cracks were also present. Hall and Hedrick (1975) stated that spray dried powder products are typically spherical in shape, although some extending parts can exist. Elversson and Millqvist-Fureby (2005) also revealed that the lactose particles generally appear as perfect spheres, which is a well known characteristic of spray dried lactose.

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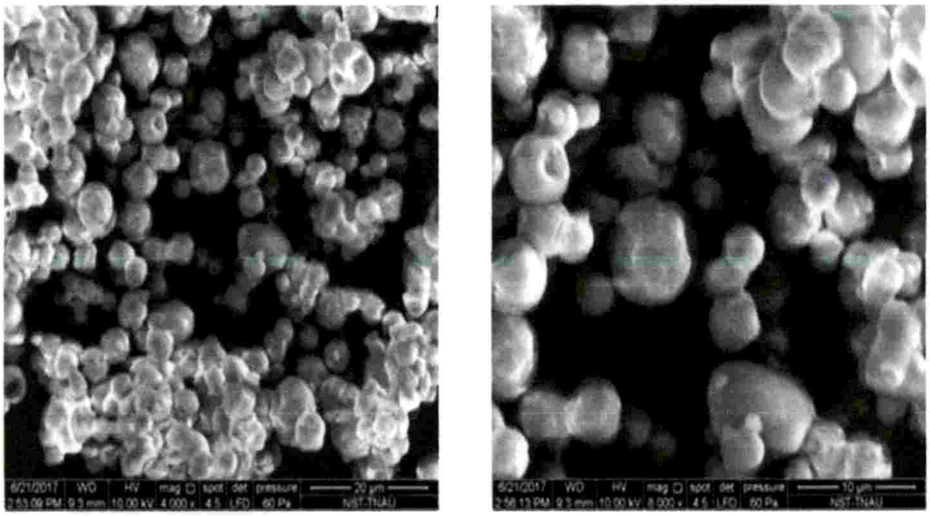

Figure 4.28 (a) SEM image with 4000X magnification (b) SEM image with 8000X magnification

4.5.2 Particle size analysis

Figure 4.29 Particle size of flavoured yoghurt powder. It is seen that the yoghurt powder had a narrower particle size range varied from 911.11 nm to 1360 nm with a moderately uniform distribution. The particle size of the developed plain yoghurt powder varied from 78.4 nm to 419.6 nm. These results showed that a little increase in particle size was observed in this case when compared with plain yoghurt powder.It might be due to the incorporation of spice extracts.

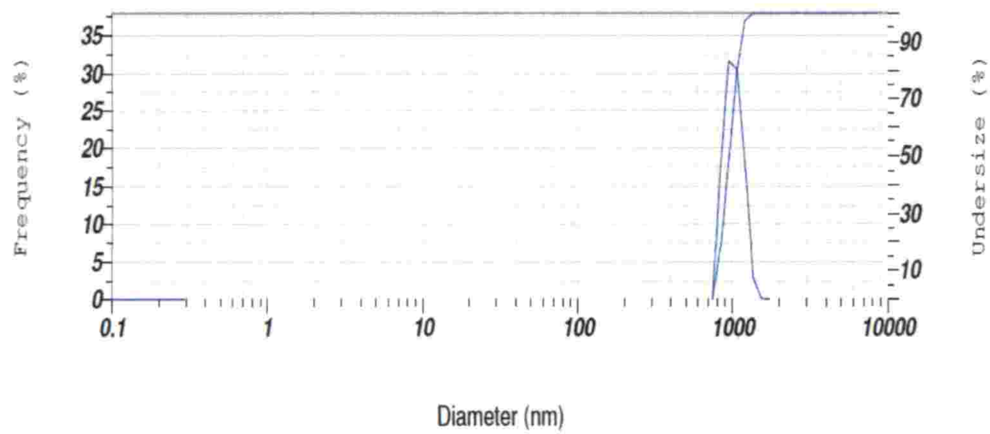

Figure 4.29 Particle size of flavoured yoghurt powder

4.5.3 Crystallinity (XRD)

X-ray diffraction is a known method used to confirm the crystalline–amorphous state of dried powder products. Usually crystalline material shows a series of sharp peaks, while amorphous material makes a broad background pattern. Fig. 30 shows the XRD profile of flavoured yoghurt powder. In this study, the flavoured yoghurt powder exhibited broad background with only one peak formation. Hence it can be concluded that the material is amorphous in nature. Peak was formed at about 20^0 (2θ). During drying process, the material did not crystallise because the high molecular weight and high viscosity that increases the glass transition temperature, turning the surface amorphous (Cano-Chauca *et al.*, 2005).

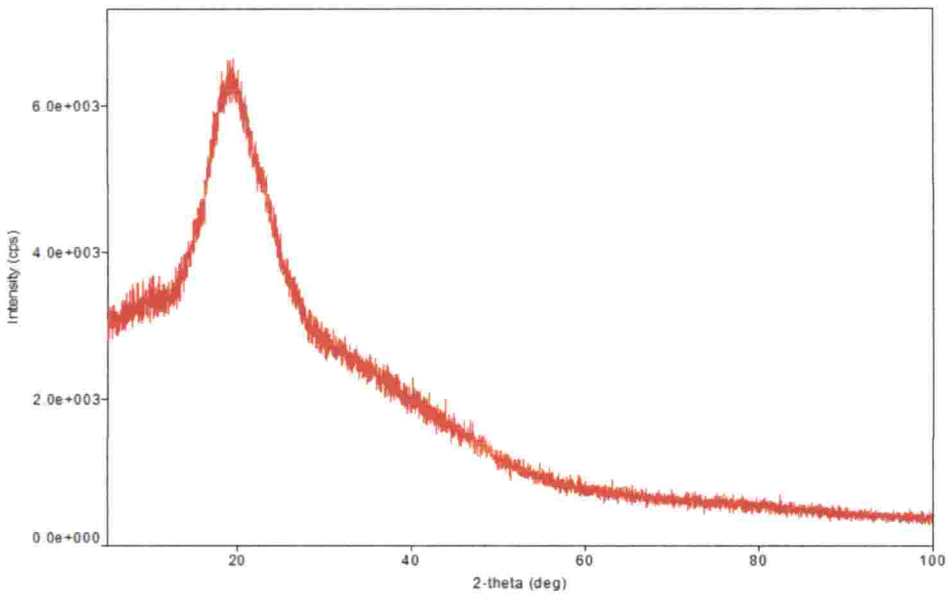

Figure 4.30 Measurement profile obtained from XRD

4.5.4 Microbiological stability

The microbial analysis was conducted for the optimised flavoured yoghurt powder sample. Total viable count observed for this product was 3.9×10^6 cfu ml^{-1}.There is no considerable change in microbial load when compared with plain yoghurt powder.

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a. Determination E.coli and Fungi in the sample

No growth of *E.coli* and fungi were found after the incubation time. Results showed that the product was free from pathogenic microbes (in 10^{-2} and 10^{-3} dilutions) due to the absence of *E.coli.* Hence, the product was safe for human consumption.

4.6 SHELF LIFE STUDIES OF THE FLAVOURED YOGHURT POWDER

Flavoured yoghurt powder was packed in aluminium laminated pouches having thickness 200 microns and sealed using a hand sealing machine and subjected to storage studies . Sealed pouches were stored at ambient condition (25-30°C) and refrigerated condition (4°C) for a period of three months and the effect of physical, chemical and microbiological characteristics during storage was studied. Samples were analysed at every 25 days interval and the best sample was selected.

4.6.1 Changes in Moisture Content of Flavoured Yoghurt Powder During Storage

The changes in moisture content of flavored yoghurt powder during storage are shown in Figure 4.31. The moisture content of yoghurt powder during initial day of packaging was 6.98 per cent (wb) for both storage conditions. After 25 days of storage, moisture content of powder increased to 7.02 per cent in ambient storage condition but moisture content of the refrigerated sample remained same. After 90 days of storage, the respective moisture content of products packed in ambient and refrigerated condition were 8.31 and 7.39 per cent (wb), respectively (Table 1, 2 - Appendix VI). The increase in moisture content was more in ambient storage than refrigerated storage. It is due to the migration of water vapour from storage environment into the packaging material. Transfer of moisture to the product affects the stability of powder. Kumar and Mishra (2003) revealed that the moisture content of mango soy fortified yoghurt powder packed at 38±1°C and 90±1% RH was 104 gradually increased when packaged in ALPE. The moisture uptake of the product relies on the water vapour permeability of the packaging film. Wong and Lim (2016) observed that the moisture achieved by the spray dried papaya powder stored in LDPE, PET was higher than those stored in ALPE. ALPE offered an actual barrier against oxygen and water vapour during the storage.

