DEVELOPMENT OF READY TO USE MILLET BASED COMPLEMENTARY HEALTH FOOD

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By
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CERTIFICATE

This is to certify that the thesis entitled ***"DEVELOPMENT OF READY TO USE MILLET BASED COMPLEMENTARY HEALTH FOOD"*** submitted by **Mr. SURESHA, K.B., ID. No. DDK 1203** in partial fulfillment of the requirements for the award of degree of *Doctor of Philosophy (Dairy Science)* in *Dairy Technology* of the Karnataka Veterinary, Animal and Fisheries Sciences University, Bidar is a record of bonafide research work done by him during the period of his study in this university under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, association ship, fellowship or other similar titles.

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Affectionately
Dedicated to
my Late PAAPU
&
To my beloved wife
SAHANA, J.C.

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With regardful memories……..

In every one's life, the day arises when one has to shape the feelings in words. Sometimes, the words become unable to express the feelings of the mind, because, the feelings of heart are beyond the reach of the words. When, I come to complete this manuscript, so many memories have rushed through my mind which is full of gratitudes to those who encouraged and helped me at various stages of this research. It gives me immense pleasure to record my feelings at this place.

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LIST OF ABBREVIATIONS

Bb-N - *Bifidobacterium bifidum HN019*

BIS - Bureau of Indian Standards

BV - Biological value

BMD - Bone Mineral Density

cP - Centipoise

CPPs - Caseinophosphopeptides

cfu/g - Colony forming unit per gram

DC - Digestible coefficients

DH - Degree of Hydrolysis

E:S - Enzyme : Substrate

FER - Feed efficiency ratio

La-N - *Lactobacillus acidophilus NCFM*

m eq - Milli equivalents

MEP - Metalized polyester

MAP - Modified atmosphere packaging

PET - Polyethylene terephthalate

PER - Protein efficiency ratio

WPC - Whey protein concentrate

WPH - Whey protein hydrolysate

INTRODUCTION

I. INTRODUCTION

Complementary feeding is the process starting when breast milk alone is no longer sufficient to meet the nutritional requirements of infants and therefore other foods and liquids are needed along with breast milk. Infants should be exclusively breastfed for the first six months of life to achieve optimal growth, development and health. The transition from exclusive breastfeeding to family foods is referred to as complementary feeding that typically covers the period from 6 - 24 months of age, even though breastfeeding may continue up to two years of age and beyond (WHO, 2003). This is a critical period of growth during which nutrient deficiencies and illnesses contribute globally to higher rates of under nutrition among children less than five years of age. A number of successful strategies have been developed to improve complementary feeding practices in low and middle-income countries, where practical difficulties can limit adherence to complementary feeding guidelines. But still the 2-5 year age group is the neglected group as no complementary food is available commercially. Many unforeseen reasons such as sending them to daycare, kids going out for playing, entering of a new kid in the family result in decreased attention by family members make children of this age group vulnerable for infections.

India remains home to one quarter of the world’s undernourished population, over a third of the world’s underweight children, and nearly a third of the world’s food-insecure people (UN, 2015). Malnutrition is brought about by the inadequacy or over consumption of one or more of the essential nutrients necessary for survival, growth and reproduction, as well as productivity at work (UNICEF, 2001). It lowers the body’s resistance to disease, exposing it to disease causing agents.

Young children are the most vulnerable, if not adequately addressed; malnutrition can lead to a permanent negative impact on their quality of life (Sandoval-Priego *et al.*, 2002). Adequate nutrition and health care during the first several years of life is fundamental to the attainment of the Millennium Development Goals (MDGs) for child survival and the prevention of malnutrition (Lutter, 2003).

Millet is more than just an interesting alternative to the many common grains. Millets are the sixth most important cereal grains in the world, sustaining more than one-third of the world's population. India is the largest producer of many kinds of millets, which are often referred to as coarse cereals. Millets comprises of Sorghum (*jola*), Pearl millet (*sajje*), while small millets include Finger millet (*ragi*), Kodo millet (*varagu*), Foxtail millet (*navane*), Proso millet (*baragu*), Banyard millet (*ooadalu*), and Little millet (*saame*). Annually, India is producing 42.04 million tonnes of coarse cereals of which sorghum accounts for nearly 63 per cent of production. Under millets also sorghum has a major share with a production of 11.85 million tonnes (GOI, 2013). Small millets production is around 3.0 million tonnes, of which finger millet accounts for about 80 per cent of production and the remaining is minor millets such as kodo millet, little millet, foxtail millet, barnyard millet and proso millet.

Millets are least allergic and most digestible grain available among all food grains. Millets are high in nutritional value as they contain nutrients including carbohydrates, protein, sugar, soluble and insoluble fiber, sodium, vitamins, minerals, fatty acids, amino acids and more. Majority of millet grains contain higher protein, fibre, calcium and minerals than wheat and rice. Therefore, these are now also being called as

“Nutri-cereals” (GOI, 2013). They contain high amount of lecithin, rich in B vitamins, especially niacin, B6 and folic acid. Millets are a good source of minerals like calcium, iron, potassium, zinc phosphorus, manganese and magnesium. In addition to the nutritional value millets also provide many health benefits (Itagi *et al.*, 2012).

Proper utilization of small millets which are hitherto neglected is being promoted as nutri-cereals. By proper processing many different kinds of food products can be made. Milled millet can be further processed to flakes, quick food cereals, ready to eat snacks, supplementary foods, extruded food products, malt based products, weaning foods and more importantly health foods. Standardization of hydrothermal treatments for processing small millets was carried out by the researchers (Ushakumari, 2009; Malleshi, 2007). Nutritional qualities of different ragi and other small millets and development of ragi based weaning food were studied by many workers (Begum *et al.*, 2003; Swamy, 2003; Mahadevaiah, 2011). There are studies on the processing and nutritional aspects of little millet, foxtail millet and proso millet and also on development of several value-added nutri-rich products such as ready-to-eat and ready-to-cook extruded products, ready to eat bakery products, composite mixes, nutrimixes and hurihittu in UAS, Bangalore and UAS, Dharwad (Begum *et al.*, 2003; Chandru *et al.*, 2010; Shaila, 2010; Ranganna, 2011; Devi, 2012). CFTRI (Mysore) has developed an improved method of parboiling of small millets and nutritional evaluation. NIN (Hyderabad) has reported the proximate composition, vitamin and mineral contents of small millets. NDRI, Karnal has standardized the formulations of pearl millet whey based complementary foods, extruded foods, probiotic foods and pearl millet based composite fermented dairy foods like yoghurt and lassi (Singh, 2011a; Singh, 2011b). In addition to the above, few attempts were made to prepare hurihittu, nutrimixes and malts to from both finger millet as well as from other small millets.

Whey components are used as potential food ingredients in variety of foods due to their excellent nutritional and promising functional properties (Jayaprakasha and Brueckner, 1999). Whey protein provides a wide range of functionality such as solubility, viscosity, water binding, whipping, emulsification and gelation (Sharma and Bhatia, 1999). By virtue of their higher proportion of essential amino acids, the biological value is higher as compared to that of other dietary protein (Renner, 1983). Whey proteins contain certain inherent bioactivity which can be further nurtured and enhanced by enzymatic hydrolysis (Jayaprakasha *et al.,* 2005). Research carried out over past decades has shown that caseins and whey proteins are the most important source of biologically active peptides as compared to other plant and animals sources of protein (Jenny and Ghosh, 2008).

Probiotic products have been reported to improve and maintain intestinal microflora, protect against infection, alleviate lactose intolerance, reduce blood cholesterol levels and also stimulate the immune system (Peter and Williams, 2007). It was found that viability of 10^9cfu/g in spray dried powder containing probiotic lactobacilli in combination with prebiotics that may be useful as functional food ingredient for the manufacture of probiotic foods.

Many research studies have demonstrated that the nutritional value of grains and seeds could be improved greatly by germination. The main components in sprouted food products were found to be millets, corn, soybean wheat, sorghum and peanuts (Huang,

2006) and further the fermentation of the composite flour resulted in an improvement in the protein content (Oumarou *et al.*, 2005). Even though many studies concentrate on formulating foods for the age group of 6-24months, no suitable food is being formulated for beyond this age group for the benefit of the children. Hence, there is an urgent need for developing a suitable food for the age group of 2-5 year children.

Keeping the above facts in mind, the present research project aims to develop suitable food formulations utilizing millets in the form of millet based complementary health food and a suitable process for manufacturing them for commercial exploitation with the following objectives:

1. To formulate complementary health food by the combination of selected millets and pulses
2. Supplementation of functional ingredients such as Skim Milk Powder and Whey Protein Hydrolyzate to enhance the health attributes
3. Incorporation of adjuncts such as Honey, Pro-biotic cultures to enhance physico-chemical, sensory and functionality of complementary food
4. To optimize the processing parameters of drying to make the optimized products ready to-reconstitute (RTR).
5. To evaluate the nutritional and functionality of such developed complementary foods
6. To study the storage stability of millet based complementary health foods.
7. To study the economics of the developed complementary foods.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

The complementary foods are very important foods for the growth of the children and toddlers in addition to the breast feeding up to the age of two years. There are many varieties of complementary foods available in the market as proprietary food, complementary food and other special foods. However, many times the children of 2-5 year age group are being in the neglected category of population due to various reasons. Therefore, there is an urgent need for the complementary food products for the toddlers of the age between two to five years as they are more vulnerable segment not only because of the faster growth but also they start spending more time in daycares, playing outside and more importantly the lesser attention given to this segment by the parents whenever the new baby arrives. Thus, more emphasis needs to be given for this sector especially with respect to food suitable for this vulnerable group. Keeping the above needs in mind, the investigation was aimed at developing complementary health food by utilizing different types of millets.

In this chapter, an attempt has been made to review the literature related to the development of the complementary foods their physical parameters, nutrient composition, ingredients used in formulating complementary foods along with various processing methods and storage stability of certain complementary foods has been furnished. Further, it also enlightens on the significance of whey protein hydrolysates, probiotics and their health benefits including the storage stability and the viability have also been reviewed here under.

2.1 Complementary foods

Complementary foods are foods other than breast milk or infant formula (liquids, semisolids, and solids) introduced to an infant to provide nutrients. The ideal time to introduce complementary foods in the diets of infants is difficult to pinpoint. Complementary foods introduced too early are of little benefit to the infant and may even be harmful due to the possibility of choking, developing food allergies, or causing an infant to consume less than the appropriate amount of breast milk or infant formula. Introducing complementary foods too late may cause an infant to develop nutritional deficiencies and/or miss that period of developmental readiness. Consequently, the infant may have difficulties learning to eat complementary foods when they are introduced later. When complementary foods are introduced appropriate to the developmental stage of the infant, nutritional requirements can be met and eating and self-feeding skills can develop properly. Pediatric nutrition authorities agree that complementary foods should not be introduced to infants before they are developmentally ready for them; this readiness occurs in most infants between 4 and 6 months of age (USDA, 2009). All the complementary foods are the part of the weaning and it refers to introduction of food other than mother's milk or complete discontinuation of breast milk or introduction of solids to diet. Generally, the term weaning is used to denote the process in which infant changes from breast milk to mixed diet (Macrae *et al.,* 1993). It is the process of expanding the diet to include food and drinks other than breast milk or infant formula as it is the period of infant vulnerability (Sajilata *et al.*, 2002). It represents a period of dietary transition, just when nutritional requirements for growth and brain development are high. Observations of traditional child feeding practices in many developing countries reveal that weaning period is the whole period during which breast milk is being replaced by other foods, usually starts when infant is 4-6 months old and is expected up to the age of two to three years (Alexander, 1983). Adoption of recommended breast feeding and complementary feeding practices and access to the appropriate quality and quantity of foods are essential components of optimal nutrition for infants and young children (Lutter and Rivera, 2003). Complementary feeding period is the time when malnutrition starts in many infants contributing significantly to the high prevalence of malnutrition in children below 5 years of age worldwide (Daelmans and Saadeh, 2003). Many factors contribute to the vulnerability of children during the complementary feeding period (Anigo *et al.*, 2010). The complementary foods are often of low nutritional quality and given in insufficient amounts. When given too early or too frequently, they displace breast milk (Villapando, 2000; WHO, 2002). Protein energy malnutrition is an important nutritional deficiency condition that often occurs during the critical transitional phase of weaning infants, crippling their physical and mental growth. This could be due to progressive decline in the incidence of breast feeding observed during the last 25-30 years (Acharya and Shah, 1998). This condition can be prevented to a large extent by introducing weaning foods of good quality and quantity at right proportion and at right stage (Pawar and Dhanvijay, 2007). Recommendations on the introduction of complementary foods provided to care givers of infants and they should take into account of the infant’s developmental stage and nutritional status; Coexisting medical conditions; Social factors; Cultural, ethnic, religious food preferences of the family; financial considerations; and other pertinent factors discovered through the nutrition assessment process (USDA, 2009).

2.2 Nutritional Requirements of Toddlers and Problems during weaning

Traditional weaning foods are typically watery gruels of low energy density and protein content. Often they are not consumed immediately after preparation and the unhygienic conditions of preparation and storage may lead to infection with enteropathogenic bacteria. Child *et al.,* (1997) reported that weaning infant is potentially at risk in developing countries, and many nutritional problems arise with the introduction of solids. The crude preservation process, poor hygiene sanitation and inadequate knowledge of weaning food preservation introduce the risks of gastrointestinal and parasitic infection because of the heavy contamination of food stuffs with infecting organisms. In addition, too early introduction of weaning food may lead to diarrhoea through the ingestion of thin, contaminated feed with insufficient calorie and protein. Too late introduction may lead to under nutrition owing to insufficient milk intake. Thus **c**omplementary feeding begins when breast milk alone is no longer sufficient to meet the nutritional requirements of infants and therefore other foods and liquids are needed along with breast milk (Weaver, 1994).

Malnutrition is one of the major causes of morbidity and mortality among young children in most of the developing countries and it begins in infancy especially during the transition stage from breast feeding to solid diet, frequently in association with diarrhoeal disease. The precise cause of such growth failure is unclear, but must be due to one or a combination of factors like, insufficient dietary intake, defective digestion or absorption, increased metabolic demands etc. (Rowland, 1980). To minimize this, low cost infant supplementary foods have been developed and are being supplied to the needy through state-sponsored nutrition intervention programmers (Milan *et al.,* 2007). Human milk is the best reference standard to which all infant formula compared and has always been considered as a specific food. Modern infant formulae are being designed for infants, based on our knowledge of human milk (Mingruo, 2007). The weaning food mix should be nutritionally well-balanced in proteins, fat, carbohydrate, essential vitamins and minerals. It should be precooked, if possible, so that it can be fed to babies as a soft product by simply stirring in hot or warm water (Desikachar, 1992)**.**

The amount of nutrients requirement of a baby per kg body weight declines over the period of birth owing to decreasing growth rate, even though energy requirement for activity increases as the infant becomes older (Makhal *et al.,* 2003). A new born baby weighs on an average 2.7 kg at birth and will be about 5.4 kg at six months and 8 kg by one year (Pawar and Dhanvijay, 2007). Macrae *et al*., (1993) suggested the protein requirement of 1.5, 0.6 and 0.4 g per kg body weight per day for the age group of 1-2, 5-6 and 9-12 months old children, respectively.