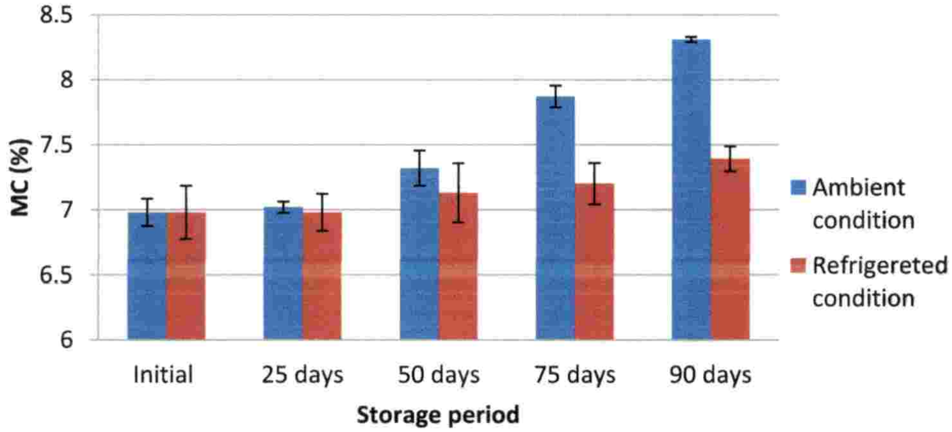

Figure 4.31 Moisture content of flavoured yoghurt powder during storage

4.6.2 Changes in Water Activity of Flavoured Yoghurt Powder During Storage

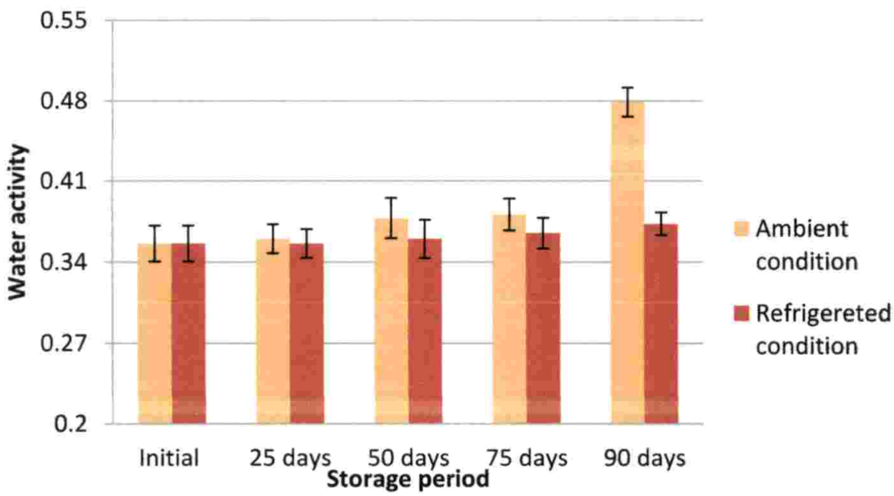

Figure 4.32 Water activity of flavoured yoghurt powder during storage

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Figure 4.32 shows the changes in water activity of flavored yoghurt powder during storage. The water activity of yoghurt powder during initial day of packaging was 0.356 for both storage conditions. After 25 days of storage, water activity of powder increased to 0.360 in ambient storage condition but water activity of the refrigerated sample remained same (Table 1 and Table 2 –Appendix VI) . After 90 days of storage, the respective water activity of products packed in ambient and refrigerated condition were 0.479 and 0.373, respectively. The increase in water activity was more in ambient storage than refrigerated storage. It is mainly due to the increase in moisture content during storage. Dak *et al.* (2014) found that the water activity of the drum dried and oven dried pomegranate powders increased with the increase of storage time.

4.6.3 Changes in Solubility of Flavoured Yoghurt Powder During Storage

The solubility changes of flavored yoghurt powder during storage is shown in Fig.4.33. From figure, it is observed that the solubility of yoghurt powder decreased with storage. The solubility of the product during initial day of packaging, 25 days, 50 days, 75 days and 90 days after packaging kept at ambient condition was 69.01, 68.98, 68.69, 67.87 and 66.53 per cent, respectively (Table 1- Appendix VI). Similarly, the corresponding solubility values at refrigerated storage was 69.01, 69.01, 68.99, 68.92 and 68.82 per cent, respectively (Table 2- Appendix VI).

The decreasing trend of powder solubility was associated to the residual moisture in the powder, when moisture content was high, the powder is being less soluble (Gaoula and Adamopoulos, 2010).

4.6.4 Changes in Wettability of Flavoured Yoghurt Powder During Storage

Fig. 4.34 shows the changes in wettability of yoghurt powder during storage . From the figure, it is shown that wettability values increased with storage period. Wettability of yoghurt powder during initial day of packaging was 384 s. After 90

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days of storage, the respective wettability of products packed in ambient and refrigerated condition were 424 s and 401 s, respectively.

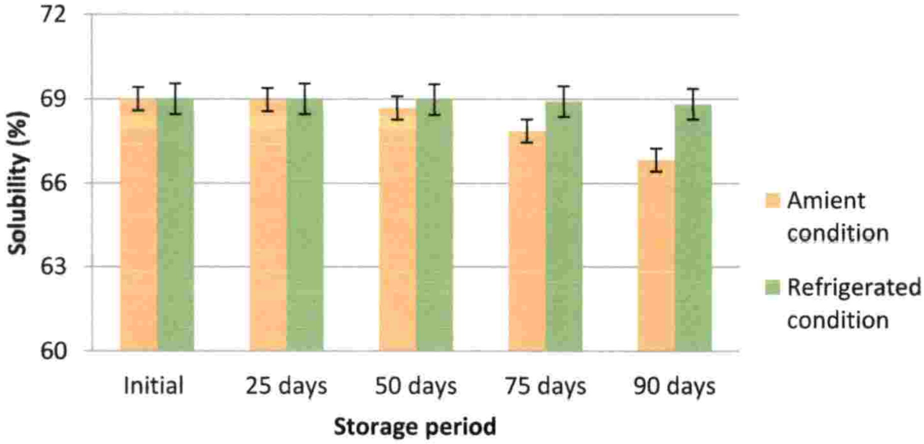

Figure 4.33 Solubility of flavoured yoghurt powder during storage

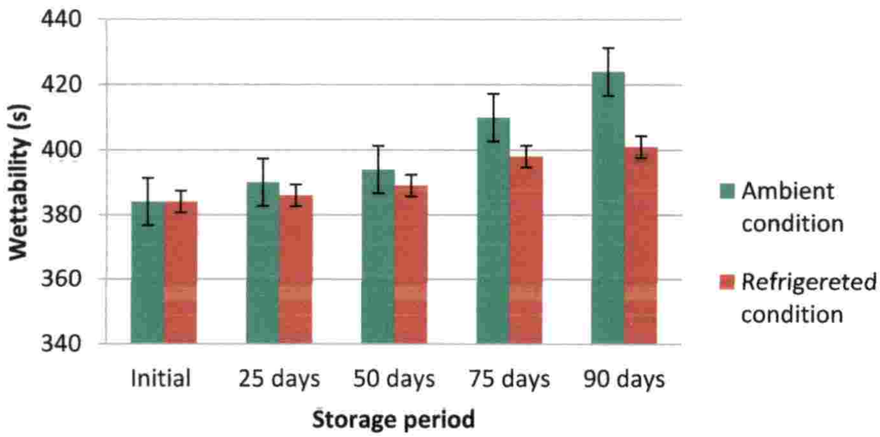

Figure 4.34 Wettability of flavoured yoghurt powder during storage

Cristina *et al.* (2008) investigated the effect of physico-chemical changes in whole milk powder during different storage conditions.Their study indicated a decrease in solubility and an increase in wettability during storage period. It might be

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due to the increased moisture content of product. Similar results were obtained during the study of fortified banana pseudostem juice powder by Saranya (2016).

4.6.5 Changes in Bulk Density of Flavoured Yoghurt Powder During Storage

The changes in bulk density of flavoured yoghurt powder during storage is shown in Fig. 4.35. Bulk density values increased with storage period. The bulk density of yoghurt powder during the initial day of packaging and 90 days of packaging kept under ambient condition increased from 0.6 g cm^{-3} to 0.658 g cm^{-3}. Similarly, the corresponding bulk density values of yoghurt powder kept under refrigerated storage were 0.6 g cm^{-3} and 0.632 g cm^{-3}, respectively.

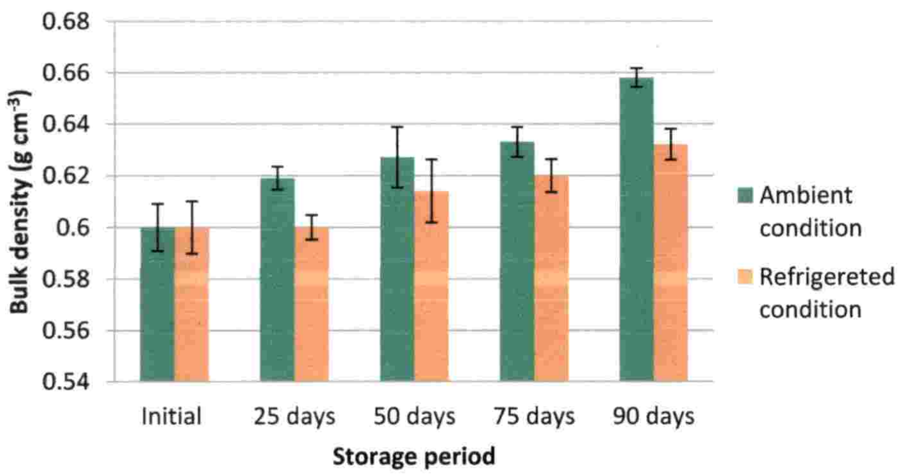

Figure 4.35. Bulk density of flavoured yoghurt powder during storage

4.6.6 Changes in TSS, pH, Titrable Acidity of Flavoured Yoghurt Powder During Storage

Table 4.12 pH, Titrable acidity of flavoured yoghurt powder during storage. From table, it was observed that pH value decreased with storage period whereas titrable acidity values increased with storage period. The pH and titrable acidity during the initial day of storage were 4.71 and 1.09, respectively. After 90 days of storage, the respective pH of products packed in ambient and refrigerated condition 108 were 4.32 and 4.59, respectively. Similarly, the corresponding titrable acidity values were 1.19 and 1.11, respectively. Koc *et al.* (2011) conducted a study on storage stability of yoghurt powder. A significant reduction in pH values was noticed during storage. Saranya *et al.* (2016) found that pH value of banana pseudo stem powders decreased after 3 months of storage. Verma *et al.* (2014) found that during the storage of spray dried powders, the conversion of sugars into acids led to increased acidic properties

Table 4.12 pH, Titrable acidity of flavoured yoghurt powder during storage

Storage period	pH		Titrable acidity (%)	
	Ambient condition	At 4^0C	Ambient condition	At 4^0C
Initial value	4.71	4.71	1.03	1.09
After 25 days	4.69	4.71	1.10	1.09
After 50 days	4.58	4.66	1.12	1.10
After 75 days	4.40	4.60	1.14	1.10
After 90 days	4.32	4.59	1.19	1.11

4.6.7 Changes in Colour Characteristics of Flavoured Yoghurt Powder During Storage

Table 4. 3 shows the colour values of flavoured yoghurt powder at ambient storage condition. A decreasing trend in L* and an increasing trend in a*,b* values were observed for both conditions. Initially L*, a*, b* values were recorded as 87.62, -0.61 and 16.87, respectively. After 90 days of storage, these values reduced to 86.88, -0.38 and 18.12 and also total colour difference (ΔE) was observed as 1.47 for the sample stored at ambient conditions.

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Table 4. 13 Colour values of flavoured yoghurt powder at ambient storage condition

Ambient condition				
Storage period	L*	a*	b*	ΔE
Initial	87.62	-0.61	16.87	0
25 days	87.44	-0.54	16.98	0.222261
50 days	87.23	-0.5	17.01	0.428719
75 days	87	-0.47	17.19	0.711618
90 days	86.88	-0.38	18.12	1.470714

Table 4. shows colour values of flavoured yoghurt powder at refrigerated storage condition. In this condition, only less variation was observed in the case of colour values when compared with ambient storage condition. Initially L*, a*, b* values were recorded as 87.62, -0.61 and 16.87, respectively. After 90 days of storage it reduced to 87.01, -0.49 and 17.1 with total colour difference of 0.662.

Table 4.14 Colour values of flavoured yoghurt powder at refrigerated condition

Refrigerated condition				
Storage period	L*	a*	b*	ΔE
Initial	87.62	-0.61	16.87	0
25 days	87.62	-0.61	16.87	0
50 days	87.44	-0.54	16.98	0.222261
75 days	87.32	-0.49	17.02	0.35623
90 days	87.01	-0.49	17.1	0.662873

4.6.8 Microbiological Analysis

Table 4.15 shows the total lactic acid bacteria count during storage. It indicated that the viability rate decreased with time during storage (Table 1-Apendix VII). A gradual decrease was observed during each 25 days of storage at ambient storage condition. The microbial load data during the storage was statistically analysed using CRD design. The results showed a significant ($p < 0.05$) effect during the storage under ambient condition, where refrigerated condition showed an insignificant effect (Appendix VII).

Kumar and Mishra, (2003) done an experiment on the storage stability of freeze dried mango fortified yoghurt powder. They stated that total lactic acid bacteria count had decreased below 10^6 cfu in samples after 35-42 days of storage at 30°C and 90% RH. This rapid decrease in bacterial viability might be due to the increase in moisture content and water activity during storage. As per the FDA standard, yoghurt powder should contain a minimum of 10^6cfu g^{-1} lactic acid bacteria at the expiry date (Koc *et al.,* 2011). Hence in this study, it could be concluded that flavored yoghurt powder stored at ambient condition is acceptable only up to 50 - 75 days. But the product stored at refrigerated condition could be used up to 3 months.

Table 4.15 Microbial load during storage period

Storage period	Total lactic acid bacteria count (log reduction)	
	Ambient Condition (25-35°C)	Refrigerated Condition (4°C)
Initial value	6.54	6.54
After 25 days	6.44	6.48
After 50 days	6.25	6.36
After 75 days	5.53	6.28
After 90 days	4.62	6.20

4.7 COST ECONOMICS

One kilogram flavoured yoghurt powder was found to be Rs. 722/-. The calculations were tabulated and presented in Appendix VIII.

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

Currently the relevance of diet on healthy wellbeing has increased, which results in the rising demand for food products that support health along with supply of adequate nutrients. One among these products is yoghurt which is made from milk. Yoghurts are prepared by fermentation of milk with bacterial cultures (mixture of *Streptococcus thermophilus* and *Lactobacillus bulgaricus*). Fermentation of milk is considered as one of the oldest methods to preserve milk with an extended shelf life. Yoghurt is effectively digestible and highly nutritious dairy product and also a rich source of more than ten essential nutrients. The nutritional composition of yoghurt relies on the strains of starter culture used for fermentation, type of milk used (whole, semi or skimmed milk), species that milk is obtained (bovine,goat, sheep), type of milk solids, solid non-fat, sweeteners and fruits added before fermentation and the duration of fermentation process.

Yoghurt is perishable in nature *ie.,* one day under ambient condition (25-30°C) and around 5 days at 7°C, which delays its commercialization. Yoghurt is maintained at 2-4°C throughout the distribution chain, this however adds to the cost of the product. The shelf life of yoghurt can be improved by reducing its water content by drying *viz.,* freeze drying, spray drying or microwave drying. The dried products obtained are in shelf stable powder form which are capable of storing at ambient temperature. Spray drying technique has showed to be highly successful in prolonging the shelf life of food products. The main aim of drying the yoghurt is to preserve it in a shelf stable powder form with good quality. Considering the above cited facts, a study was undertaken to develop a process protocol for making yoghurt powder with the following objectives. 1) Development of yoghurt powder with maltodextrin and corn starch as carrier materials. 2) Standardization of process parameters for the development of spray dried yoghurt powder 3) To Conduct the storage studies of spray dried yoghurt powder.

The physico-chemical characteristics of freshly prepared yoghurt containing *Lactobacillus bulgaricus* were carried out. The spray drying of yoghurt was carried out in lab scale spray dryer with twin fluid atomizer. Maltodextrin, corn starch and their combinations were used as wall material to produce yoghurt powder. Different proportion of wall materials were selected for spray drying- B_1 100% maltodextrin, B_2 combination of 75% maltodextrin and 25% corn starch, B_3 50% both B_4 75% corn starch and 25% maltodextrin, and B_5 100% corn starch. The yoghurt- wall material emulsions were then spray dried at different inlet temperatures of 160,170 and 180°C and at different feed rates of 10 rpm, 12 rpm and 14 rpm. With the help of detailed review of literature, spray dryer parameters like main blower rpm, outlet temperature and pressure in the drying chamber were kept constant. The main blower rpm, outlet temperature and pressure in the drying chamber was kept as 2100 rpm , 60-65°C and 2 kg cm^{-2}, respectively. Physicochemical properties of spray dried yoghurt powder such as moisture content, water activity, bulk density, TSS, titrable acidity, pH, colour characteristics, vitamin C and hygroscopicity were evaluated by standard procedures. The reconstituted yoghurt samples prepared from spray dried yoghurt powder were evaluated in terms of solubility and wettability. The process parameters were optimized based on the physico-chemical and microbiological properties of the developed yoghurt powder.