2.3 Ingredients used in complementary foods

The formulation of complementary food to meet the requirements of the nutrients of the toddlers involves utilization of ingredients from different sources. Breast milk is a biological fluid of exceptional complexity, containing essential nutrients for the growth and development of infants. However, bovine milk-based dried formulations have become a prominent feature of weaning food dietetics (Thompkinson and Kharb, 2007). Most of the nursing mothers used local ingredients to formulate weaning foods for their babies. The nutritional compositions of these foods are of high quality and suitable as weaning foods, particularly for infants of low income parents who are unable to access commercial weaning foods (Ijarotimi and Ogunsemore, 2007). Attempts have been made to utilize the ingredients like chickpea, wheat (Haque, 1981), ragi, green gram, groundnut etc. in the development of weaning food formulations (Anon and Plahar, 1995; Swamy, 2003; Rani, 2006; Mahadevaiah, 2011; Shashikumar, 2011).

2.3.1 Cereals and legumes

Cereals and millets are the staple food for majority of the population in the world. They are the main sources of proteins in the several developing countries and are important ingredients in weaning foods preparations (Suhasini and Malleshi, 2003). Mensa *et al.,* (2003) formulated the weaning food using maize (corn), cowpeas, peanuts, soybeans and soybean oil. Ragi (var. HR-374), mung beans (var. BM-4), peanuts (var. ICGS-4), and dried skim milk in the ratio of 35:35:10:20. The formulated weaning food had greater than or equal to 20 per cent protein (Kshirsagar *et al.,* 1994). Charalampopoulos *et al.,* (2002) developed a functional weaning food using novel cereal components as substrates, dietary fibre prebiotics and probiotics. The weaning foods formulated by Gahlawat and Sehgal, (1994) contained 5.06-5.68 g moisture, 10.28-13.71 g protein, 2.91-3.77 g ash, 1.08-1.87 g fat, 14.42-14.98 mg iron, 1.03-1.27 g crude fibre and 357-374 K cal energy for 100 g.

2.3.2 Millets

Millets are the sixth most important cereal grains in the world, sustaining more than one-third of the world's population. India is the largest producer of many kinds of millets, which are often referred to as coarse cereals. Millets comprises of Sorghum (jola), Pearl millet (sajje), while small millets include Finger millet (ragi), Kodo millet (varagu), Foxtail millet (navane), Proso millet (baragu), Barnyard millet (ooadalu), and Little millet (saame). Annually, India is producing 42.04 million tonnes of course cereals of which sorghum accounts for nearly 63 per cent of production (GOI, 2013). Under millets also sorghum has a major share with a production of 11.85 million tonnes. Small millets production is around 3.0 million tonnes. Of this, finger millet accounts for about 80 per cent of production and the remaining is minor millets such as kodo millet, little millet, foxtail millet, barnyard millet and proso millet (GOI, 2013).

2.3.2.1 Nutritional significance of millets

Millets are least allergic and most digestible grain available among all food grains. Millets are high in nutritional value as they contain nutrients including carbohydrates, protein, sugar, soluble and insoluble fiber, sodium, vitamins, minerals, fatty acids, amino acids and more. Majority of millet grains contain higher protein, fibre, calcium and minerals than wheat and rice. Therefore, these are now also being called as “Nutri-cereals” (GOI, 2013). They contain high amount of lecithin, rich in B vitamins, especially niacin, B6 and folic acid. Millets are a good source of the minerals like calcium, iron, potassium, zinc phosphorus, manganese and magnesium. In addition to the nutritional value of millets, they also provide many health benefits (Itagi *et al.,* 2012).

2.3.2.2 Health Benefits of millets

Millet is gluten-free, therefore an excellent option for people suffering from celiac diseases and also useful for people who are suffering from atherosclerosis and diabetic heart disease (Gélinas *et al.*, 2008). High amount of lecithin present in millets is reported to be good for nervous system and reduce risk of wheezing and asthma among children

(Naik, 2011). Magnesium from millets not only help to reduce the severity of asthma and migraine attacks, but also helps to reduce high blood pressure, diabetic heart disease, atherosclerosis and heart attack. (Amadou *et al.,* 2013) Niacin is been used since ages to reduce high cholesterol levels in the body (Guigliano *et al.*, 2011). Phosphorus from millets is an important mineral for energy production and also forms an essential part of nervous system and cell membranes (Shashi *et al.,* 2007). Lignin present in millets is thought to protect against breast cancer as well as heart diseases. The insoluble fiber from millets helps in gallstones prevention, known to lower triglycerides and also reported to reduce the risk of type 2 diabetes mellitus. Millets help to lower blood glucose levels and improves insulin response (Lakshmi and Sumathi., 2002). Finger millet is a humble grain with low glycemic index which makes it more suitable for diabetic patients (Pradhan *et al.,* 2010). Millet may have health promoting effects equal to or even in higher amount than fruits and vegetables and have a protective effect against insulin resistance, heart diseases, diabetes, ischemic stroke, obesity, breast cancer, childhood asthma and premature death (Cade *et al.,* 2007). The grain is also rich in phytochemicals, including phytic acid and antioxidants present in high amounts in millets which is believed to lower cholesterol, and phytate, which is associated with reduced cancer risk (Coulibaly *et al.*, 2011; Izadi *et al.*, 2012). Choi *et al.*, (2005) and Park *et al.*, (2008) reported that protein concentrate of Korean foxtail millet and proso millet significantly elevated plasma adiponectin and HDL cholesterol levels and caused major decreases in insulin levels relative to a casein diet in type 2 diabetic mice. Proso mill*et al*so improved glycemic responses and plasma levels (Park *et al.,* 2008). In addition, proso millet protein concentrate has protective effects against D-galactosamin-induced liver injury in rats (Ito *et al.,* 2008). Devi *et al.,* (2011) review the nature of polyphenols and dietary fiber of finger millet and their role with respect to the health benefits associated with millet.

2.3.2.3 Utilization of millets

Proper utilization of small millets which are hitherto neglected is being promoted as nutri-cereals. By proper processing many different kinds of food products can be made. Milled millet can be further processed to flakes, quick food cereals, ready to eat snacks, supplementary foods, extrusion cooking, malt based products, weaning foods and more importantly health foods. Earlier researchers worked on standardization of hydrothermal treatments for processing small millets (Ushakumari, 2009; Malleshi, 2007). Study of nutritional qualities of different ragi and other small millets and development of ragi based weaning food (Begum *et al.,* 2003; Swamy, 2003; Mahadevaiah, 2011). There are many studies on the processing and nutritional aspects of little millet, foxtail millet and proso millet and also has developed several value-added nutri-rich products including ready-to-eat and ready-to-cook extruded products, ready to eat bakery products, nutrimixes and hurihittu at UAS, Bangalore and UAS, Dharwad (Begum *et al.,* 2003; Chandru *et al.,* 2010; Ranganna, 2011; Devi, 2012). CFTRI (Mysore) has developed an improved method of parboiling of small millets and has worked on various aspects of nutritional evaluation. NIN (Hyderabad) has reported the proximate composition, vitamin and mineral contents of small millets. NDRI, Karnal is has standardized the formulations of pearl millet whey based complementary foods, extruded foods, probiotic foods and pearl millet based composite fermented dairy foods like yoghurt and lassi (Singh, 2011a; Singh, 2011b). In addition to the above various attempts were made to prepare hurihittu, nutrimixes and malts to from both finger millet as well as from other small millets. The nutritional value of grains and seeds could be improved greatly by germination. The optimum formulation for the main components in sprouted food products was found to be millets, corn and soybean 11 per cent and wheat, sorghum and peanuts 22 per cent (Huang, 2006). Fermentation of the composite flour resulted in an improvement in the protein content (Oumarou *et al.*, 2005)

2.3.2.4 Foxtail Millet

Foxtail millet (*Setaria italica*) is one of the most important food crops of the semiarid tropics. This cereal is also known as Italian millet. In India, this millet is grown primarily in the hot drought – prone arid and semiarid zones – and used mostly for food purposes especially by people of economically weaker sections. Foxtail millet is tasty, with a mildly sweet, nut-like flavor and contains a myriad of beneficial nutrients. This millet contains 12.3 per cent crude protein and 63-64 per cent carbohydrate 3.3 per cent minerals (Gopalan *et al.,* 1991). The foxtail millet grain contain about 63-64 per cent carbohydrate, a good proportion of which is in the form of non- starchy polysaccharides and dietary fibre. This helps the prevention of constipation, lowering of blood cholesterol and most importantly slow release of glucose to the blood stream during digestion. In fact, it is considered to be one of the least allergenic and most digestible grains available and it is a warming grain (Prashant *et al.,* 2005; Xue *et al.,* 2008). The millet bran is used as animal feed in China extensively (En *et al.,* 2008).

In addition to protein, contains moderate amounts of fiber, B-complex vitamins including niacin, thiamin, and riboflavin, the essential amino acid methionine, lecithin, and some vitamin E. It is particularly high in the minerals iron, magnesium, phosphorous, and potassium (FAO, 2008). Foxtail millet is highly nutritious, non-glutinous, and like buckwheat and quinoa, is not an acid forming food so it is soothing and easy to digest. It is considered to be one of the least allergenic and most digestible grains available and it is a warming grain that helps to heat the body in cold or rainy seasons and climates (FAO, 2008; Kamara *et al.*, 2009).

Foxtail millets could be milled to remove the husk, cooked and puffed for use in the development of breakfast and specialty foods and malted for use as an adjunct in brewing and also in the development of high-calorie density of weaning foods (Malleshi and Desikachar, 1988).

2.3.2.5 White Ragi

Ragi belongs to millets, meaning small grain cereal. It is the staple food of the millions of the arid and semi arid tropics of the world. The grains of finger millet being nutritionally superior to rice and wheat, provide cheap proteins, minerals and vitamins to the poorest of the poor where the need for such ingredients is maximum (Seetharam *et.al.*, 1986). White and brown ragi (*Eleusine coracana*) varieties were analysed for tannin, phytate phosphorus, total phosphorus, iron, ionisable iron, zinc and soluble zinc content. White ragi had no detectable tannin while in brown varieties it ranged from 351 to 2392 mg per 100 g. Germination brought about a progressive decrease in tannin and phytate phosphorus and an increase in ionisable ion and soluble zinc content of grain ragi. Both in raw and germinated grain, ionizable iron was significantly higher in white than in brown varieties (Rao and Deosthale, 1988). Availability of white grain ragi varieties, which were expected to be free of tannin, provided an opportunity to test and compare them for their tannin content, ionisable iron and soluble zinc contents, in vitro parameters of bioavailability (Puar, 1983; Rao and Prabhavathi, 1978). One brown and one white ragi were analysed for their protein, amino acid, tannin and mineral composition. White ragi had higher protein (12.3 %) and iron (12 mg/100 g) than the brown ragi (8.7 % protein and 4.4 mg/100 g of iron). White ragi was devoid of tannin while brown ragi had 2.4 per cent of tannin. Malting decreased the tannin by 54 per cent in brown ragi and phytin phosphorus by 58 and 65 per cent in brown and white ragi, respectively. Ionisable iron (271 and 55%) and soluble zinc (81 and 25%) contents increased significantly after malting brown and white ragi. There were no significant differences in the amino acid compositions of brown and white ragi proteins (Rao, 1994). Finger millet is used in various food preparations. It is usually converted into flour and made into cakes, bread and other bakery products. The sprouted seeds are also nutritious and easily digested. The grain may also be malted and a flour of the malted grain is used as a nourishing food for infants (Mgonja *et al.*, 2007). The chemical compositions of the ingredients play vital role in deciding of the formulations to be prepared and the resultant composition of the developed product. The chemical composition of the raw flours used for the preparation of extruded flours and also in preparation of flakes. The chemical composition of the raw flours is depicted in Table-1. The compositional values in raw white ragi flour for moisture, fat, protein, carbohydrate, crude fibre, and ash content were 9.00, 1.65, 11.98, 69.37, 4.20 and 3.80 per cent respectively. The energy density of the raw white ragi flour was 340.25 kcal/100g (Ravishankar *et al.*, 2015).

2.3.2.6 Sorghum

Sorghum is the fifth most important cereal crop in the world after wheat, rice, maize, and barley. Grain sorghum is a staple food in the semi-arid tropics. Asia and Africa contribute about 65 per cent of the total grain sorghum production in the semi-arid tropics. About 700 million people are nourished by sorghum, since it constitute a source of calories, protein and minerals. Sorghum produced in India is consumed mostly in the form of roti (unleavened bread) and Mudde (thick porridge). Besides traditional uses, sorghum can also be use alternative for popping and flaking. Apart from the use as snack food, popped sorghum can be used in weaning food formulations. Sorghum flakes will be a good alternative for corn flakes as breakfast cereal (Sailaja, 1992). Utilization of sorghum in the form of ready-to-eat pops and flakes is likely to improve its consumption significantly. A number of different processes are used in the preparation of ready-to-eat cereals, including flaking, puffing, shredding and granule formation in wheat, corn and rice. Whereas, utilization of sorghum in flaking and popping processes have not been explored much till now. The grain characteristics required to produce traditional food products of high quality have been reported (Rooney and Murty, 1982; Rooney *et al.*, 1986). However, very little is known about the physicochemical characteristics of grain which influence the processing and sensory quality of sorghum pops and flakes so as to select appropriate cultivars for popping and flaking. The effect of modern methods of processing of wheat on the in vitro starch digestibility has been investigated by earlier workers (Holm *et al.,* 1985; Holm and Bjorck, 1988). Cooking has also been found to lower protein digestibility in sorghum (Axtell *et al.,* 1981). During processing, some interactions do occur among the constituents of grain. These interactions might lead to some changes that affect the digestibility of constituents and thereby its nutrient availability. Physical properties of grain vary considerably due to the influence of genotype and environment. The influence of certain physical characteristics of grain such as hardness or vitreousness on the quality of traditional sorghum food products has been well demonstrated (Murty and House, 1980; Rooney *et al.,* 1980, Cagampang *et al*., 1982; Rooney and Murty, 1982). Sorghum grains with a high proportion of vitreous endosperm are preferred for making thick porridges, cookies and for popping (Chandrashekar and Desikachar, 1986) of floury endosperm are preferred for making fermented and unfermented bread (Rooney *et al.*, 1986).