The quality of plain yoghurt powder was improved by incorporating dried white pepper extract (C_1- 2%, C_2-2.5 % and C_3- 3%) and ginger extract (G1-2%, G2-3% and G3-4%) at different combinations. The spices incorporated yoghurt product was spray dried at optimized operating parameters. The parameters of the flavored yoghurt powder were optimized based on physico-chemical and microbiological properties. The reconstituted yoghurt prepared from flavored yoghurt powder was subjected to sensory analysis. Sensory analysis was conducted using 9-point Hedonic scale test. The sensory attributes considered were colour and appearance, taste, flavour, and overall acceptability. Freshly prepared yoghurt was kept as control.

Flavoured yoghurt powder was packed in laminated aluminium pouches and sealed using a hand sealing machine and subjected to storage studies . Sealed pouches were stored at ambient (25-30°C) and refrigerated storage(4°C) for a period of three months and the effect of physical, chemical and microbiological characteristics during storage was studied. Samples were analysed at every 25 days interval and the best treatment was selected based on physicochemical properties, probiotic viability and sensory analysis.

The results of the experiments are summarised as follows:

Yoghurt was white in colour with pH 4.5. It had an initial moisture content of 82 per cent (wb). The titrable acidity, vitamin C and water activity of yoghurt were 0.87 per cent, 0.085 mg and 0.863, respectively. The L*, a*, b* values were 90.95, -1.11 and 11.69, respectively. Also, the TSS and viscosity values were 6.5°B and 223 cP.

The moisture content of yoghurt powder made from carrier blend ratio B_1, feed rate 10 rpm and inlet air temperatures 160°C, 170°C, 180°C were 8.57, 7.69 and 6.46 per cent, respectively. Yoghurt powder made from carrier blend ratio B_2(3:1), feed rate 10 rpm (F_1) and inlet air temperature 180^0C (T_3) showed the minimum moisture content (6.41 %). Highest moisture content of 9.83 per cent was observed for sample made from B_5 at 160°C for the feed rate 14 rpm. Results shows that moisture content increased significantly with increase in feed rate. However, a reverse effect in moisture content was observed with inlet air temperature.

Hygroscopicity of yoghurt powder increased with increase in inlet temperature. Maximum value of 18.2 g/100 g was observed for the carrier blend ratio B_1 at inlet air temperature 180°C and minimum value of 14.25 g/100 g for B_2 at 160°C. From the result, it is understood that the hygroscopic value has a reverse effect with product moisture content.

Bulk density of yoghurt powder decreased with an increase in inlet air temperature. Yoghurt powder made from carrier blend ratio B_4 (1:3) and B_5 (0:1), feed rate 10 rpm (F_1) and inlet air temperature 180°C (T_3) showed the minimum bulk

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density of 0.45g cm^{-3}. Maximum bulk density of 0.72 g cm^{-3} was observed for sample made from B_3 at 160°C. Increase in bulk density values were observed with increased feed rate. Highest bulk density values were recorded for the feed rate of 14 rpm (F_3). Also, increase in maltodextrin had a positive effect on bulk density for all feed rates.

Hunter 'L*' values varied from 91.08 to 95.33; 91.50 to 94.64 and 91.06 to 94.18 at feed rates 10 ,12 and 14 rpm, respectively. The corresponding 'a*' and 'b*' values for these feed rates were -0.71 to 0.56; -0.89 to 0.56 and -0.89 to -0.24; 7.9 to 10.71; 7.90 to 10.71 and 8.52 to 10.71, respectively. Yoghurt powder made from carrier blend ratio B_5, and inlet air temperature 160°C showed the maximum 'L*'value of 95.33 at 10 rpm. From the results, it is observed that 'L*' values decreased with an increase in inlet air temperature. It showed almost similar variation for all feed rates. Total color difference (ΔE) of yoghurt powder also had an inverse effect on inlet air temperature for all feed rates.

The titrable acidity of yoghurt powder was in the range of 0.99 and 1.29 per cent and the pH values were in the range of 3.58 - 4.7. The titrable acidity values of yoghurt powder were higher than that of fresh yoghurt. pH values decreased with increase in inlet temperature. TSS value increased with increase in wall material concentration. The TSS of reconstituted powder solution was found in the range of 8-9°B. The reconstituted yoghurt powder solution contains 0.072-0.084 mg of vitamin C. The solubility of yoghurt powder varied from 67.87 per cent to 71.62 per cent. The survival ratio of *Lactobacilllus bulgaricus* and *Streptococcus thermophilus* was found to be 21.9, 18.8 and 2.10 per cent for 160°C, 170°C and 180°C . From the results, it is understood that survival rate decreases with increase in inlet air temperature. By considering all the physico chemical and microbiological analyses done on the spray dried yoghurt powder at different processing conditions, powder sample processed at 170°C inlet temperature with carrier blend B_2 (3:1) at feed rate of 10 rpm was selected as optimized sample.

The flavoured yoghurt powder was prepared by incorporating dried white pepper extract (C_1- 2%, C_2-2.5 % and C_3- 3%) and ginger extract (G1-2%, G2-3%

and G3-4%) at different combinations. Minimum moisture content of 6.90 per cent was observed for the spice combination C_2G_3 and C_3G_3 and maximum of 7.03 per cent was for C_1G_1 (2% white pepper extract and 2% ginger extract). Maximum water activity was obtained for C_1G_1 treatment and minimum for C_3G_3.The bulk density values showed only less variation. Minimum value of 0.58 g $cm^{-3}$was observed for C_1G_1 and maximum of 0.63 g cm^{-3} was for C_3G_3. Hygroscopicity variation was from 14.84 to 15.86 g/100 g. There is insignificant change in the values were observed in this flavoured sample when compared with standardized yoghurt powder without the addition of flavours. The solubility value of flavoured yoghurt powder was found to be in the range of 68.11- 69.01per cent. Among treatments with different flavor loads ,feed concentration with 3 per cent white pepper extract and 4 per cent ginger extract (C_3G_3) scored less solubility value and 2 per cent white pepper extract and 2 per cent ginger extract (C_1G_1) scored more solubility value. Solubility and wettability are inversely proportional to each other, wetting time of flavoured yoghurt powder varied between 389-398 s. Maximum wetting time was observed for product combination of C_3G_3 and minimum was for C_1G_1.

By considering the physico-chemical qualities of the flavoured yoghurt under different processing conditions, the sample incorporated with 2.5 per cent white pepper extract and 3 per cent ginger extract (C_2G_2) was selected as the optimized sample.

Storage study of optimized sample was done for three month periods. Samples were packed inside an aluminium laminated pouches and stored under both ambient (25-30°C) and refrigerated condition (4°C).

The moisture content of yoghurt powder during initial day of packaging was 6.98 per cent (wb) for both storage conditions. After 25 days of storage, moisture content of powder increased to 7.02 per cent in ambient storage condition but moisture content of the refrigerated sample remained same . After 90 days of storage, the respective moisture content of products packed in ambient and refrigerated condition were 8.31 and 7.39 per cent (wb) respectively. The increase in moisture content was more in ambient storage than refrigerated storage. It is due to the migration of water vapour from storage environment into the packaging material.Transfer of moisture to the product affects the stability of powder. it is observed that the solubility of yoghurt powder decreased with storage. pH value decreased with storage period whereas titrable acidity values increased with storage period. The total viable count of bacteria decreased during storage. Initial count obtained before storage was 3.5 $x10^6$ cfu ml^{-1}, a gradual decrease was observed during each 25 days of storage at ambient storage condition. As per the FDA standard, yoghurt should contain a minimum of 10^6cfu/ml lactic acid bacteria. Hence flavored yoghurt powder stored at ambient condition is acceptable only up to 50 -75 days. But the product stored at refrigerated condition can be used up to 3 months.

The cost of production of one kilogram of spray dried flavoured yoghurt powder using the pilot model spray drier was estimated to be Rs. 722/-.

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Appendices

APPENDIX I

Physico-chemical properties of spray dried yoghurt powder

Table 1. Moisture content (% wb) values of yoghurt powder

Carrier Blend ratio	Feed rate (10 rpm)			Feed rate (12 rpm)			Feed rate (14 rpm)		
	160⁰C	170°C	180°C	160⁰C	170°C	180°C	160⁰C	170°C	180°C
B_1 (4:0)	8.573	7.692	6.467	8.799	7.695	6.468	8.785	7.696	6.469
B_2 (3:1)	8.276	7.288	6.414	8.368	7.387	6.429	8.483	7.488	6.431
B_3 (1:1)	8.323	7.608	6.548	8.783	7.573	6.897	8.813	7.485	6.8
B_4 (1:3)	8.87	7.695	6.478	8.8	7.596	6.489	9.334	7.798	7.0
B_5 (0:4)	9.1	8.18	6.866	9.24	8.185	7.587	9.839	8.69	8.0

Table 2. Water activity values of yoghurt powder

Carrier Blend ratio	Feed rate (10 rpm)			Feed rate (12 rpm)			Feed rate (14 rpm)		
	160⁰C	170°C	180°C	160⁰C	170°C	180°C	160⁰C	170°C	180°C
B_1 (4:0)	0.447	0.362	0.278	0.458	0.369	0.28	0.475	0.385	0.281
B_2 (3:1)	0.437	0.33	0.247	0.442	0.346	0.253	0.459	0.359	0.264
B_3 (1:1)	0.457	0.394	0.282	0.478	0.398	0.292	0.497	0.389	0.293
B_4 (1:3)	0.497	0.479	0.357	0.5	0.399	0.369	0.555	0.412	0.358
B_5 (0:4)	0.499	0.492	0.398	0.517	0.478	0.388	0.558	0.51	0.4

Table 3. Hygroscopicity (g/100 g) values of yoghurt powder

Carrier Blend ratio	Feed rate (10 rpm)			Feed rate (12 rpm)			Feed rate (14 rpm)		
	160⁰C	170°C	180°C	160⁰C	170°C	180°C	160⁰C	170°C	180°C
B_1 (4:0)	14.97	16.87	18.2	14.77	16.84	17.9	14.74	16.77	17.78
B_2 (3:1)	14.66	16.65	17.9	14.55	16.55	17.68	14.25	16.37	17.63
B_3 (1:1)	14.79	16.75	18.23	14.79	16.6	17.91	14.65	16.56	17.89
B_4 (1:3)	14.73	16.87	17.91	14.7	16.65	17.6	14.5	16.65	17.39
B_5 (0:4)	14.75	16.88	17.92	14.72	16.64	17.65	14.62	16.64	17.38

Table 4. Bulk density (g cm^{-3}) values of yoghurt powder

Carrier Blend ratio	Feed rate (10 rpm)			Feed rate (12 rpm)			Feed rate (14 rpm)		
	160⁰C	170°C	180°C	160⁰C	170°C	180°C	160⁰C	170°C	180°C
B_1 (4:0)	0.67	0.59	0.48	0.69	0.61	0.5	0.72	0.63	0.54
B_2 (3:1)	0.66	0.58	0.49	0.66	0.6	0.51	0.7	0.62	0.52
B_3 (1:1)	0.68	0.53	0.46	0.7	0.52	0.49	0.68	0.54	0.5
B_4 (1:3)	0.65	0.52	0.45	0.67	0.54	0.48	0.69	0.58	0.48
B_5 (0:4)	0.64	0.5	0.45	0.66	0.52	0.47	0.68	0.54	0.49

Table 5. Colour values of yoghurt powder at 10 rpm

Feed rate at 10 rpm				
Carrier blend ratio	Inlet temp (^0C)	L*	a*	b*
B_1	160	92	-0.34	9.81
B_2		92.08	-0.71	10.71
B_3		92.13	-0.54	9.14
B_4		94.52	-0.71	10.71
B_5		95.08	-0.42	10.28
B_1	170	93.1	-0.54	9.14
B_2		93.56	-0.24	10.54
B_3		91.52	-0.71	10.71
B_4		93.5	-0.34	9.81
B_5		94.64	-0.51	10.54
B_1	180	91.52	-0.71	10.71
B_2		91.87	-0.24	10.56
B_3		91.08	-0.42	10.28
B_4		93.1	-0.54	9.14
B_5		95.33	0.56	7.9

Table 6. Colour values of yoghurt powder at 12 rpm

Feed rate at 12 rpm				
Carrier blend ratio	Inlet temp (^0C)	L*	a*	b*
B_1	160	92	-0.34	9.82
B_2		92.17	-0.42	10.28
B_3		92.08	0.56	7.9
B_4		94.22	0.43	7.9
B_5		94.18	-0.4	10.29
B_1	170	92.1	-0.24	10.54
B_2		92.56	-0.89	8.52
B_3		90.52	-0.24	10.54
B_4		92.5	-0.51	10.54
B_5		94.64	-0.42	10.28

B_1	180	91.50	-0.71	10.71
B_2		91.77	0.56	7.9
B_3		90.54	-0.24	10.56
B_4		93.1	-0.71	10.71
B_5		94	-0.34	9.82

Table 7. Colour values of yoghurt powder at14 rpm

Feed rate at 14 rpm				
Carrier blend ratio	Inlet temp (^{0}C)	L*	a*	b*
B_1	160	91.64	-0.51	10.54
B_2		92.19	-0.54	9.14
B_3		92.52	-0.71	10.71
B_4		93.41	-0.24	10.54
B_5		94.18	-0.42	10.28
B_1	170	92.05	-0.4	10.29
B_2		92.08	-0.42	10.28
B_3		92.52	-0.71	10.71
B_4		93.57	-0.24	10.54
B_5		93.97	-0.24	10.54
B_1	180	91.06	-0.4	10.29
B_2		91.18	-0.42	10.28
B_3		91.8	-0.27	9.82
B_4		93.64	-0.51	10.54
B_5		93.73	-0.89	8.52

Table 8. Total colour difference (ΔE) on yoghurt powder

Carrier blend ratio	Inlet Temperature	10 rpm	12 rpm	13 rpm
B1	160^{0}C	3.072361	2.873378	2.608256
B2		3.69275	2.084682	3.773937
B3		3.258435	4.037945	2.595708
B4		2.595708	4.070749	3.03259
B5		2.084682	2.353657	2.367678

B1	170^{0}C	4.375786	2.395224	2.334545
B2		2.084682	4.029801	2.367678
B3		2.144225	2.395224	2.595708
B4		2.557225	3.344099	3.163764
B5		2.608256	2.084682	1.87867
B1	180^{0}C	2.392446	2.144225	2.061577
B2		2.144225	1.866494	2.084682
B3		2.084682	3.848506	2.514339
B4		3.04097	2.595708	2.103093
B5		3.848506	2.695685	3.778796

Table 9. Solubility (%) of yoghurt powder

Carrier Blend ratio	Feed rate (10 rpm)			Feed rate (12 rpm)			Feed rate (14 rpm)		
	160^{0}C	170°C	180°C	160^{0}C	170°C	180°C	160^{0}C	170°C	180°C
B_1 (4:0)	69.76	69.32	68.56	69.86	69.42	68.66	69.96	69.52	68.76
B_2 (3:1)	71.32	70.13	68.51	71.42	70.23	68.9	71.62	70.33	69.02
B_3 (1:1)	69.79	69.24	67.87	69.89	69.34	68.97	69.99	69.54	68.71
B_4 (1:3)	70.12	69.89	68.88	70.22	69.99	68.98	70.42	69.99	68.89
B_5 (0:4)	70.05	69.83	68.83	70.15	69.93	68.93	70.25	69.93	68.99

Table 10. Wettability (Seconds) of yoghurt powder

Carrier Blend ratio	Feed rate (10 rpm)			Feed rate (12 rpm)			Feed rate (14 rpm)		
	160°C	170°C	180°C	160°C	170°C	180°C	160°C	170°C	180°C
B_1 (4:0)	386	466	575	390	470	581	400	481	591
B_2 (3:1)	335	439	540	347	440	550	357	458	560
B_3 (1:1)	396	456	580	399	476	595	410	462	611
B_4 (1:3)	350	440	550	357	440	552	367	450	565
B_5 (0:4)	352	445	558	360	445	558	377	453	567