2.3.2.7 Little millet

Little millet is one of the minor millet. The crop is well known in Tamil Nadu, Karnataka, Andhra Pradesh, Maharashtra, Jharkhand, Madhya Pradesh, Orissa, and Gujarat and grown quite extensively in many parts of the country. The crop is strongly associated with tribal agriculture and grown as an important catch crop in view of its earliness and resistance to adverse agro climatic conditions. The stover is a good fodder for cattle (Sharma, 2008) Although little millets are superior to other cereals with many nutritional benefits, their utilization is limited mainly to poor section of population or to cattle and poultry feed, or finds place as fasting food, reason being low palatability coarseness of grain, lack of time to process the grains and slow the digestibility of protein and carbohydrates.

Composite mixes were developed using little millet or cereals (wheat, rice and sorghum), pulses (green gram dhal and bengal gram dhal), oilseed (peanut) and green leafy vegetables (amaranthus or chakramuni) by employing roasting and dehydration techniques. Multigrain mixes possessed higher moisture (5.67%), protein (14.85%) and ash (2.14%) compared to little millet based mixes (5.58, 13.79 and 2.03%). Crude fat (7.60%), carbohydrates (70.12%) and energy (404 Kcal) content were higher in little millet based mixes. Amaranthus incorporated mixes had higher iron content (6.61-8.76mg/100g). Multigrain mix with amaranthus had better IVPD (70.4%) and IVSD (115.56mg glucose/g). Little millet based mix possessed higher total (16.55%) and insoluble (11.25%) fiber, while multigrain mix had higher soluble fiber (6.45%). Little millet mix had excellent shelf life to 60 days, while multigrain mix had storage life of 105 days with better sensory scores. Though there was increase in moisture and peroxide value during storage, little millet mix with amaranthus leaf powder was highly appreciated in the form of thalipattu and laddu by a panel of judges. It was concluded that little millet can be utilized in the form of composite mix similar to multigrain mix (Shaila, 2010). The study on utilization of little millet was used in biscuits, vermicelli, pasta products, pakoda, dosa, masala roti, laddoo, chikki, kodubale and masala vada revealed that little millet can be incorporated from 30 to 100 per cent in the value added products (Usha, 2007).

2.3.3 Wheat

Wheat grain is the second largest food grain in India. Over 80 per cent of the production is consumed in the form of various traditional products from whole wheat flour and wheat consumption is increasing in developing countries (Sudha and

Venkateshwara Rao, 2009). Wheat contains higher amounts of protein and energy as compared to other cereals and millets (Gopalan *et al.*, 1991). Though wheat contains higher amounts of protein as compared to other cereals and pulses, its protein is relatively low in amino acids especially lysine, methionine and tryptophan but rich source of carbohydrates (70%) and relatively high in B-complex group vitamins like thiamine and niacin. On the contrary, it is a poor source of riboflavin, pyridoxine and carotene but the wheat germ is rich in vitamin E (Saibaba, 1995). Like other cereals, wheat contains more phytates which contributes significantly to poor absorption of zinc and some other trace elements. Upon germination of grains, the phytates content gets reduced due to enzymatic breakdown of phytates which improve the iron bioavailability (Malleshi, 1995). However, the wheat based product preparation may enhance or reduce the nutritive value significantly depending on the factors such as cooking method, ingredients used, consistency and also the serving size (Chaman *et al.,* 2003).

2.3.4 Green gram

Protein requirements of the Indian diets mainly come from the vegetable proteins particularly cereals and pulses**.** Green gram is one of the important pulses among the different pulses that contains about 8.4 - 9.3 per cent moisture, 24.66 - 27.77 per cent crude protein, 3.55 - 4.03 per cent minerals, 57.34 - 61.38 per cent total carbohydrate, 1.10 -1.97 per cent crude fat and about 138mg/100g calcium, 46.2mg/100g phosphorus and 5.63mg/100g iron (Sood *et al.*, 1992). Lysine, a limiting amino acid in cereals is present in appreciable amount in green gram (5.51-7.65g/100g protein). Even though it contain higher amount of lysine than that recommended in FAO reference protein, its chemical score is poor (33.2) due to low content of methionine (270mg/1000g) and threonine. Many attempts have been made earlier to formulate malted weaning foods by using ragi and green gram (Malleshi *et al.*, 1986**;** Swamy, 2003).

2.3.5 Skim Milk Powder and milk proteins

SMP is a creamy fine powder to feel, white in colour contains almost the same amount of proteins and carbohydrates as in the liquid form on dry basis. Milk powders are extremely useful products and as this realization grows, so does the demand for a high quality product. Consumers can benefit from the durability, convenience, and stability to microbial spoilage of these products (Schwambach and Peterson, 2006). Skim milk is a source of lactose and casein and other nutrients. Since the fat percentage is decreased to almost nil, skimmed milk powder is deficient in fat soluble vitamins, but the proteins, water-soluble vitamins and minerals are preserved as in milk. Milk powders are more stable than fresh milk but protection from moisture, oxygen, light and heat is needed in order to maintain their quality and shelf life. Milk powders readily take up moisture from the air, leading to a rapid loss of quality and caking or lumping (Masters, 2004). SMP can be reconstituted easily by just adding water and can be used as regular milk for drinking and incorporated in many recipes. SMP is a highly nutritious, versatile, and multi-functional food ingredient with a wide range of applications. It may be used as a food ingredient in bakery, confectionery, dairy, sports and nutrition products, infant formulas, and other consumer products. The foaming and whipping properties of SMP allows this product to work well in ice creams, cakes, dry mixes, mousses, and aerated confections such as malted milk and nougat centered candy. SMP addition aids in the formation and stabilization of emulsions, and enhances mouth feel in salad dressings, soups and sauces, dairy beverages, sausages, and sour cream. The thickening, water binding, and gelling properties of this product provides an ingredient suitable for puddings, set yogurts, sauces, and dairy beverages (Upadhyay, 1999).

Milk proteins are superior quality proteins. They possess good functional properties primarily because of their unique amino acids composition as; they provide essential amino acids required for infant and adult nutrition and also due to desirable physico-chemical attribute (Harwalky, 1993). The milk proteins are classified into two families, casein and whey proteins. Milk proteins have long been considered as food proteins for young mammals as they are the principal source of amino acids (Anne-merie fiat *et al.,* 1993). From time immemorial the power of milk was visualized as the eternal between the mother and her offspring as assurance of survival for the newborn. Sin e then the biological expedition for the quest of the new molecules in milk has become an unending exploration (Sood and Ganguli, 2000).

In addition to nutritional role, milk proteins have physiological importance such as iron transport and are rich source of biologically active peptides. These numerous peptides exhibit multifunctional biopotency which include opiate activity, antihypertension, and immunomodulation, bioconversion of metal ion such as calcium, antithrombotic activities and antibacterial properties (Nayak *et al.,* 1999).

2.3.6 Whey protein and its nutritional and functional characteristics

Whey is the largest by-product of the dairy industry. Whey is rich in lactose, whey proteins, water soluble vitamins and minerals. Whey is considered as a way for health in light of the benefits that are imparted by whey proteins (Alok and Kanawajia, 2010). Biological value of whey proteins is superior to most other proteins, whey proteins also have a high content of sulphur-containing amino acids, which support antioxidant functions (Sinha *et al.,* 2007). Whey solids could be effectively used and should be exploited in novel food formulations to overcome the nutritional deficiencies in grains and legumes. Because of their high quality proteins, particularly the sulphur containing amino acids and acts as a balancing ingredient in weaning food formulation (Makhal *et al.,* 2003).

Whey proteins are one of the highest quality natural proteins available (Patel *et al.,* 1991). Owing to their excellent nutritional and functional properties, whey protein concentrate has been seriously considered as a nutritional ingredient to improve nutritional richness of variety of foods (Huffman, 1996), compared to the various sources of other proteins such as soya, beef, egg, casein etc. They also exhibit multi-dimensional functionality (Lahl and Braun, 1994**;** Mann, 1998; Jayaprakasha and Brueckener, 1999) as they possess proportionately more sulphur containing amino acids (cysteine and methionine) than caseins, which contributes to the higher PER of whey proteins (3.2) than casein (2.6). Any protein with a PER of 2.5 or more is considered as good quality proteins (Walzem *et al.,* 2002**).** Whey proteins possess higher nutritional value because of higher concentrations of essential amino acids such as lysine, tryptophan, isoleucine, threonine, etc. (Renner, 1983) and they also contain a relatively high proportion of branched chain and essential amino acids (Ha and Zemel, 2003). Pasim and Miller, (2000) reported that Biological Value (BV), Net Protein Utilization (NPU), Protein Efficiency Ratio (PER) and Protein Digestibility Corrected Amino Acids's of whey proteins are higher (104, 92, 3.6, 1.6) as compared to casein (77, 76, 2.9, 1.0), whole egg (100, 94, 3.8, 1.0), respectively.

Whey proteins provide good functional and nutritional properties for formulation novel products which have potential to improve the quality of food products. Most of the key functional properties are classified into two main groups: hydration related and surface related (Morr and Ha, 1993). Hydration related functional properties include dispersability, solubility, swelling, viscosity and gelation. Surface related properties include emulsification, foaming, and absorption at air water interfaces (Dewit, 1989; Kinsella and Whitehead, 1989; Jayaprakasha and Brueckner, 1999; Rathore *et al.,* 2004). The presence of WPC with high protein content (WPC 80) resulted in a decrease in the firmness and consistency and an increase in the cohesiveness of dough (Conforti and Lupano, 2004). The functional peptides derived from milk serve to modulate processes such as digestion, circulation, immunological responsiveness, cell growth and repair of nutrient uptake. They also act as opioid agonistic, opioid antagonistic, antihypertensive, immunomodulatory, antimicrobial, antithrombic and mineral binding activities (Nayak *et al.,* 1999).

2.3.7 Whey Protein Hydrolysate and its nutritional and functional properties

Whey proteins contain certain inherent bioactivity which can be further nurtured and enhanced by enzymatic hydrolysis (Jayaprakasha *et al.,* 2005). The enzymatic hydrolysis of whey protein is known to improve some of their functional properties and offers interesting opportunities for food applications (Euston *et al.,* 2001). Enzymatic hydrolysis of whey proteins improves their functional properties such as increased solubility, decreased viscosity and significant changes in foaming, gelling and emulsifying properties **(**Jenny and Ghosh, 2008). The most important whey proteins are α-lactalbumin and β-lactoglobulin. Both of these proteins are likely to provoke allergic responses. Whey protein hydrolysates have also been used as the major proteins in formulas for infant’s allergic diseases to reduce antigen reactions. Whey protein hydrolysates based infant formula is likely to have not only low antigen reactivity, but also to have a favorable clinical effect over casein hydrolysates based infant formula for infants with atopic dermatitis (Cantani and Micera, 2005). Research carried out over past decades has shown that caseins and whey proteins are the most important source of biologically active peptides as compared to other plant and animals sources of protein (Jenny and Ghosh, 2008).

The nutritional quality of the whey protein hydrolysate has been considered as good, as it results in high nitrogen protein utilization and biological value as compared to reference protein. Besides these, whey protein hydrolysates reduce antigenicity, improve therapeutic and prophylactic properties (Boja *et al.,* 1995). Several studies have shown that protein hydrolysates containing mostly di-and tripeptides are absorbed more rapidly than free form amino acids and much more rapidly than intact protein (Manninen, 2004). Several infant formulae were subjected to an in-vitro enzymic procedure simulating physiological digestion. The formation of bioactive peptides has mineral carrier properties in the gastrointestinal tract, which resist further proteolysis (Miquel *et al.,* 2005). Physiological activity of peptides of whey protein may be used as food additives to promote the absorption of calcium and prevent bone disorders. The calcium binding peptides were produced by tryptic hydrolysis of whey protein concentration (Rvi, 2009).

Whey proteins contain some immunomodulatory peptides which can be released by enzymatic digestion. Identification and isolation of such bioactive peptides would promote development of potent immunomodulatory products (Mercier *et al.,* 2003). These hydrolysed products also possess higher digestibility and better functionality (Pintado and Malcatta, 2000). The water absorption capacity of whey protein concentrate was 10ml/100g and upon enzymatic hydrolysis increased to about 16 to 34ml/100g depending on duration of hydrolysis. Emulsion capacity (45ml of oil/g of control WPC) showed a decreasing trend with increasing time of hydrolysis (Rhicha-sinha *et al.,* 2007). Bioactive peptides which are of significance are those with opioid, antagonistic opioid, immunomodulatory, antithrombic, ion transporting or which are having antihypertensive activity (Schanbachar *et al.,* 1998; Nayak *et al.,* 1999; Meisel, 2001). Milk and milk products are rich sources of bioactive peptides, which are known for inducing ACE-inhibitory, mineral binding, antimicrobial and opioid activities (John *et al.,* 2007). Potential allergic reactivity of the protein hydrolysate is a crucial factor in the formulation of hypoallergic infant formulae. Hydrolysis of milk protein to produce protein hydrolysis of low molecular weight of about 1-3 KD are shown to reduce the allergenicity completely (Bendels and Boerma, 1994). Opioid peptides with agonistic (β-casomorphin-5) antagonist activity were found in a peptide extract from the formula and also in its pepsin/trypsin hydrolysate (Jarmolowska *et al.,* 2007).

2.3.8 Honey

Honey is the natural sweet substance produced by honeybees from the nectar of blossoms or from the secretion of living parts of plants or excretions of plant sucking insects on the living parts of plants, which honeybees collect, transform and combine with specific substances of their own, store and leave in the honey comb to ripen and mature (Codex, 2001).