APPENDIX II

Table 1 ANOVA table for moisture content

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	2.94	44	0.067	83.16	< 0.0001	significant
A-carrier blend ratio	0.022	4	5.502E-003	6.84	< 0.0001	
B-inlet temperature	2.49	2	1.25	1549.73	< 0.0001	
C-feed rate	0.11	2	0.056	69.73	< 0.0001	
AB	0.058	8	7.246E-003	9.01	< 0.0001	
AC	0.028	8	3.488E-003	4.34	0.0002	
BC	0.19	4	0.047	58.80	< 0.0001	
ABC	0.041	16	2.559E-003	3.18	0.0002	
Pure Error	0.072	90	8.042E-004		< 0.0001	
Cor Total	3.01	134	0.067			
Std. Dev	0.028					
C.V. %	0.42					

Table 2 ANOVA table for water activity

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	8.530E-003	44	1.939E-004	11.39	< 0.0001	Significant
A-carrier blend ratio	2.623E-004	44	6.556E-005	3.85	0.0062	
B-inlet temperature	4.888E-003	4	2.444E-003	145.6	< 0.0001	
C-feed rate	5.966E-004	2	2.983E-004	17.5	< 0.0001	
AB	5.722E-004	2	7.152E-005	4.20	0.0003	
AC	2.780E-004	8	3.475E-005	2.04	0.0502	
BC	1.029E-003	8	2.573E-004	15.1	< 0.0001	
ABC	9.041E-004	4	5.650E-005	3.32	0.0001	
Pure Error	1.532E-003	16	1.702E-005			
Cor Total	0.010	90				
Std. Dev.	4.126E-003					
C. V.%	1.39					

Table 3 ANOVA table for Hygroscopicity

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	281.80	44	6.40	60.87	< 0.0001	Significant
A-carrier blend ratio	4.64	4	1.16	11.03	< 0.0001	
B-inlet temperature	30.68	2	15.34	145.79	< 0.0001	
C-feed rate	103.25	2	51.62	490.63	< 0.0001	
AB	12.79	8	1.60	15.19	< 0.0001	
AC	13.12	8	1.64	15.58	< 0.0001	
BC	104.11	4	26.03	247.37	< 0.0001	
ABC	13.21	16	0.83	7.85	< 0.0001	
Pure Error	9.47	90	0.11			
Cor Total	291.27	134				
Std. Dev.	0.32					
C.V.%	2.44					

Table 4 ANOVA table for Bulk density

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	0.43	44	9.716E-003	70.52	< 0.0001	Significant
A-carrier blend ratio	5.803E-003	4	1.451E-003	10.53	< 0.0001	
B-inlet temperature	0.22	2	0.11	796.01	< 0.0001	
C-feed rate	0.024	2	0.012	88.01	< 0.0001	
AB	0.032	8	4.044E-003	29.35	< 0.0001	
AC	0.017	8	2.147E-003	15.59	< 0.0001	
BC	0.079	4	0.020	144.13	< 0.0001	
ABC	0.049	16	3.072E-003	22.30	< 0.0001	
Pure Error	0.012	90	1.378E-004			
Cor Total	0.44	134				
Std. Dev.	0.012					
C.V.%	2.04					

Table 5. ANOVA table for colour values – L* values

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	201.76	44	4.59	5.33	< 0.0001	Significant
A-carrier blend ratio	24.35	4	6.09	7.08	< 0.0001	
B-inlet temperature	18.10	2	9.05	10.52	< 0.0001	
C-feed rate	42.38	2	21.19	24.64	< 0.0001	
AB	2.78	8	0.35	0.40	0.9152	
AC	14.77	8	1.85	2.15	0.0392	
BC	65.75	4	16.44	19.11	< 0.0001	
ABC	33.63	16	2.10	2.44	0.0041	
Pure Error	77.41	90	0.86	5.33	< 0.0001	
Cor Total	279.17	134				
Std. Dev.	0.93					
C.V.%	1.00					

Table 6. ANOVA table for colour values – a* values

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	7.89	44	0.18	8.01	< 0.0001	Significant
A-carrier blend ratio	2.90	4	0.72	32.33	< 0.0001	
B-inlet temperature	0.23	2	0.11	5.08	0.0081	
C-feed rate	0.32	2	0.16	7.04	0.0014	
AB	0.54	8	0.068	3.02	0.0048	
AC	0.50	8	0.062	2.79	0.0084	
BC	1.05	4	0.26	11.70	< 0.0001	
ABC	2.36	16	0.15	6.59	< 0.0001	
Pure Error	2.02	90	0.022			
Cor Total	9.91	134				
Std. Dev.	0.15					
C.V.%	37.03					

Table 7. ANOVA table for colour values – b* values

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	44.86	44	1.02	2.93	< 0.0001	Significant
A-carrier blend ratio	5.76	4	1.44	4.14	0.0040	
B-inlet temperature	0.72	2	0.36	1.03	0.3595	
C-feed rate	0.59	2	0.29	0.84	0.4332	
AB	3.75	8	0.47	1.35	0.2302	
AC	5.16	8	0.64	1.86	0.0770	
BC	1.14	4	0.28	0.82	0.5173	
ABC	27.75	16	1.73	4.99	< 0.0001	
Pure Error	31.27	90	0.35			
Cor Total	76.13	134				
Std. Dev.	0.59					
C.V.%	5.94					

Table 8 ANOVA table for pH

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	7.95	44	0.18	6.75	< 0.0001	Significant
A-carrier blend ratio	0.11	4	0.029	1.07	0.3751	
B-inlet temperature	1.13	2	0.57	21.10	< 0.0001	
C-feed rate	5.69	2	2.84	106.24	< 0.0001	
AB	0.19	8	0.024	0.89	0.5312	
AC	0.15	8	0.019	0.72	0.6708	
BC	0.39	4	0.098	3.67	0.0082	
ABC	0.28	16	0.017	0.65	0.8319	
Pure Error	2.41	90	0.027			
Cor Total	10.36	134				
Std. Dev.	0.16					
C.V.%	3.83					

Table 9. ANOVA table for Titrable acidity

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	0.72	44	0.016	12.10	< 0.0001	Significant
A-carrier blend ratio	0.024	4	6.057E-003	4.48	0.0024	
B-inlet temperature	0.59	2	0.29	217.33	< 0.0001	
C-feed rate	0.000	2	0.000	0.000	1.0000	
AB	0.11	8	0.013	9.96	< 0.0001	
AC	0.000	8	0.000	0.000	1.0000	
BC	0.000	4	0.000	0.000	1.0000	
ABC	0.000	16	0.000	0.000	1.0000	
Pure Error	0.12	90	1.353E-003			
Cor Total	0.84	134				
Std. Dev.	0.037					
C.V.%	3.20					

Table 10. ANOVA table for Vitamin C

Source	Sum of Squares	df	Mean Square	F Va lue	p-value Prob > F	
Model	2.466E-003	44	5.605E-005	8.33	0.6001	Not Significant
A-carrier blend ratio	8.188E-005	4	2.047E-005	3.04	0.8211	
B-inlet temperature	5.615E-006	2	2.807E-006	0.42	0.6600	
C-feed rate	1.850E-005	2	9.252E-006	1.38	0.7580	
AB	1.188E-004	8	1.485E-005	2.21	0.0339	
AC	1.075E-003	8	1.344E-004	19.98	0.6001	
BC	3.954E-005	4	9.885E-006	1.47	0.2180	
ABC	1.127E-003	16	7.045E-005	10.47	0.7631	
Pure Error	6.053E-004	90	6.726E-006			
Cor Total	3.072E-003	134				
Std. Dev.	3.26					
C.V.%	2.5					

Table 11. ANOVA table for Solubility

Source	Sum of Squares	df	Mean Square	F Val ue	p-value Prob > F	
Model	146.27	44	3.32	10.81	< 0.0001	Significant
A-carrier blend ratio	40.47	4	10.12	32.91	.05435	
B-inlet temperature	58.84	2	29.42	95.69	< 0.0001	
C-feed rate	0.41	2	0.21	0.67	0.0512	
AB	43.71	8	5.46	17.77	< 0.0001	
AC	1.66	8	0.21	0.67	0.7129	
BC	0.24	4	0.059	0.19	0.9418	
ABC	0.95	16	0.059	0.19	0.9997	
Pure Error	27.67	90	0.31			
Cor Total	173.94	134				
Std. Dev.	0.55					
C.V.%	0.82					

Table 12. ANOVA table for Wettability

Source	Sum of Squares	df	Mean Square	F Val ue	p-value Prob > F	
Model	2.022E+005	44	4594.96	3.65	< 0.0001	Significant
A-carrier blend ratio	1.848E+005	4	46212.10	36.71	0.9957	
B-inlet temperature	10.80	2	5.40	4.289E-003	< 0.0001	
C-feed rate	0.000	2	0.000	0.000	0.0043	
AB	17319.20	8	2164.90	1.72	0.1045	
AC	0.000	8	0.000	0.000	1.0000	
BC	0.000	4	0.000	0.000	1.0000	
ABC	0.000	16	0.000	0.000	1.0000	
Pure Error	1.133E+005	90	1258.93			
Cor Total	3.155E+005	134				
Std. Dev.	35.48					
C.V.%	8.50					