Fructose (~ 38% w/w) and glucose (~31%) are the two major sugars present in honey, with lesser amounts of sucrose (~1%), other disaccharides and oligosaccharides (Weston *et al*., 1999). Gluconic acid, other acids and small amounts of proteins, enzymes (including glucose oxidase), amino acids and minerals may also be present. Potassium is the major mineral present. Honey is mildly acidic with a pH around 3.9. Moisture content is low (~17%), as is water activity (0.562 – 0.62) (White, 1979). Honey is said to facilitate better physical performance and resistance to fatigue, particularly for repeated effort; it also promotes higher mental efficiency (Sato and Miyata, 2000). Honey also has a major role to play as a carrier of foods containing relatively high levels of vitamins and minerals, and has been shown to help the body absorb minerals such as calcium (Ustunol, 2002). The use of honey mixed with milk or milk products is a very common home remedy against colds and infections of the throat. In the industrial sector some non-medicinal honey-milk products exist, such as pasteurized and homogenized milk sweetened with honey. One particular honey-milk is prepared with dried milk powder plus 25 per cent honey and 10 per cent glucose (Krell, 1996; Ruth, 2008). Thus, when used at suitable levels, honey does not inhibit the growth of common bacteria such as *Streptococcus thermophilus, Lactobacillus acidophilus, Lactobacillus delbrueckii* and *Bifidobacterium bifidum* which contribute to maintain a healthy gastrointestinal tract (Amy *et al*., 1996). Ustunol, (2002) examined the growth of lactic acid bacteria and bifidobacteria in a honey medium. Twelve percent nonfat dairy milk containing 5 per cent (w/w) clover honey, fructose or sucrose were pasteurized and inoculated with commercial strains of *Steptococcus thermophilus, Lactobacillus delbrukeii subsp bulgaricus* and probiotics *Lactobacillus acidophilus* and *Bifidobacterium bifidum*.

Viability of bacteria was not influenced by sweetener type indicating that honey was not inhibitory at the 5 per cent level. In addition, honey significantly enhanced the growth/production of lactic acid from *Bifidobacteria*. These results indicate that honey, a natural sweetener comprising vitamins, enzymes, minerals, and antioxidants, contains a number of fermentable carbohydrates including a variety of oligosaccharides that can function as prebiotics and enhance the growth, activity and viability of bifidobacteria in milk, and fermented dairy products such as yoghurts.

2.4 Processing of weaning foods and complementary foods

Suitable and effective processing of the complementary foods and weaning foods is an important step to not only to improve the shelf life but also nutritional and functional properties of the developed food. Weaning food containing germinated flour/meal contained higher nutrient levels than those containing non-germinated flour and resulted in enhanced growth and development (Ikujenlola and Fashakin, 2005). For commercial preparation of weaning food, the most commonly adopted methods are roller drying, extrusion cooking and spray drying to a limited extent. However, weaning food can also be made based on some traditional food processing techniques such as malting or sprouting of cereals and legumes, fermentation, popping and flaking cereals (Malleshi, 1995). Weaning food prepared by malting of cereals promotes low bulk higher calorie and dense supplementary foods (Malleshi and Desikachar, 1988). Malted seeds produce finer flours with diminished starch swelling capacity and reduced gruel viscosities (Griffith and Perez, 1998).

Processing techniques known to improve nutritional status of weaning food by decreasing anti-nutritional components. Food processing methods to remove and/or degrade phytate (removal of phytate by enzymic degradation, extrusion cooking, roller-drying, soaking, germination, fermentation) have been recommended in order to improve iron absorption (Hurrell, 2004). Some of the phytates are water soluble in nature and can be reduced by soaking cereal in water (Perlas and Gibson, 2005). Bioavailability of iron increased by 62 per cent in green gram, 39 per cent in chickpea and 20 per cent in finger millet with a reduction in tannin content upon germination (Hemalatha and Srinivasan, 2007). Low cost, nutritious and highly digestible weaning food was developed by using malted ragi and malted green gram (Malleshi and Desikachar, 1982). This enhanced the nutritive value of foods by increasing lysine and tryptophan and reducing antinutritional factors and improved the overall bioavailability of nutrients (Kadam *et al.*, 1984). The finger millet and kidney bean which were sprouted, autoclaved and fermented were used in weaning food for feeding to 2-5 years old children. A good percentage of essential to total amino acids was observed with finger millet (44.2- 44.9%) and kidney beans (44.2-45.1%) as compared to FAO/WHO reference protein (33.9%) (Stephen *et al.*, 2000). The nutritional and textural benefits of malting are utilized for development of nutritional food for different target groups (Gokavi, 2001).

Cereals, pulses and jaggery were used in the proportion of 70:30:25, roasting and malting were used to process cereals and pulses for development of weaning foods. It was observed that starch and protein digestibility and iron bioavailability of weaning foods improved (Gahlawat and Sehgal, 1994). Roller-drying method reduced in-vitro protein digestibility of weaning foods and concluded that partial digestion of weaning foods with alpha-amylase may improve nutrition of children by reducing viscosity of the food, and improving digestion and absorption of the foods (Weaver, 1994). Roasting and malting were also resulted in a significant increase in HCL-extractable minerals, an index of their bioavailability to humans (Pawar and Dhanvijay, 2007).

2.5 Physical parameters of the complementary foods and composite mixes

Physical characteristics *viz*., particle size, bulk density, viscosity and water activity of complementary foods and composite mixes play an important role in determining the acceptability of the product. Viscosity of the formulation was measured at 5, 10, 15 and 20 percent hot paste slurry showed 16, 24, 56 and 92 cp respectively (Chandrashekhar *et al.*, 1988). The particle sizes analysis of the malt based weaning foods were formulated using sorghum, green gram and sesame revealed that 30 – 47.24 per cent of particles were of 250 µ in size and very little quantity (0.12 – 0.14 %) had particle size of 67 µ (Kulkarni *et.al.*, 1991). Kshirsagar *et al.* (1994) developed malted, roasted and formulated weaning mixes using finger millet, green gram, groundnut and skim milk powder at 35:35:10:20 proportion. The developed malted food (49.1 m.pa.s) showed lowest cold paste viscosity followed by formulated + 5 percent barley malt added food (73.6 m.pa.s) compared to formulated (834 m.pa.s) and roasted (1374 m.pa.s). The effect of processing on the hot paste viscosity was maximum in formulated + 5 percent barley malt added food (82.6 m.pa.s), followed by malted (98 m.pa.s) food at the shear rate of 7.66 per sec. Cooked paste viscosity of malted (122.7 m.pa.s), roasted (9571 m.pa.s) and formulated food (9989 m.pa.s) was higher than hot paste viscosity (98, 6037 and 5546 m.pa.s respectively).

Grain amaranth (70%) and Italian millet (30%) were used to develop weaning foods by employing malting and roasting techniques (Suma, 1998) indicated that malted mix had lower viscosity (560 cpu) when compared to roasted (3520 cpu). The viscosity of roasted food reduced significantly (1800 cpu) with the addition of 5 percent Amylase Rich Food.

The physical parameters of formulated malted and roasted supplementary mixes using cereals (sorghum, rice, and finger millet), pulses (soybean, green gram), oilseed (peanut) and amaranth leaves in equal proportion revealed that significantly higher proportion of roasted formulation had particle size between 250 and 420µ (47.11%), while nearly one third of malted formulation was less than 105µ (30.06%) in size and between 180µ and 250µ (27.78%) indicating that malted formulation had finer particles than roasted mix (Banakar, 2005). Poongodi and Jemima (2009) mixed kodo and barnyard millet flours in the ratio of 1:1. The mixture was passed through 40 mesh sieve had particle size of more than 250µ. The percentage of fine flour particles was reduced with increasing the percentage of millet flour. Bulk density, true density, porosity, swelling power, hot paste viscosity and cold paste viscosity decreased with the increase in millet incorporation (0.6 – 0.54g/ml, 2.5 – 1.19g/ml, 76 – 54.5%, 3.165– 2.715ml/g, 1942 –1053 cp and 2972 – 2578cp) respectively.

2.6 Nutrient composition of complementary foods and composite mixes

Chemical composition of the mixes changes with the processing. Roasting increases the protein digestibility by denaturing the native protein and by destroying the trypsin inhibitor (Aworth, 2008). Malting enhances the nutritional quality of mix through the action of amylases and proteases as well as brings about an increase in vitamins, by reducing the trypsin inhibitors. The nutritional value of two weaning mixes were developed using pearl millet or barley with roasted amaranth, green gram and jaggery in the ratio of 60:20:40:45 revealed that the moisture, protein, energy, ash, iron and calcium contents of the mixtures ranged from 5.90 to 6.03g, 9.84 to 9.95g, 416 to 441 Kcal, 3.77 to 4.32g, 17.75 to 19.42 mg and 150 to 190 mg per 100g respectively (Gupta and Sehgal, 1991). Mixes developed using sorghum, green gram and sesame flour at different proportions (Kulkarni *et al.,* 1991) contained 14.31 to 17.46g of protein, 3.10 to3.40/ 16g N available lysine 2.35 – 2.63g ash, 1.7 – 2.34 g crude fiber, 75.5 – 80.83 carbohydrates, 361 -385 Kcal, 18.29 – 26.2 mg ascorbic acid and 11.37 – 12.01 mg of iron. The formulated composite mix using maize (20%), sweet potato (50%), soybean (25%) and peanut (5%) contained 14-25 percent protein, 6.41 percent fat, 2.39 percent ash, 67.36 percent carbohydrates, 59.6 mg calcium, 187.5 mg phosphorous and 2.4 mg iron per 100g (Idowu *et al.,* 1993). The mix had lower values iron compared to commercial weaning food cerelac. Kshirsagar *et al.,* (1994) formulated and nutritionally tested four weaning foods based on finger millet, green gram, peanut, skim milk powder in the ratio 35:35:10:20 with or without addition of 5 percent barley malt. Protein content of the mixes ranged from 20.8-21.7 percent, fat from 3.5 – 3.7 percent, ash from 3.1 – 3.7 percent and crude fibre 1.64– 1.79 percent.

Geetha and Suja (1996) formulated two mixes using rice or finger millet, lima bean and peanut at the ratio of 65:25:15 and analysed the nutrient composition. The authors reported that every 100g of finger millet based mix had higher protein (12.08g), fat (6.8g), ash (1.10g), iron (2.5mg), phosphorus (283mg) and calcium (260mg) compared to rice based mix (12.20g, 5.9g, 0.9g, 0.5mg, 205mg and 63mg/100g respectively). Roasted and malted weaning mixes using amaranth grain and Italian millet in the ratio of 70:30 were developed by Suma (1998) reported that the roasted mix contained higher protein (14.79g/100g), fat (4.75g/100g) and ash (2.24g/100g); lower fibre (1.73g/100g) and carbohydrates (71.79g/100g), compared to malted mix (14.15g, 4.15g, 2.21g, 2.05 and72.16g per 100g of mix respectively). Nnam (2000) formulated eight multi-mixes using maize, sorghum, cowpea, soybean, yam, coco yam, plantain and sweet potato at the ratio of 65:30:05 (cereal: legume: starchy staple). Results of nutrient analysis revealed that, soybean in combination with sorghum or maize contained higher amounts of protein (20.03 to 23.0 %), fat (7.67 – 7.74 %), crude fibre (2.46 – 3.71 %) and calcium (70.06 – 81.69 mg). Maize in combination with soybean plus plantain and sorghum with cowpea plus plantain contained higher amount of iron (3.66 mg/100g). Srivastava *et al.* (2001) developed proso millet based malted and popped convenience mixes along with soybean and peanut flours, in the ratio of 70:15:15. Popped mix contained significantly higher amounts of fat (5.43g/100g), protein (15.98g/100g) and energy (336 Kcal/100g) compared to malted mix (5.0g, 14.35g, and 328 Kcal/100 g respectively). Composite mixes were formulated using popped cereals (40% wheat, finger millet, pearl millet or sorghum), legumes (20 or 10% defatted soy flour or 10 % bengal gram dhal), jaggery (30%) and vegetable fat (5%), fortified with vitamins and minerals contained 10.4 to 12.5g protein, 4.2 to 5.9g fat, 10.0 to 13.0 g dietary fibre, 1.8 to 3.6g ash, 64 to 67g carbohydrates and 340 to 398 Kcal of energy (Baskaran *et al.*, 2001). The mixes were well within PAG recommendations of protein and could meet 1/3rd RDA for children. The formulated millet based weaning food, using malted flours of foxtail millet (30%), barnyard millet (30%), roasted soy flour (25%) and skim milk powder (15%). Weaning mix contained 18.37, 4.0, 9.0, 0.41 and 60.89 percent of protein, total ash, crude fat, crude fibre and carbohydrates respectively (Thathola and Srivastava, 2002). Further weaning mix was fortified with multivitamin-mineral mixture to meet PFA standards. Banakar (2005) developed supplementary foods using roasted or malted sorghum, finger millet, green gram and roasted rice, soybean and peanuts. To enhance the micro nutrients powdered amaranth leaves were added. When analysed for nutritional quality, roasted food contained significantly higher amount of protein (16.88%), fat (4.27%) and ash (2.97%) compared to malted (15.96, 3.89 and 2.86% respectively) while, malted food contained significantly higher amounts of moisture (5.93%), crude fibre (2.52%) and total carbohydrates (68.84%) compared to that of roasted (5.89, 2.43 and 67.56% respectively). The energy value of roasted and malted foods was 376 and 374 Kcal respectively. Every 100 gram of malted mix had comparatively higher amounts of calcium (430.50 mg), iron (11.18mg), zinc (4.5mg) and copper (3.48 mg) than roasted (4.27, 10.97, 4.28 and 3.39mg respectively). Ahmed *et al.,* (2008) formulated six mixes using flours of wheat and soybean at different proportions. Soybean was heat treated for 5, 10 and 15 min, before powdering and mixed with wheat flour at the ratio of 95:5 or 90:10. Further 3g of milk powder and 5g sugar were blended to all the mixes and analysed for proximates. Mixes contained 12.52 to 13.63g protein, 4.58 to 4.88g fat, 1.47 to 1.57g ash and 72.69 to 73.72g carbohydrates. The above studies support the statement of development of many nutritious formulations in the form of complementary food.

2.7 Protein quality of composite mixes

The quality of a protein, required for building or maintenance of tissues, depends upon the essential amino acid composition. If the amino acid composition of a food meets that of a tissue, the food protein is said to be of high quality. A relative deficiency of a particular amino acid in a food is known as the limiting amino acid like lysine in cereal protein, tryptophan in maize, methionine in legumes etc. Hence mutual supplementation improves quality in terms of amino acid profile. Many scientists evaluated the protein quality of developed composite mixes employing in vivo and in vitro methods. Low cost weaning mixtures were prepared by mixing malted cereals (pearl millet or barley); roasted grain amaranth, green gram and jaggery in the ratio of 60:20:40:45 (Gupta and Sehgal, 1991) and evaluated for protein quality. Results revealed that processing of cereals and pulses brought about 24.93 to 28.29 percent increase in in vitro protein digestibility of the weaning mixtures which was 80.22 and 84.43 percent in pearl millet and barley based mixes respectively. Livingstone *et al.* (1993) evaluated protein quality of developed malted, popped and roller dried weaning foods based on wheat, chickpea, skim milk powder and sucrose (60:30:5:5). Results indicated that malted foods had better NPR (4.00), PER (2.91), BV (88.3), TD (87.5) and NPU (77.3) compared to popped (3.94, 2.68, 86.7, 82.9 and 71.9, respectively) and roller dried (3.44, 2.37, 85.7, 80.9 and 69.4 respectively). Begum and Kupputhai (1993) developed supplementary food mixes based on wheat and soybean with or without peanut or sesame (70:30 or 70:25:5) and evaluated for protein quality. Sesame added supplementary mix had higher PER, DC, BV and NPU (2.28, 92.8, 91.53 and 84.48 respectively) compared to soy added (2.23, 92.32, 90.76 and 82.91 respectively) and peanut incorporated (2.21, 91.23, 90.17 and 82.20 respectively) mixes.

Protein quality assessment of roasted and malted formulation with or without barley malt (5%) using finger millet, green gram, peanut and skim milk powder in the ratio of 35:35:10:20 indicated that malted and malt added foods had IVPD of 70.98 and 60.19 respectively (Kshirsagar *et al.*, 1994). Four weaning blends were developed and evaluated for protein digestibility by Griffith *et al.* (1998) using pearl millet, teff, cowpea and peanut at 60:40 ratio of cereal and legume/oilseed blend. The peanut plus pearl millet mix had IVPD of 51.2 – 56.1 percent, peanut+pearl millet+teff based mix had IVPD of 52 – 56.8 percent, which was 13.8 percent higher than cowpea based blends (43.9 – 50.0 and 43.9 – 52.0 respectively). The fermented and malted blends had better digestibility (56.8% and 58.4% respectively) compared to unprocessed blends, indicating that processing methods improved IVPD by 12 – 14 percent. Multi-mixes formulated by Nnam (2000) with cereal, legume and starchy staple at the proportion of 65:30:5 using processed sorghum, maize, soybean, cowpea, yam, coco yam, plantain and sweet potato by employing sprouting and fermentation techniques, were assessed for protein quality using chemical score and net protein value. Though all the mixes contained adequate amounts of most of the essential amino acids, they were reported to be limiting in methionine (30.97 – 69.09). Second most limiting amino acid in cowpea based mixes was lysine (76.91 – 81.76) and phenylalanine (79.93 – 89.31) was the second most limiting amino acid in soybean based mixes, while cowpea plus maize plus coco yam based mix had tryptophan (79.06) as second most limiting amino acid. Maize based mixes had better net protein value (9.89 – 11.3) compared to sorghum based mixes (5.22 – 7.19). Malted and popped proso millet (70%) was used in the preparation of convenience mixes, along with 15 percent roasted soy flour and 15 percent roasted peanut flour. The mixes were subjected to protein quality evaluation in terms of PER against casein diet as control and reported that malted mix had higher PER (2.13) compared to popped convenience mix (1.88) while that of casein diet was 2.50 (Srivastava *et al*, 2001). Bhaskaran *et al.* (2001) developed supplementary mixes based on popped cereals (wheat, finger millet, pearl millet or sorghum) at 40 percent and legumes (soybean and bengal gram) at 10 or 20 percent and evaluated for protein quality in terms of FER, PER and NPU using growing albino rats. The FER (0.28 to 0.34), PER (2.7 to 2.9) and NPU (62 to 68) values of the mixes were comparable with those of the control diet (FER – 0.36, PER – 3.04, NPU – 73.5)

Banakar (2005) formulated and evaluated the multi-grain supplementary foods for protein quality. Sorghum, rice, soybean, green gram, peanut and amaranth leaves containing mixes were developed by employing roasting and malting techniques. In the roasted mix, methionine was the most limiting amino acid with a chemical score of 0.63 followed by phenylalanine (0.76) and lysine (0.81). With the addition five percent wheat ARF the scores augmented, though methionine contained to be the most limiting amino acid with a chemical score of 0.77 followed by phenylalanine (0.97). Malted supplementary food was found to have significantly higher in vitro protein digestibility (76.13 %) compared to roasted (69.96%).

Ijirotimi *et al.,* (2006) developed five mixes using sorghum and pigeon pea at the ratio of 90:10 (SP1), 80:20 (SP2), 70:30 (SP3), 60:40 (SP4), 50:50 (SP5) and biological evaluation was carried out. The results revealed that animals fed with SP2 had higher weight gain followed by those with SP3. Keeping control as 100, higher BV (110.7) and true nitrogen digestibility (121.2) were recorded in SP2 while maximum PER (92.8) and NPU (116.1) were registered in SP3 and SP5 respectively. Thus, developed mixes contained most of the essential amino acids, except methionine.

2.8 Sensory evaluation of composite mixes

Sensory evaluation plays a very important role in deciding of the optimized formulations in the new product development. Gupta and Sehgal (1991) formulated weaning mixtures by employing roasting and malting techniques. Pearl millet and barley were malted, amaranth and green gram were roasted. Two mixes formulations were prepared by mixing pearl millet or barley with amaranth, green gram and jaggery in the ratio of 60:20:40:45. Both the formulations were rated ‘like moderately’ by a panel of ten judges with a score of 6.66 and 6.88. Mixes were prepared by Rathod and Udipi (1991) comprising of cereal (malted or roasted wheat, raw, puffed or flaked rice), grain amaranth (roasted, malted and puffed) and dehydrated leafy vegetable (spinach and drumstick leaves) in a ratio of 7:2:1. In the mixes containing puffed or flaked rice, part of amaranth and leafy vegetable were replaced by skim milk powder in the ratio of 14:3:2:1 (cereal: amaranth: skim milk powder: leafy vegetable). The mixes when evaluated for acceptability, results indicated that four mixes were most acceptable (malted wheat +malted amaranth +spinach; raw rice+ roasted amaranth+ spinach; puffed rice+ puffed amaranth+ skim milk powder+ spinach; rice flakes+ puffed amaranth+ spinach). Six mixes were formulated using pre-gelatised maize, sweet potato, soybean and peanuts (Idowu *et al.,* 1993). Maize and sweet potato were blended in the proportion of 60:10, 50:20, 40:30, 30:40, 20:50 and 10:60. Soybean and defatted peanut flours were used at 25 and 5 percent respectively and evaluated for sensory quality in the form of porridge. The blend of 20:50 of maize and sweet potato was most acceptable, among all the mixes. Flour blends of rice and green gram were prepared at the ratio of 100:0, 80:20, 60:40, 50:50, 40:6, 20:80 and 0:100. To each of the blend sesame and carrot flours of 5g each were added. The blends were subjected to sensory evaluation in the form of gruels and results revealed that among the blends 50:50 was most acceptable with the overall acceptability scores of 6.8 (Naikare and Mabesa, 1993).

Banakar (2005) formulated malted and roasted supplementary foods using sorghum, finger millet, rice, soya bean, green gram, groundnut and amaranth leaves at specific proportion. Both roasted and malted supplementary foods scored between liked very much to liked moderately. Malted food in the form of porridge received higher scores for consistency (8.13), taste (8.05), aroma (7.72) and overall acceptability (7.99) compared to roasted (7.25, 7.57, 7.16 and 7.37 respectively) by panel of judges though both the mixes were acceptable. Ahmed and co-workers (2008) developed weaning food based on overnight soaked and heat treated soy flour (0, 5 or 10%), wheat flour (100, 95 or 90%), whole milk powder (3%) and sugar (5%). The mixes were subjected to sensory evaluation in the form of porridge. Results indicated that, 5% soy flour incorporated mixes were scored better (7.5-7.7) in overall acceptability. With an increase in heat treatment there was a decrease in sensory attributes like colour (7.6 - 5.1), flavour (8.0 – 5.5) and texture (7.7 – 7.6).

2.9 Utilization of composite mixes

Proso millet based malted convenience mix developed by Srivastava *et al.,* (2001) was used in the preparation of sweet gruel, salty gruel, halwa, burfi and biscuits. The products were evaluated for sensory quality and nutrient composition was computed. All the products contained 3.97 – 11.93g protein, 79 – 378 kcal of energy, 0.69 – 8.33g fat, 22.91 –68.73 mg calcium, 2.45 – 7.36 mg ascorbic acid, 1.16 – 3.5 mg iron and 17.75 – 53.25μg of β-carotene per 100g of products. Halwa and sweet gruel prepared from the convenience mix were scored between liked moderately and liked very much (7.2 and 7.7 respectively), while salty gruel, burfi, biscuits received sensory scores between liked slightly to liked moderately (6.6 – 6.9) on a 9 point scale. Weaning formulations were developed by Sadana and Chabra (2004) using germinated wheat, pulses (bengal gram, green gram and lentil) and roasted peanut in the ratio of 75:25:25, while un-germinated wheat formulations were treated as control. Panjiri, kheer, halwa and dalia were prepared using all the formulations and subjected to sensory evaluation by a panel of 10 judges. Results indicated that, all the products received scores between 7 and 8 *i.e.* liked moderately to like very much. Panjiri prepared from germinated wheat obtained highest scores (8.10) for taste followed by lentil supplemented (7.60). With regard to overall acceptability, kheer prepared from germinated wheat received highest scores of 7.93 followed by germinated wheat with bengal gram (7.85), where as un-germinated received minimum scores of 7.63. Halwa prepared out of non-germinated and germinated wheat with green gram received highest scores *i.e.* 7.58 and 7.55 respectively.

2.10 Extrusion Cooking

Extrusion cooking is one of the fastest growing and most important food processing operations (Harper, 1981a; Paton and Spratt, 1984). It is a multivariable unit operation which includes mixing, shearing, cooking, puffing and drying in one energy efficient, rapid continuous process. The hot extruder consists of a high tolerance screw rotating in a barrel. The food materials with optimum moisture content are fed into the extruder where cooking takes place. It results in an elevation of temperature and pressure. As the dough exits the die, it puffs largely due to flashing of moisture vapour (Smith, 1971). This process of HTST extrusion bring gelatinization of starch, denaturation of proteins, modification of lipids and inactivation of enzymes, microbes and many anti nutritional factors. The advantages of an extruded product would be the elimination of prolonged cooking by the consumer and less degradation of nutrients (Konstance *et al.*, 1988). This technology is widely applied to the production of cereal-based snack-like products and it is recommended for being a shorter and more flexible process when compared to others (Harper, 1981b). It is being used increasingly for the manufacture of snack foods. In extrusion processes, cereals are cooked at high temperature for a very short time. Starch is gelantinized and proteins may be inactivated, microorganisms are largely destroyed and the product's shelf life is there by extended. The products are easily fortified with additives (Sowbhagya and Ali, 2001).

2.10.1 Hot Extruded Products and Breakfast cereals

The extruder is a long, barrel-like apparatus that performs several operations along its length. The first part of the barrel kneads the ingredients together. Heat is applied at the central section of the extruder barrel to cook the ingredients. The dough remains in a compact form as it extrudes through the die located at the end and a rotating knife slices it into properly sized pellets. The steps followed under the preparation of extruded flakes were drying, cooling, flaking, toasting and packaging. Fast and Caldwell (1990) enumerated the steps in extruded flake production. Ready-to-eat cereals are processed grain formulations suitable for human consumption without requiring further cooking. They are made primarily from maize, wheat, oats or rice, usually with added flavour and fortifying ingredients (Fast, 1993). Cereal grains contain little fat and are abundant source of complex carbohydrates including dietary fibre. Breakfast cereals are made primarily from corn, wheat, oats and rice with added flavour and fortified nutrients. Breakfast cereals include flaked cereals, extrusion puffed, oven puffed, gun puffed, granola and baked products (Singh *et al.*, 1996). Puffed cereals are commonly used as ready-to eat breakfast foods or as ingredients in snack formulations. They are appreciated mainly for their lightness and crispness, qualities related to their cellular structure (Peleg, 1997). Extrudates were made using pearl millet grits de-fatted soy flour. The extrudates were sprinkled with fat, cooked in microwave oven for 45 seconds. The extrudates were dipped in 81ºbrix sugar syrup and then dried to prepare ready-to-eat snacks and were slightly liked‟ to “moderately liked” in terms of overall acceptability. The result indicated that pearl millet can be processed and utilized with soy flour to develop value added ready-to-eat extruded snacks (Choudhary *et al.*, 2003). Foxtail millet grains were decorticated in rice-milling machine and the decorticated millet were processed to prepare flaked, extrusion cooked, roller-dried products and popped millet (Ushakumari *et al.*, 2004). Extrusion cooking for the production of breakfast cereals involved high-temperature cooking and forced passage of extrudate through a die (Coponio *et al*., 2007). Sensory properties of these products were greatly influenced by the extent of lipid degradation even if the products have low lipid contents. Guzman *et al.* (2008) reported that the extrusion process affects the functional properties of common beans. Temperature, moisture and cultivar as major effects were significant, but interactions of second and third order were also significant on the functional properties. Shirani and Ganesharanee (2009) reported that a blend of chickpea and rice flour supplemented with 15% fenugreek polysaccharide could be extruded with promising characteristics for use as a low GI (glycemic index) snack product with acceptable physical and sensory properties. Vijayakumar and Mohankumar (2009) studied the effect of incorporation of millet flour blend on the improvement of the quality of composite flour in terms of increasing nutrient density, thinner the gruel by lowered viscosity and increase in the level of syneresis which may improve the resistant starch content on storage. Marti *et al*. (2010) extracted starches from parboiled rice flour and produced pasta samples by two extrusion processes – a conventional method carried out at 50°C and an extrusion cooking process at 115°C. The products were evaluated by differential scanning calorimeter and size exclusion chromatography. The molecular changes induced by both pasta making and cooking process in boiling water were also investigated using iodine absorption properties of samples. Balasubramanium *et al*., (2011) studied the quality of millet-soy blended extrudates formulated through linear programming. The formulated composite flour of whole pearl millet, finger millet and decorticated soy bean was extruded through twin screw food extruder at different feed rate (6.5–13.5 kg/h), screw speed (200–350 rpm), constant feed moisture (14%, w.b.), barrel temperature

(120°C) and cutter speed (15 rpm). Ranganna *et al*., (2012) used a sophisticated Brabender Single Screw Extruder to develop small millets based extruded pasta by blending cassava flour.