APPENDIX III

Table 1. Physiochemical properties of flavoured yoghurt powder

Spice combination	L*	a*	b*	ΔE	Solubility (%)	Wettability (Sec)	Vitamin C (mg)
C1G1	87.53	0.24	15.27	7.678815	69.01	389	0.085
C2G1	87.56	-0.15	18.18	9.714819	68.9	389	0.086
C3 G1	87.55	-0.34	14.82	8.688464	68.85	390	0.087
C1G2	87.71	0.03	15.29	7.540418	68.84	391	0.087
C2G2	87.62	-0.61	16.87	7.378923	68.79	393	0.093
C3G2	87.69	-0.66	15.08	7.432691	68.82	395	0.095
C1G3	83.69	-0.51	12.32	10.03286	68.17	397	0.098
C2G3	83.45	-0.14	16.36	11.60595	68.14	398	0.099
C3G3	83.26	1.21	15.71	11.69557	68.11	398	0.099

APPENDIX IV

Table 1. ANOVA table for Moisture content – Flavoured yoghurt powder

Source	Sum of Squares	df	Mean Square	F Val ue	p-value Prob > F	
Model	0.053	8	6.600E-003	0.099	0.9988	Not Significant
A-white peppr Extract	0.010	2	5.200E-003	0.078	0.9256	
B-ginger extract	0.042	2	0.021	0.31	0.7368	
AB	8.000E-004	4	2.000E-004	2.988E-003	1.0000	
Pure Error	1.20	18	0.067			
Cor Total	1.26	26				
Std. Dev.	0.26					
C.V.%	3.71					

Table 2. ANOVA table for wateractivity

Source	Sum of Squares	df	Mean Square	F Val ue	p-value Prob > F	
Model	0.036	8	4.440E-003	2.14	0.0862	Not Significant
A-white peppr Extract	0.033	2	0.017	8.04	0.0032	
B-ginger extract	4.283E-004	2	2.142E-004	0.10	0.9025	
AB	1.684E-003	4	4.210E-004	0.20	0.9336	
Pure Error	0.037	18	2.077E-003			
Cor Total	0.073	26				
Std. Dev.	0.046					
C.V.%	12.38					

Table 3 ANOVA table for Bulk density

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	2.532E-003	8	3.165E-004	0.42	0.8946	Not Significant
A-white peppr Extract	8.000E-004	2	4.000E-004	0.53	0.5978	
B-ginger extract	5.055E-004	2	2.527E-004	0.33	0.7200	
AB	1.227E-003	4	3.067E-004	0.41	0.8019	
Pure Error	0.014	18	7.554E-004			
Cor Total	0.016	26				
Std. Dev.	0.027					
C.V.%	0.60					

Table 4. ANOVA table for L*

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	139.23	8	17.40	2.10	0.0906	Not Significant
A-white peppr Extract	103.08	2	51.54	6.23	0.0088	
B-ginger extract	10.32	2	5.16	0.62	0.5472	
AB	25.83	4	6.46	0.78	0.5522	
Pure Error	148.89	18	8.27			
Cor Total	288.12	26				
Std. Dev.	2.88					
C.V.%	3.34					

Table 5. ANOVA table for a*

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	1.63	8	0.20	0.58	0.7821	Not Significant
A-white peppr Extract	1.63	2	0.81	2.31	0.1280	
B-ginger extract	3.292E-003	2	1.646E-003	4.676E-003	0.9953	
AB	1.162E-003	4	2.905E-004	8.254E-004	1.0000	
Pure Error	6.33	18	0.35			
Cor Total	7.96	26				
Std. Dev.	0.57					
C.V.%	57.14					

Table 6. ANOVA table for b*

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	62.02	8	7.75	51.59	< 0.0001	Significant
A-white peppr Extract	37.95	2	18.98	41.66	< 0.0001	
B-ginger extract	8.08	2	4.04	6.36	< 0.0001	
AB	15.99	4	4.00	12.96	< 0.0001	
Pure Error	0.000	18	0.000			
Cor Total	62.02	26				
Std. Dev.	0.65					
C.V.%	0.43					

Table 7. ANOVA table for Hygroscopicity

Source	Sum of Squares	df	Mean Square	F Val ue	p-value Prob > F	
Model	1.12	8	0.14	0.64	0.7320	Not Significant
A-white peppr Extract	0.21	2	0.10	0.48	0.6280	
B-ginger extract	0.27	2	0.13	0.61	0.5532	
AB	0.65	4	0.16	0.74	0.5755	
Pure Error	3.92	18	0.22			
Cor Total	5.04	26				
Std. Dev.						
C.V.%						

Table 8. ANOVA table for Vitamin C

Source	Sum of Squares	df	Mean Square	F Val ue	p-value Prob > F	
Model	1.41	8	0.18	9.31	< 0.0001	Significant
A-white peppr Extract	0.27	2	0.13	7.01	0.0056	
B-ginger extract	0.61	2	0.31	16.16	< 0.0001	
AB	0.53	4	0.13	7.03	0.0014	
Pure Error	0.34	18	0.019			
Cor Total	1.75	26				
Std. Dev.	0.14					
C.V.%	72.95					

Table 9. ANOVA table for solubility

Source	Sum of Squares	df	Mean Square	F Val ue	p-value Prob > F	
Model	3.28	8	0.41	0.063	0.9998	Not Significant
A-white peppr Extract	0.032	2	0.016	2.469E-003	0.9975	
B-ginger extract	3.23	2	1.62	0.25	0.7824	
AB	0.017	4	4.333E-003	6.674E-004	1.0000	
Pure Error	116.87	18	6.49			
Cor Total	120.15	26				
Std. Dev.	2.55					
C.V.%	3.71					

Table 10. ANOVA table for wettability

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	444.00	8	55.50	0.27	0.9693	Not Significant
A-white peppr Extract	62.00	2	31.00	0.15	0.8631	
B-ginger extract	378.00	2	189.00	0.90	0.4223	
AB	4.00	4	1.00	4.787E-003	0.9999	
Pure Error	3760.54	18	208.92			
Cor Total	4204.54	26				
Std. Dev.	14.45					
C.V.%	3.71					

APPENDIX V

Sensory score for spray dried flavoured yoghurt powder

Sample	Colour and Appearance	Taste	Flavour	Overall acceptability
T1 C_1G_1 (2:2)	7	6.5	6	6.5
T2 C_2G_1 (2.5:2)	6	6.5	7	6.5
T3 C_1G_2 (2:3)	7	7	7.5	7
T4 C_2G_2 (2.5:3)	7.5	7.5	8	7.5
T5 C_3G_2 (3:3)	6	6.5	6	6
T6 C_3G_3 (3:4)	6	6	6.5	6.5
T7 (Control)	8	8	8	8

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

APPENDIX VI

Storage studies on flavoured yoghurt powder

Table 1.Powder properties during storage at ambient condition (25-30^{0}C)

Storage period	MC (%)	Water activity	Solubility (%)	Wettability (S)	Bulk density (g cm^{-3})
Initial value	6.98	0.356	69.01	384	0.6
After 25 days	7.02	0.36	68.98	390	0.619
After 50 days	7.32	0.378	68.69	394	0.627
After 75 days	7.87	0.381	67.87	410	0.633
After 90 days	8.31	0.479	66.83	424	0.658

Table 2. Powder properties during storage refrigerated condition(4^{0}C)

Storage period	MC (%)	Water activity	Solubility (%)	Wettability (S)	Bulk density (g cm^{-3})
Initial value	6.98	0.356	69.01	384	0.6
After 25 days	6.98	0.356	69.01	386	0.6
After 50 days	7.13	0.36	68.99	389	0.614
After 75 days	7.2	0.365	68.92	398	0.62
After 90 days	7.39	0.373	68.82	401	0.632

APPENDIX VII

Table 1 Microbial load during storage period

Storage period	Total plate count (cfu/ml)	
	Ambient Condition	Refrigerated Condition
Initial value	3.5×10^6	3.5×10^6
After 25 days	2.8×10^6	3.0×10^6
After 50 days	1.8×10^6	2.3×10^6
After 75 days	3.4×10^5	1.9×10^6
After 90 days	4.2×10^4	0.96×10^6

Table 2 ANOVA table during storage (Ambient condition (25-30˚C)