2.10.2 Quality, Colour and Texture of Extruded Products

The effect of feed moisture on product expansion was studied by many researchers like Mercier and Feillet (1975), Chiang and Johnson (1977) and Seiler *et al*., (1980). The results obtained by these researchers indicated that moisture has greatest influence on quality of finished products. Thymi *et al*., (2005) reported that apparent density increased slightly as the residence time increased for all temperature and moisture contents, while the porosity and the expansion ratio of extruded products decreased with the residence time. Higher feed moisture contents decreased the radial expansion ratio of the extrudates resulting in a higher apparent density and lower porosity values. The temperature increase seems to have the opposite effect resulting in a significant density decrease and higher porosity. Anton and Luciano (2007) conducted experiment on extrusion technology for the snack products focused on instrumental techniques, texture evaluation of extruded snacks. Empirical techniques are suggested as an alternative to fundamental techniques, especially to food scientists and food manufactures interested in predicting consumer perception of texture. Lazou (2010) studied structural and textural properties of extruded corn and corn–lentil mixtures as a result of process conditions, including extrusion temperature (170–230 ºC), feed rate (2.52–6.84 kg/h) and feed moisture content (13–19 %, wb). Lentil was used in mixtures with corn flour at a ratio of 10–50% (legume/corn). Apparent density increased with feed rate, moisture content, and material ratio and decreased with temperature, while expansion ratio showed an opposite behaviour. Modulus of elasticity increased with feed composition and decreased with extrusion conditions. Number of peaks during compression decreased with extrusion temperature and feed composition. The examination of macrostructure confirmed the effects of extrusion conditions and feed composition on structural and textural properties. The properties correlation revealed critical relationships among instrumental and sensorial characteristics. Hence, simple power model equations were developed which enable their prediction and consequently the design of extruded snacks with acceptable quality characteristics. Shirani and Ganesharanee (2009) investigated the effects of fenugreek flour (Trigonella foenum-graecum) and debittered fenugreek polysaccharide (Fenulife) inclusion on the colour measurements of all the extruded puffs after grinding into powder were carried out in triplicate using a Minolta CR-400 Colorimeter (Ramsey, NJ, USA) and L*, a*, and b* readings were recorded. Results showed that addition of fenugreek at 5 and 10% and fenugreek polysaccharide at 15 and 20% significantly ($P < 0.05$) lowered the lightness (L) compared to the control blend. Increase in redness (a+) and decrease in yellowness (b+) of the products with addition of fenugreek flour and fenugreek polysaccharides were also noted. Slight changes in colours (increase in redness and decrease in yellowness) of the products containing fenugreek and fenugreek polysaccharide may be attributed to the changes in composition and different colors of feed mixtures. Miranda *et al.*, (2011) prepared extruded snacks from flour blends made with taro and nixtamalized (TF-NMF) or non-nixtamalized maize (TF-MF) using a single-screw extruder. A Hunter Lab Colorimeter Model 45/0L (Hunter Associates Lab., Ind., USA) was used to determine colour values of extrudates in terms of L, a and b parameters. The total color difference (ΔE) was also determined. The extrudates were ground in a laboratory grinder and sieved at 0.420 mm prior to colour analysis. Result showed that there was no significantly difference ($p > 0.05$) between the total color change (ΔE) of TF and NMF, whereas ΔE of MF was significantly higher ($p < 0.05$) to NMF may be by the nixtamalization process.

2.11 Probiotics and their health benefits

Probiotics are “organisms and substrates which contribute to the intestinal microbial balance”. Probiotics are the live microbial feed supplement which beneficially affects the host animal by improving the intestinal microbial balance (Fuller, 1989). There has been a long term interest in the effects of various probiotics or fermented milk containing probiotics for the prevention and treatment of diarrhea (Kazuheto, 2007). Probiotic products have been reported to improve and maintain intestinal microflora, protect against infection, alleviate lactose intolerance, reduce blood cholesterol levels and also stimulate the immune system (Peter and Williams, 2007). A study was found that viability of 10^9cfu/g in spray dried powder containing probiotic lactobacilli in combination with prebiotics which may be useful as functional food ingredients for the manufacture of probiotic foods.

Since the native microorganisms could positively affect the host’s health, the production and consumption of the food products supplemented with these friendly microorganisms have increased dramatically in the past two decades (Mattila *et al.*, 2002). According to FAO/WHO (2002) obtained probiotic bacteria defined as “live microorganisms which when administered in adequate amounts confer a health on the host”.

Administration of probiotics may have therapeutic and/or preventive benefits in the development of sensitization and atopic disease, particularly in infants with atopic dermatitis (Brouwer *et al.,* 2006), traveler's diarrhoea (Mulder, 2004), atopic eczema/dermatitis syndrome (Viljanen *et al.,* 2005). In Japan, a standard has been developed by the Fermented Milks and Lactic Acid Bacteria Beverages Association which recommends a minimum of 10^7 cfu/g viable counts of probiotic bacteria to be present in dairy products (Shah, 2000).

Functional food ingredients such as prebiotics and probiotics could effect a beneficial modification in the composition and activities of gut microflora of infants by increasing positive flora components. The prebiotic approach aims to increase resident bacteria that are considered to be beneficial for human health, e.g. bifidobacteria and lactobacilli (Parracho *et al.,* 2007). The probiotic currently available in the market are based on lactic acid bacteria, lactobacilli, bifidobacteria and streptococci which have been shown to be important components of gastrointestinal microflora and are relatively harmless (Jayaprakasha *et al.,* 2005). Various health benefits such as controlling colon cancer, antiatherogenic properties have been attributed to probiotics (Vibha and Yadav, 2007). Probiotics can combat traveler's diarrhoea and atopic diarrhoea (Mulder, 2004).

Probiotics are able to improve immunological factors that are related to overweight health problems. In addition, probiotics have been shown to be able to prevent the development of diabetes which is highly linked to obesity (Sofia *et al.,* 2010). Probiotic foods affect the health of consumers by reducing the risk of heart attacks by improving the microflora of the intestinal tract. Yoghurt enriched with either

Bifidobacterium bifidum or *Lactobacillus acidophilus* was known to reduce cholesterol level (Niazmand *et al.*, 2005). It also has been shown to reduce the incidence of allergy at-risk infants through administration of *L. rhamnosus GG* to infants during the first half-year of life (Ouwehand, 2007)

There is strong evidence that *Lactobacillus rhamnosus GG* decreases the duration and severity of rotavirus-associated diarrhoea in children. These are also show promise in the treatment of some forms of inflammatory bowel disease and colon cancer (Santosa *et al.*, 2006). There is strong evidence for their efficacy in some clinical scenario as they are now widely used in many countries by consumers and in clinical practice (Boyle *et al.*, 2006). The use of probiotic food-based approach in the prevention of colorectal cancer has been reviewed by Telang *et al.*, (2005). Probiotic microorganisms such as *Lactobacillus rhamnosus*, *Lactobacillus acidophilus* and *Bifidobacterium bifidum* are used in the treatment of food allergies associated with milk proteins (Akalin and Unal, 2005). The presence of probiotics in the foods of neonates and children proved to be preventing acute diarrhoea, antibiotics-induced diarrhoea, traveler’s diarrhoea and produce several antimicrobial substances which have shown inhibitory activity towards gastric pathogen (Nomoto, 2005; Harnal and Shah, 2006).

2.11.1 Bifidobacteria

Bifidobacteria are claimed to provide several prophylactic effect and therapeutic benefits. Intestinal contents have viable microbial count of about 10^{12} cfu g^{-1}. Bifidobacteria are gram-positive, nonmotile, non-sporeforming and anaerobic organisms (Desponde, 2007). The importance of bifidobacteria should not be under estimated especially in small children and breast fed infant as it is found to promote better bifidobacterial growth in the intestine as compared to standard formula feeding (Harmsen *et al.,* 2000). Bifidobacteria are predominant in the newborn and have been known as one of the major groups of saccharolytic bacteria in the human colon, constituting up to 25 per cent of the total population in the adult colon (Wang *et al.,* 1999). Supplementation of bifidobacteria has been shown to influence immunoparameters such as stimulation of local Iga-production (Amster *et al.,* 1994) as well as other beneficial effects such as synthesis of folate (Crittenden *et al.,* 2003) are well known.

2.11.2 Lactobacillus acidophilus

Lactobacillus acidophilus group are found to stimulate an immune system against the unwanted microflora, improve milk digestibility and help in controlling serum cholesterol levels. The bacterium also possesses anticarcinogenic properties (Mathur *et al.,* 2003). Studies by Michetti *et al.,* (1995) suggest that *Lactobacillus jonshnii* LA-1 balances the gastrointestinal microflora, enhances immune system and acts as adjuvant in Helicobacter pylori treatment. It is the normal inhabitant of lower end of the small intestine and in this niche the species occupies the lumen of gut and adheres to the surface of the intestinal wall. Growth of *Lactobacillus acidophilus* may occur at temperature as high as 45^{o}C but optimum growth occurs within 35- 40^{o}C. Its acid tolerance varies from 0.3 to 1.9 per cent titratable acidity (Gomes and Malcatta, 1999) and most of them attained maximum growth at 24 h of incubation at 37^{o}C. Maximum viable count of 9.2 $\log_{10}$ cfu/ml was recorded for *Lactobacillus acidophilus* (Borpuzari *et al.,* 2007).

2.12 Probiotic weaning and Complementary foods

Adding prebiotics or probiotics to infant formula to improve the intestinal flora of formula fed infants is considered to be a major innovation. Several companies have brought relevant formulations onto the market. However, comparative data on the effects of pre- and probiotics on the intestinal microflora of infants are not available (Bakker *et al.,* 2005). Concoran *et al.,* (2004) developed powder containing probiotic lactobacilli in combinations with prebiotics having viability of 10^9 cfu/g which could be used as functional food ingredient in the manufacture of probiotic foods. And it is recommended that between 10^5 and 10^8 cfu/g is an acceptable level for live probiotic population in final product (Shah *et al.*, 1995).

The safety and tolerance of 2 milk infant formulas supplemented with different probiotic bacteria *Bifidobacterium lactis* (BB-12), *Lactobacillus reuteri* (ATCC 55730) and probiotics-free formula in early infancy aged < 4 months were evaluated. A comparison of growth parameters and variables of feeding, stooling and crying and irritability did not reveal any significant differences between groups. It was concluded that the use of formula supplemented with either *L. reuteri* or *B. lactis* in early infancy is safe, well tolerated and does not adversely affect growth, stooling habits or infant behaviour (Weizman and Alsheikh, 2006). Establishment and maintenance of normal intestinal microbiota may help several neonatal inflammatory conditions and may interact with host metabolic activities and immune functions, infant formulae supplemented with probiotics or prebiotics are safe and well tolerated (Waligora *et al.*, 2006).

2.13 Bioassay studies

A rat bioassay was conducted to pre-clinically evaluate the nutritional quality of 2 supplementary foods (SF) based on corn and soy blends for feeding preschool children. The SF were prepared by extrusion cooking and then modified to taste either sweet or salty. Groups of male weanling rats were fed with SF for 4 weeks to evaluate the protein quality. Results showed that the body weight gain of rats fed with SF were significantly higher than those fed with skim milk powder diet (control). The PER and NPU results of SF were not significantly different ($p>0.05$) from values of the control group it was concluded that these SF are nutritionally comparable to skim milk powder (Baskaran *et al.,* 2001). Effect of different kinds of feed on Feed Efficiency Ratio (FER) and the resultant PER has been demonstrated by some of the earlier workers (Suhasini and Malleshi, 2003). Several studies have shown that protein hydrolyzates contain mostly di- and tri-peptides which are known to be absorbed more rapidly than intact protein (Manninen, 2004) leading to increase in PER**.** Storage of weaning food did not adversely affect the PER and sensory qualities of the weaning food containing malt (Malleshi and Desikachar, 1988). Weaning food formulated from germinated corn flour, legume meal and sesame seed meal compared with non-germinated blends as weaning foods for infants. Weanling rats weighing 55-65 g were given feeds containing germinated or non-germinated flour for a period of 28 days. The germinated flour diets appeared to be more palatable to the rats, leading to higher feed intakes. Germination increased alpha-amylase activity, which altered the nutrient composition of the grains and improved polysaccharide digestibility (Ikujenloa and Fashakin, 2005).

2.14 Modified Atmosphere Packaging (MAP)

Modified Atmosphere Packaging (MAP) is the enclosure of food in a package, inside which the atmosphere is modified with respect to carbon dioxide, oxygen, nitrogen, water vapour and trace gases. This modification is generally achieved using one of the two processes such as gas flush packaging or vacuum packaging (Farber, 1991). The technology of packaging products in modified atmosphere is the most advanced food preserving technique with many advantages (Floros *et al.,* 2000). Enfors and Molin (1980) reported that the gram negative bacteria were more sensitive to CO_2 while the growth rates of lactic acid bacteria were much less affected. Various inhibition actions of CO_2 on bacterial cell suggested (Farber, 1991; Davis, 1995) that displacement of oxygen, and penetration of cell membrane lead to changes in intracellular pH, physico-chemical properties of cell proteins, direct inhibition of enzymes or decrease in the enzyme activity and alteration of cell membrane, effect on nutrients uptake and absorption. The nitrogen is considered as an inert and filler gas and replaces the oxygen in the pack thus delays the oxidative rancidity of the product and inhibits the growth of aerobic microbes indirectly (Sahoo and Anjaneyalu, 1995).

In 1877, Pasteur and joubert recorded that Bacillus anthraces could be inactivated by using MAP (Sivertsvik *et al.,* 2002). The modified atmosphere composition has a marked impact on the growth of spoilage micro-organisms as well as on pathogens. The anti-microbial effect of CO_2 on micro-organisms has been intensively documented. However, it has been shown recently that only CO_2 levels well above 20 per cent significantly affect the growth of psychrotrophic pathogens that are relevant to modified atmosphere packaging (Bennik *et al.,* 1995). Fedio *et al.,* (1994) investigated the effect of

MAP on the growth of microorganisms in cottage cheese and reported that samples inoculated with Listeria showed growth in packages containing air and 100 per cent nitrogen but not in packages containing elevated carbon dioxide levels. The 100 per cent CO_2 environment inhibited the growth of many microorganisms and extended the shelf life of cottage cheese up to 60 days.

2.15 Storage studies

The viability of *Lactibacillus acidophilus* and *Bifidobacterium bifidum* was studied for stability during storage in refrigerated conditions for 4 months. The highest numbers of live cells, up to the fourth month of storage in refrigerated conditions was in the order of 10^7cfu/g (Goderska and Czarnecki, 2008). *S. thermophilus* and *B. infantis* survived at 51.1 per cent and 68.8 per cent respectively, in the freeze-dried fermented soymilk after 4 months of storage. Meanwhile, in the spray-dried fermented soymilk showed a survival per cent of 29.5 and 57.7, respectively (Yi-Chieh *et al.,* 2004). Dehydrated strain of *Lactobacillus acidophilus* maintained its viability during two months when stored at 4°C and its viability dropped by one order of magnitude when stored at 25°C for 1 month (Riveros *et al.,* 2009).

The storage stability of the extruded products prepared by using blends of peanuts, maize and soybean obtained shelf life periods of 7.8-10.4 months for the extruded raw blend, and 5.6-7.1 months for the extruded pre-roasted blend when stored at the average ambient temperature (approx. 30°C) in Ghana. In general, pre-roasting treatment was found to reduce the quality characteristics of the extruded product (Plahar *et al.,* 2003). Peroxide values and fat acidity increased with increasing storage time (0-60 days in polythene bags at 25-30°C and 70-80 % RH).

Malted weaning foods had higher peroxide values than roasted foods. All weaning foods were judged acceptable for consumption even after 60 days storage (Gahlawat and Sehgal, 1994). Fungi, coliforms, Salmonella and Shigella were absent in all foods (Wadud *et al.,* 2004). Storage of composite mixes results in changes in sensory and chemical parameters i.e. moisture content, free fatty acid, peroxide value and alcoholic acidity when packed in various packaging materials and stored at different environmental conditions.

Solanki (1986) studied the shelf life of RTE mixes packed in polythene bags, heat sealed and stored in glass jars for a period of 42 days. The product with malted wheat, bengal gram and peanut showed higher increase in moisture (5.49 to 5.52%) compared to other mixes, but the increase in peroxide value was high in mix with sesame seeds (1.2 to 9.3meq/kg fat). However the increase in moisture and peroxide value was within the ISI specifications.

Malted formulation developed using malted finger millet, horse gram and roasted peanut at the proportion of 65:25:10 (Chandrasekhar *et al.,* 1988) was evaluated for storage stability. Mix was stored in household containers like plastic containers, tins, glass bottles and polythene bags for a period of 45 days and results revealed that as storage period progressed, moisture content increased. But the per cent increase was higher in tins (6.25 to 9.02) and lower in polythene bags (6.25 to 7.39) compared to plastic containers (6.25 to 8.86) and glass bottles (6.25 to 9.02). The stored formulation was also tested for bacterial count. In the beginning of the study, plate count was 10,150 but at the end of storage, it increased to 38,550 in polythene bag which was much less compared to other packages. However, mixes stored in all the packages were within the ISI specifications (50,000 colonies per gram of mix) till the 45th day with respect to bacterial count. Four supplements developed using cereals (wheat, pearl millet), pulses (bengal gram, green gram) amaranth leaves and jaggery at the proportion of 4:1:1:1:4 (Dahiya and Kapoor, 1994), were stored in three packaging materials viz., polythene bags, tins and glass bottles for a period of 30 days. As the storage period increased there was a significant increase in moisture, peroxide value, fat acidity and alcoholic acidity. Mixes stored in tins possessed higher moisture (6.85 – 8.16%), peroxide value (3.65 – 5.3 meq/kg fat), fat acidity (24.43 – 25.95 %) and alcoholic acidity (0.083 – 0.124%). Pearl millet based supplements had higher moisture (7.9 – 8.16%), peroxide value (4.38 – 5.11 meq/kg fat), fat acidity (25.43 –25.95%) and alcoholic acidity (0.110 – 0.124%) on 30th day of storage. Organoleptic characteristics of all the supplements were not affected till one month of storage except the fact that pearl millet based supplements exhibited a change in taste. The packed mixes in polythene pouches, bottles and plastic containers and stored for a period of 45 days revealed that moisture content showed slight increase between zero to fifteen days of storage. The maximum level of increase in moisture was noticed for the samples stored in plastic container (6.10 to 8.3% in rice based mix and 5.30 to 7.45 % in finger millet based mix) compared to polythene pouches and bottles (Geetha and Suja, 1996). The keeping quality of the developed weaning mixes using grain amaranth and Italian millet at the proportion of 70:30 by employing roasting and malting techniques by Suma (1998) revealed that increase in moisture (4.7 to 7.6%) and peroxide value (0 to 3.5 meq/kg fat) of roasted mix from 0 to 8th week of storage was less compared to malted mix (5.29 to 8.59% moisture and 0 to 2.9 meq/kg fat peroxide value) from zero to fifth week of storage. HMF is an indication of the severity of heat treatment and also length and condition of storage (Hurtado *et al.*, 1998). The effect of storage condition on HMF content has been studied by several earlier workers and reported that HMF content keeps increasing during storage depending on temperature irrespective of packaging material (Antonio *et al.*, 2003). Progressive increase in HMF content of dried milk upon storage at varying temperature (20 to 37°C) was observed by Hurtado *et al.*, (1998). Thathola and Srivastava (2002) developed weaning mix using malted flours of foxtail and barnyard millet (30% each), roasted soybean flour (25%) and skim milk powder (15%) kept in an airtight plastic container for four months reported that the mix was liked on par with fresh sample (7.8) in overall acceptability (7.7) by trained panel of ten judges. Banakar (2005) developed malted and roasted supplementary foods using either malted or roasted cereals (sorghum, finger millet, rice), pulses (soybean, green gram), peanut and amaranthus leaf powder at equal proportion. Formulated foods were packed in polythene and laminated pouches and stored for a period of six months revealed that the moisture content of roasted and malted foods increased significantly from 5.89 to 8.96 percent and 5.93 to 10.49 percent from zero to 180 days of storage respectively. The foods packed in polyethylene pouches on an average had higher moisture of 7.9 percent compared to laminated pouches (7.42%). The free fatty acid content increased significantly from 0.74 to 1.50 percent oleic acid (polyethylene) and 0.74 to 1.36 percent of oleic acid (laminated). Malted food contained significantly higher amounts of free fatty acid (1.07% oleic acid) compared to roasted (0.94% oleic acid). The foods were acceptable up to 135 days in both polyethylene and laminated pouches. Thus, the developed mixes had a shelf life of 90 to 135 days. Roasted mixes had higher storage stability compared to malted mixes. During storage there was an increase in biochemical parameters with a decrease in sensory scores. The sensory and consumer acceptability of all the products prepared using the formulated mixes indicated that the products were liked by the panelists and consumers. Hence, cereal and millet based mixes could be employed in the preparation of various food products suitable for different age groups such that they can become part of the daily routine diet.

MATERIALS AND METHODS

III. MATERIALS AND METHODS

Millet based complementary health food was formulated by the application of functional food ingredients such as skim milk powder, whey protein hydrolysate along with the admixture of malted Foxtail millet, Little Millet Sorghum and White ragi, malted wheat, malted green gram, sugar and other ingredients. The materials used in the investigation and methods adopted in developing the millet based complementary health foods are presented in this chapter.

3.1 Materials

3.1.1 Ingredients

The ingredients used in the investigation namely foxtail millet, little millet, sorghum, white ragi, wheat, green gram, sugar, multi-vitamins; sugar and Dabur honey were procured from the local market.

3.1.2 Skim milk powder

Commercially available "NANDINI" brand of skim milk powder manufactured by Mother Dairy, Yelahanka of the Karnataka Milk Federation (KMF), Bangalore, Karnataka was used in the formulations of millet based complementary health foods.

3.1.3 Whey protein hydrolysate

Whey Protein Hydrolysate (WPH) of brand "ARLA" imported from ACE international, New Delhi, India was procured from Shri Durga Sales Corporation, Bengaluru was used in the formulations of millet based complementary health foods with WPH.

3.1.4 Probiotic culture

Freeze dried probiotic cultures namely *Bifidobacterium bifidum* and *Lactobacillus acidophilus* were imported from Head Quarters, Chr. Hansen, Bøge Allé 10-12, DK-2970 Hørsholm, Denmark.

3.1.5 Microbiological media

3.1.5.1 Rogosa SL Agar

Rogosa SL agar M130-500G was procured from HiMedia, Laboratories Mumbai to enumerate *Lactobacillus acidophilus*

3.1.5.2 Bifidobacteria Agar

Bifidobacteria agar M1396-500G was procured from HiMedia to enumerate *Bifidobacterium bifidum.*

3.1.5.3 Standard Plate Count Agar

Standard Plate Count Agar (SPCA), M091-100G was procured from HiMedia to enumerate total plate count in the formulated products.

3.1.5.4 Violet Red Bile Agar

Violet Red Bile Agar, M049-100G was procured from HiMedia to enumerate coliforms in the formulated products.

3.1.5.5 Potato Dextrose Agar

Potato Dextrose Agar, M096-100G was procured from HiMedia to enumerate yeast and molds in the formulated products.

3.1.6 Packaging material

Poly Ethylene Terephthalate (PET) and Metallized Polyester (MPE) were procured from Shakthi packaging company, Bangalore.

3.1.7 Experimental animals

Twenty one days old male albino rats (Wister strains) were procured from Venkateshwara Enterprises, Rajajinagar, Bengaluru for bioassay studies.

3.1.8 Chemicals and reagents

The chemicals and reagents used were of analytical grade. All the necessary reagents were prepared in distilled water. For all analytical purpose freshly prepared reagents were used.

3.1.9 Glassware

The “Borosil” make glassware was used for chemical and microbiological analysis of weaning food. Prior to use, all the glasswares were thoroughly washed, air dried and sterilized in a hot air oven at 160-180^{o}C for 2 h for microbiological study.

3.1.10 Utensils

Stainless steel utensils were used to handle the ingredients in the formulation of complementary food. All the utensils and accessories were thoroughly washed with suitable detergent and rinsed with tap water before use.

3.1.11 Vitamin and mineral mixtures

The vitamin and mineral mixtures for the formulation were procured from M/s Global Calcium, Bangalore.

3.1.12 Equipments

3.1.12.1 Millet Cleaning and de-husking machines

The millet grains were cleaned using cleaning, grading and destoning machine (Bhavani Industries) and de-husked using the de-husking machine (Plate-1) of AVM industries, Salem, Tamil Nadu installed at the Centre of Excellence for Small Millets, All India Coordinated Research Project on Post Harvest Engineering and Technology (AICRP on PHET), University of Agricultural Sciences (UAS), GKVK, Bengaluru.

3.1.12.2 Tray dryer

GMP model Tray Dryer supplied by CM envirosystems, Bangalore was used to dry sprouted millets.

3.1.12.3 Millet mill

A domestic Grain Pulverizer (make: Anand Associates, Shivamogga) (Plate-1) was used to mill different millet rice grains into suitable flours/grits. The pulverizer of

Cleaning, grading and destining machine

De-husking machine

Flour mill

Plate 1: Cleaning, De-husking and milling machines used in the study

was a complete stainless steel construction with detachable sieves to facilitate milling of the raw material into appropriate sized flours. The pulverized flours/grits were further sieved manually using BS 60 mesh for flours and for the grits BS 18 mesh sieve in order to obtain flour / grits of relatively uniform particle size.

3.1.12.4 Millet roaster

The sprouted millets were roasted /kilned using the roaster installed at the Centre of Excellence for Small Millets, AICRP on PHET, UAS, GKVK, Bengaluru.

3.1.12.5 Spray dryer

Pilot scale spray dryer of 5 kg of water evaporation capacity per hour (Make: Milktech Engineers, Bangalore) was used for spray drying of best adjudged formulations of millet based complementary health foods (Plate-2).

3.1.12.6 Fluid bed dryer

Multi sample fluid bed dryer of imported from Germany and GMP model fluid bed dryer of two kg wet material capacity per batch, fabricated and supplied by Milk-Tech Engineers, Bengaluru was used to dry formulations of millet based complementary health foods.

3.1.12.7 Vacuum tray dryer

Laboratory scale vacuum dryer with porridge loading capacity of 5kg per batch (Make: Milktech Engineers, Bengaluru) was used for vacuum drying of best adjudged formulations of millet based complementary health foods (Plate-2).

Vacuum tray drier

Spray drier

Plate 2: Spray drier and vacuum drier used in the study

3.1.12.8 Extruder

Twin Screw hot extruder of Make DAYI make imported from China and installed at Pagaria Foods, Harohalli, Kanakapura Taluk was used to extrude the millet flours.

3.1.12.9 Roller flaking machine

Roller flaking machine of Make DAYI make imported from China and installed at Pagaria Foods, Harohalli, Kanakapura Taluk was used to make the flakes using extruded millet flours.

3.1.12.10 Drying machine

Drying machine of Make DAYI make imported from China and installed at Pagaria Foods, Harohalli, Kanakapura Taluk was used to dry the flakes.

3.1.12.11 Roasting machine

Roasting machine of Make DAYI make imported from China and installed at Pagaria Foods, Harohalli, Kanakapura Taluk was used to roast the dried flakes.

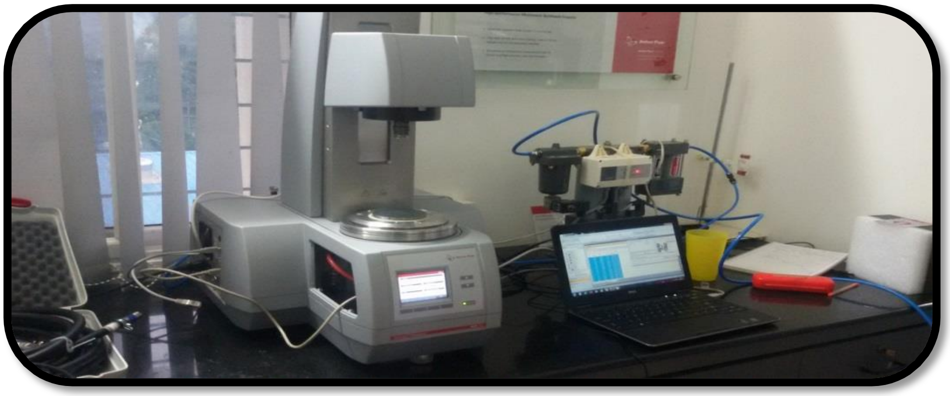
3.1.12.12 Rheometer

Anton Paar rheometer (MCR 702) available at Anton Paar laboratory, Bengaluru, was used to analyze the rheological properties of the porridges (Plate-3).

3.1.12.13 Particle analyzer

Particle size analyzer of M/s Malvern, Bengaluru (Plate-3) installed at Malvern Aimil laboratory, Nagavara, Bengaluru was used to analyze the particle size of the formulated foods.

Spectrophotometer



Anton paar rheometer

Particle analyzer

Plate 3: **Spectrophotometer, Anton paar rheometer and Particle analyzer used in the study**

3.1.12 .14 Sieves and sieving machine

The sieving machine with 70µ sieve screen available at Shree Agro Foods, Peenya was used sieve the malted flours.

3.2 Methods

The Millet based complementary health foods were formulated using malted foxtail millet flour, malted little millet flour, malted sorghum flour, malted white ragi flour, malted wheat flour, malted green gram flour, SMP, hydrolyzed WPC, sugar, Honey and multivitamins and minerals besides supplementation with probiotics.