Source	**D.F.**	**SS**	**MSS**	**Cal. F**	**TAB. F(5%)**	**TAB. F(1%)**
Treatment	4	7.788	1.947	36.359	**S**	**S**
Replication	2	0.056	0.028	0.519	**NS**	**NS**
Error	10	0.536	0.054			
TOTAL	14					
S.Em	0.134		**TAB F(5%)**	3.478		
CV	3.398		**TAB F(1%)**	5.994		

Table 3 ANOVA table during storage (Refrigerated condition (4˚C)

Source	**D.F.**	**SS**	**MSS**	**Cal. F**	**TAB. F(5%)**	**TAB. F(1%)**
Treatment	4	0.577	0.144	2.502	**NS**	**NS**
Replication	2	0.104	0.052	0.900	**NS**	**NS**
Error	10	0.577	0.058			
TOTAL	14					
S.Em	0.139		**TAB F(5%)**	3.478		
CV	3.796		**TAB F(1%)**	5.994		

APPENDIX VIII

Cost economics of Flavoured yoghurt powder

Capacity of the Spray dryer	=	1000 g of water evaporation/ h
Working hour per shift	=	8
Number of shifts per day	=	2
Total capacity of the unit per day	=	4 kg
Cost of the Spray drier (S)	=	Rs.12,00,000/-
Cost of incubator	=	Rs. 20,000/-
Cost of induction stove	=	Rs.2,500/-
Cost of mixer	=	Rs. 2,000/-
Cost of sealing machine	=	Rs. 1,500
Life span of the unit (n)	=	15 years
Annual usage (A)	=	300 days
Interest rate (i)	=	11% annum

A) Fixed cost of the Spray drier unit

$$= \frac{i(i+1)^n}{(i+1)^n+1} \times C$$

$$= \frac{0.11(0.11+1)^{15}}{(0.11+1)^{15}+1} \times 12{,}00{,}000$$

= Rs. 1,09,181/-

B) Fixed cost of the incubator = Rs. 1,800/-

C)Fixed cost of the induction stove = Rs. 225/-

D)Fixed cost of the mixer = Rs. 180/-

E) Fixed cost of the sealing machine = Rs. 135/-

F) Fixed cost of floor area 5 m^2, water charge and installation charge = Rs. 9000/-

Total fixed cost/ year = A+B+C+D+E+F

= Rs. 1,20,521/-

II. Variable cost per year

i) Repair and maintenance of spray dryer = 2 % of initial cost of the spray dryer

$$\frac{2}{100} \times 12{,}00{,}000$$

= Rs. 24,000/-

ii)Repair and maintenance of the incubator = 2 % of initial cost of the incubator

Rs. 400/-

iii)Repair and maintenance of the induction stove = Rs. 50/-

iv)Repair and maintenance of the mixer = Rs. 40/-

v)Repair and maintenance of the sealing machine = Rs. 30/-

Total Repair and maintenance charge = i+ii+iii+iv+v

Rs. 24,480/-

b) Cost of energy

Energy requirement (motor + heating coils)	=	131.57 kWh / 16 h
Energy consumed by induction, sealing machine, weighing balance and incubator	=	60 kWh/16 h
Energy requirement		
2 fan = 80 w/h 3 light = 120 w/h 2 Exhaust = 80 w/h	=	2.24 kWh / 16 h
Total energy requirement	=	193.81kWh / 16 h
Electricity charges	=	7 kWh
Electricity consumption charges	=	No. of days x Energy/day x Rate
	=	Rs. 407001/-

c) Labour charges

One women labour @ Rs. 350/shift	=	Rs. 350/-
Labour charge /day	=	Rs. 700/-
Cost of labour per year	=	Rs. 2,10,000/-

d) Cost of raw materials

i) Quantity of milk required	=	3 litres per day
Cost of milk	=	Rs.40/litre
Cost of milk for 300 days	=	Rs. 36,000/-

ii) Quantity of starter culture required	=	0.12 litre/day
Cost of starter culture	=	40/day
Cost of starter culture for 300 days	=	Rs. 1,440/-
iii) Quantity of maltodextrin required	=	0.12 kg/day
Cost of maltodextrin	=	60/kg
Cost of maltodextrin for 300 days	=	Rs.3,600/-
iv) Quantity of corn starch required	=	0.10 kg
Cost of corn starch	=	40/kg
Cost of corn starch for 300 days	=	Rs.1,200/-
v) Quantity of ginger required	=	0.54kg/day
Cost of ginger	=	50/day
Cost of ginger for 300 days	=	Rs.8,100/-
vi) Quantity of white pepper required	=	0.45kg/day
Cost of white pepper	=	Rs.400/kg
Cost of white pepper for 300 days	=	Rs.54,000 /-
Total variable cost of flavoured yoghurt		a+b+c+d
powder / year	=	Rs. 7,45,821/-

Total cost for the production of flavoured	=	Total variable
yoghurt powder / year (m)		Cost + Total fixed cost

Rs. 7,45,821 + Rs. 1,20,521

Rs. 8,66,342 /-

Total production of flavoured yoghurt	=	4 x 300
powder / year (n)	=	1200 kg/year
Cost of production of one kg of flavoured	=	m/n = 8,66,342/1200
yoghurt powder / year	=	Rs. 722/kg

- The market selling price of 1 gm of flavoured yoghurt powder = Rs. 1.00/g

$$\text{Benefit -cost ratio} = \frac{1.00}{0.722} = 1.38/g$$

DEVELOPMENT AND QUALITY EVALUATION OF SPRAY DRIED PROBIOTIC FLAVOURED YOGURT CONTAINING *Lactobacillus bulgaricus*

by

SREEKUTTY SURESH V.

(2015-18-003)

ABSTRACT OF THE THESIS

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(Agricultural Processing and Food Engineering)

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Kerala Agricultural University

Department of Food and Agricultural Process Engineering

KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

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ABSRACT

Yoghurt is one of the most popular fermented milk products, it is a product of the lactic acid fermentation of milk by addition of a starter culture containing *Lactobacillus bulgaricus* and *Streptococcus thermophilus* . Commercial production of yoghurt has not been able to prove its supremacy in market due to its shorter shelf life. The shelf life of yoghurt can be improved by reducing its water content by drying. The dried products obtained are in shelf stable powder form which can be stored at ambient temperature. Spray drying technique has showed to be highly successful in prolonging the shelf life of food products. Considering these facts, a study was undertaken to develop a process protocol for flavored yoghurt powder. The objectives of the study are 1) Development of spray dried yoghurt powder using different carrier blend ratio and process conditions, 2) Standardisation of the process parameters and 3) Storage studies of the developed product. The physico-chemical characteristics of freshly prepared yoghurt were carried out. The spray drying of yoghurt was carried out in lab scale spray dryer with twin fluid atomizer. The spray drying experiments were conducted with different process parameters *viz.,* carrier blend ratio (B_1, B_2, B_3, B_4 and B_5), inlet air temperatures (T_1, T_2 and T_3) and feed rates (F_1, F_2 and F_3). Maltodextrin, corn starch and their combinations were used as wall material to produce yoghurt powder. Physicochemical properties of spray dried yoghurt powder were evaluated by standard procedures. The reconstituted yoghurt samples prepared from spray dried yoghurt powder were evaluated in terms of solubility and wettability. The process parameters were optimized based on the physico-chemical and microbiological properties of the developed yoghurt powder. By considering all the physico chemical and microbiological analyses done on the spray dried yoghurt powder at different processing conditions, powder sample processed at 170°C inlet temperature with carrier blend B_2 (3:1) at feed rate of 10 rpm was selected as optimized sample.

The quality of plain yoghurt powder was improved by incorporating dried white pepper extract (C_1- 2%, C_2-2.5 % and C_3- 3%) and ginger extract (G1-2%, G2-3% and G3-4%) at different combinations. The spices incorporated yoghurt product was spray dried at optimized operating parameters. The parameters of the flavored yoghurt powder were optimized based on physic-chemical and microbiological properties. By considering the physico-chemical qualities of the flavoured yoghurt under different processing conditions, the sample incorporated with 2.5 percent white pepper extract and 3 percent ginger extract (C_2G_2) was selected as the optimized sample. Flavoured yoghurt powder was packed in laminated aluminium pouches and sealed using a hand sealing machine and subjected to storage studies . Sealed pouches were stored at ambient and refrigerated storage(4°C) for a period of three months and the effect of physical, chemical and microbiological characteristics during storage was studied. The product stored at ambient condition is acceptable only up to 50 -75 days. But the product stored at refrigerated condition found safe up to 3 months.Cost analysis of the products wasdone and cost of production of one kilo gram was estimated as Rs.722/-.