3.2.1 Initial processing of the ingredients

The ingredients used in the formulation of millet based complementary health food were preprocessed by following standard protocol before used in the formulation. Millet malt flour was prepared as per the procedure described by Swamy (2003) with slight modifications optimized to suit for small millets. The whole malted wheat flour was prepared as per the procedure of Taragopal *et al.*, (1982). The green gram and other grain malts were prepared as per the procedure outlined by Malleshi (1995).

3.2.2 Preparation of flours

3.2.2.1 Preparation of sprouted foxtail millet flour

The parameters for the sprouting were optimized for the preparation of sprouted millet flours from foxtail millet. The grains were soaked for 24h with a grain to water ratio of 1:3. The soaked grains were spread on a muslin cloth at temperature of 37°C. The optimum time for germination of foxtail millet were observed to be 30-36h. The sprouted grains were dried at 50°C for 24h in a tray dryer. The dried grains were subjected to kilning in the machine to get uniform kilned grains. The resultant grains were de-husked to obtain millet rice. Milling of the millet grains was done in a domestic flour mill to get the flour.

3.2.2.2 Preparation of sprouted little millet flour

The parameters were optimized for the preparation of sprouted millet flours using little millet. The grains were soaked for 24 hours with a grain to water ratio of 1:3. The soaked grains were spread on a muslin cloth at a controlled temperature of 37°C. The optimum time for germination of little millet was observed to be 24-30h. The sprouted grains were dried at 50°C for 24h in a tray dryer. The dried grains were subjected to kilning in the machine to get uniform kilned grains. The resultant grains were de-husked to obtain millet rice. Milling of the millet grains was done in a domestic flour mill to get the flour.

3.2.2.3 Preparation of sprouted sorghum flour

The parameters were optimized for the preparation of sprouted millet flours from sorghum. The grains were soaked for 24h with a grain to water ratio of 1:3. The soaked grains were spread on a muslin cloth at a temperature of 37°C. The optimum time for germination of little millet was observed to be 18-24h. The sprouted grains were dried at 50°C for 24h in a tray dryer. The dried grains were subjected to kilning in the machine to get uniform kilned grains. The resultant grains were de-husked to obtain millet rice. Milling of the millet grains was done in a domestic flour mill to get the flour.

3.2.2.4 Preparation of sprouted white ragi flour

The same protocol was followed as in the case of sprouted sorghum flour.

3.2.2.5 Preparation of malted wheat flour

The whole malted wheat flour was prepared as per the procedure of Taragopal *et al.,* (1982). Good quality wheat was cleaned and soaked in clean water for 12h. The soaked grains were spread on a muslin cloth at a temperature of 37°C for 36h. The sprouted grains were dried at 50°C for 24h in a tray dryer. The dried grains were subjected to kilning in the machine to get uniform kilned grains. Milling of the grains was done in a domestic flour mill to get the flour.

3.2.2.6 Preparation of malted green gram flour

The green gram malt was prepared as per the procedure outlined by Malleshi (1995) with slight modification. A good quality green gram procured from the local market was cleaned and soaked in clean water for 12h. The soaked grains were spread on a muslin cloth at a temperature of 37°C for 24h. The sprouted grains were dried at 50°C for 24h in a tray dryer. The dried grains were subjected to kilning in the machine to get uniform kilned grains. The resultant grains were de-husked to obtain malted dhal. Milling of the dhal was done in a domestic flour mill to get the flour.

3.2.2.7 Preparation of extruded flours

The water was added to make the optimum moisture content for proper extrusion of wheat and millet flours using the standard process conditions. The extruded material was dried, roasted, cooled and milled to get the extruded flours. The extruded flours were prepared with wheat, and using all the four millets namely foxtail millet, little millet, sorghum and white ragi.

3.2.3 Storage of sprouted flours

The resultant flours were sieved to have 70 microns size uniform quality sprouted millet flour to be used for further formulation studies. The flour was then stored in an air tight container at room temperature until the formulation studies initiated to develop millet based complementary dairy food.

3.2.4 Formulation of millet based complementary health food

Various blends of Foxtail, Little millet and Sorghum based complementary foods were prepared by blending various levels of sprouted millet flours with sprouted green gram flour and sugar. The flours blended with sprouted wheat flour for preparation of complementary dairy food was used as the control. The prepared formulation was made into porridge by adding the required quantity of water. The sensory evaluation studies to adjudge the best combination of the blend were conducted. The porridge samples were also subjected to sensory evaluation studies using 9 point hedonic scale by a team of judges.

A - Malted wheat flour (100%)
B - Malted wheat flour (75%) + Malted millet flour (25%)
C - Malted wheat flour (50%) + Malted millet flour (50%)
D - Malted wheat flour (25%) + Malted millet flour (75%)
E - Malted millet flour (100%)

The formulations for preparation of complementary food were with 70 % of the above blends + 11.5 % malted green gram flour + 18.5 % sugar.

3.2.4.1 Optimization of millet flour level in millet based complementary food

The portion of malted wheat flour was replaced with millet malt flour at 25, 50, 75 and 100 per cent levels. The blends were added with water at 1:4 ratio and cooked to make into porridge. The resultant products were subjected to sensory evaluation studies by serving to a panel of 5 judges in order to select the right levels of millet malt that could be incorporated in the millet based complementary food.

3.2.5 Formulation of millet based complementary food with SMP

The optimized millet based complementary food with respect to malted millet flour level was further added with SMP for replacing part of malted green gram flour. The flours blended with sprouted green gram flour for preparation of complementary food was used as a control. The prepared formulation was made into porridge by adding the required quantity of water. The sensory evaluation studies to adjudge the best combination of the blends were conducted. The porridge samples were subjected to sensory evaluation studies using 9 point hedonic scale by a team of judges.

The formulations for preparation of complementary food were with best level of the millet flour + 11.5 % malted green gram flour + 18.5 % sugar as control. The complementary foods with SMP were prepared with the following combinations:

A - Malted Green gram flour (100%)
B - Malted Green gram flour (75%) + SMP (25%)
C - Malted Green gram flour (50%) + SMP (50%)
D - Malted Green gram flour (25%) + SMP (75%)
E - SMP (100%)

3.2.5.1 Optimization of level of replacement of malted green gram flour with SMP in the complementary food

The optimized millet based complementary food with respect to malted millet flour level was further added with SMP by replacing part of malted green gram. The part of green gram used in the in the optimized millet based complementary food was replaced with 25, 50, 75 and 100 per cent levels of SMP in the millet based complementary food. The blends were reconstituted with water at 1:4 ratios, cooked, and make into porridge. The resultant gruel was subjected to sensory attribute studies in order to select the right level of replacement of malted green gram with SMP.

3.2.6 Formulation of Millet based complementary food with WPH

The optimized millet based complementary food with respect to malted millet flour level was further added with WPH for replacing part of SMP. The flours blended with optimized level of SMP for preparation of complementary food was used as a control. The prepared formulation was made into porridge by adding the required quantity of water. The sensory evaluation studies to adjudge the best combination of the blends were conducted. The porridge samples were subjected to sensory evaluation studies using 9 point hedonic scale by a team of judges.

The formulations for preparation of complementary food were with best level of the millet flour + SMP + 18.5 % sugar as control. The complementary foods with SMP were prepared with the following combinations:

A – Complementary food with SMP
B - SMP (50%) + WPH (50%)
C - SMP (25%) + WPH (75%)
D - WPH (100%)

3.2.6.1 Optimization of level of replacement of SMP with WPH in the complementary food

The optimized millet based complementary food with respect to malted millet flour level was further added with WPH by replacing part of SMP. The part of SMP used in the in the optimized millet based complementary food was replaced with 50, 75 and 100 per cent levels of WPH to increase the protein content of the millet based complementary food. The blends were reconstituted with water at 1:4 ratios, cooked, and make into porridge. The resultant gruel was subjected to sensory attribute studies in order to select the right level of replacement of WPH with SMP.

3.2.7 Formulation of millet based complementary food with honey

The best adjudged formulation of the millet based complementary food was added with the commercially standardized level of honey at 5 per cent. The formulations without honey were used as a control. The blends were reconstituted with water at 1:4 ratios, cooked, and make into porridge. The resultant gruel was subjected to sensory attribute studies to know the acceptability of the complementary food with honey.

3.2.8 Formulation of millet based complementary food with honey and probiotic bacteria

The best adjudged formulation of the millet based complementary food with honey was added with the suggested level of freeze dried probiotic organisms to have sufficient number of viable organisms for a probiotic food . The formulations without probiotic bacteria were used as a control. The blends were reconstituted with water at 1:4 ratios, cooked, and make into porridge. The resultant gruel was subjected to sensory attribute studies to know the effect of addition of probiotic organisms on the acceptability of the millet based complementary food.

3.2.9 Process optimization with respect to total solids in gruel and cooking of formulated complementary health food

The formulated complementary health food that was adjudged best was reconstituted with potable water to have 20, 25, 30 and 35 per cent total solids and cooked at various temperatures (70, 75, 80 and 85^{o}C) for 10 min. The resultant product was evaluated by subjecting to various physical and sensory attribute studies to select the optimum level of cooking temperature and total solids for obtaining right consistency of porridge for consumption.

3.2.10 Estimation of the gelatinization temperature of the flours to optimize the cooking temperature

Gelatinization temperature and the range of the gelatinization of the flours and the formulated complementary foods were estimated using Differential Scanning Colorimeter (DSC), Spectroscopy lab, SID, at the Indian Institute of Science, Bangalore (Plate-4).

3.2.11 Development of ready to use complementary food

3.2.11.1 Process optimization for spray drying of formulated complementary food

The formulated complementary food was adjusted to a desired level of total solids and cooked at optimum time temperature combination. The cooked porridge was

Differential scanning colorimetry (DSC) equipment for identifying gelatinization profile

Modified Atmospheric Packaging setup

Plate 4: Equipments for differential scanning colorimetry (DSC) for identifying gelatinization profile of raw flours and modified atmospheric packaging machines

subjected to spray drying at various combinations of outlet air temperature namely 75, 80, 85 and 90^{o}C and various feed inlet temperature viz 50, 55 and 60^{o}C in order to assess the effect of spray drying processing parameters on the quality of resultant powder.

3.2.11.2 Process optimization for vacuum drying of formulated complementary food

The formulated weaning food was adjusted to a desired level of total solids by adding water at 1:2 and 1:3 proportions based on the weight of the formulated product and cooked by bringing it to boil and till the product become viscous. The cooked weaning porridge was subjected to vacuum drying at various feed inlet temperature viz 40, 45, 50 and 55^{o}C in order to assess the effect of vacuum drying processing parameters on the quality of resultant powder.

3.2.11.3 Standardization of fluidized bed drying

The formulated food was rewetted to have 15 per cent moisture and subjected to fluid bed drying at various outlet temperatures (40, 45, 50 and 55^{o}C) to assess the optimum temperature of drying.

3.2.11.4 Development of ready to use millet based extruded complementary food

The millet flour was added with water to make the optimum moisture content (22%) for proper extrusion of the millet flour as the millet flours bound to bind more water than the wheat. The modification of conditioning of the millet based formulation was done with the addition of increased amount of water and use of the standard process conditions of the corn and wheat flakes (120±5°C for extrusion, 100±2°C for drying and 150°C for roasting) were followed in the preparation of extruded the millet flour. The extruded flours were blended with optimized level of SMP for preparation of complementary food. In the similar way honey (5 per cent) and probiotic bacteria were also blended to obtain ready to use millet based extruded complementary food with probiotic bacteria. The prepared formulations were made into porridge by adding the required quantity of water. The sensory evaluation studies of the formulated blends were conducted using 9 point hedonic scale by a team of judges to adjudge the best extruded millet based food among the millets by keeping extruded wheat based product as a control.

3.2.12 Development of flakes from millets

Millet based flakes were developed by completely replacing the corn flour in the formulation. The millet flour, sugar, vitamin and mineral mixtures, liquid malt, salt were blended at the standardized levels for the commercial wheat flakes and water was added to make the optimum moisture content for proper extrusion of the millet flour as the millet flours bound to bind more water than the wheat. The modification of conditioning of the millet based formulation with the addition of increased amount of water and use of the standard process conditions of the corn and wheat flakes (120±5°C for extrusion, 100±2°C for drying and 150°C for roasting of flakes) were followed in the preparation of the millet flakes. The flakes were prepared with all the four millets namely Foxtail millet, Little millet, Sorghum and White Ragi. The developed flakes with hot milk, flakes with cold milk, and flakes in the form of masala snacks were subjected to sensory evaluation studies using 9 point hedonic scale by a team of judges to know the best type of millet for the preparation of millet flakes and also to know best form of consuming the millet flakes.

3.2.13 Bioassay studies for formulated millet based complementary health food

Fourteen types of diets were selected for conducting bioassay studies. For each of these diets, vitamin mixture was supplemented externally. Formulated complementary health foods were subjected for bioassay studies on white albino rats.

Clinically healthy animals of weaning albino (Wister strain) rats aged 21 days weighing about 32.20-34.50 g were randomly selected and divided into 15 groups of 6 rats for each experimental group were housed in metabolic cage and allowed to acclimatize to experimental condition for 5 days. For the experimental groups (14no) the complementary food was given along with the regular feed 2 times a day (one at 11am and other at 4.30pm) and the control group was without complementary food. The feed and water were given ad libitum for a period of 28 days. The residual feeds were collected every day, weighed and feed consumption was recorded. Records were kept for the weight changes and total food intake. The gain in weight was recorded at weekly basis and evaluated for the Protein Efficiency Ratio (PER) and Feed Efficiency Ratio (FER) and Net Protein Utilization (NPU).

3.2.14 Bioassay parameters

The PER of the control and experimental test diets were determined as per the procedure of IS: 7481 (1974). The nutritive value of protein was expressed as the ratio of gain in body weight (g) to the protein consumed (g) in a specified period of time. The food value and growth rate as effected by food intake was determined as feed efficiency ratio (FER) and expressed as gain in weight in grams per unit of food consumed. NPU was measured as per the standard procedure and the blood glucose level was also measured using glucometer.

3.2.15 Storage studies

3.2.15.1 Storage stability of best adjudged formulations of RTU millet based complementary health foods

The best adjudged formulations of RTU millet based complementary health foods were packed in MPE and PET packaging material under normal and modified atmospheric packaging conditions. The formulated complementary food samples were subjected to MAP (Plate-4). The gases used in the study for MAP were carbon dioxide and nitrogen in the ratio of 100:0, 20:80, 40:60, 60:40, 80:20 and 0:100. The packaged products were stored at room temperature (30^{o}C) for a period of 6 months. At a regular interval of 30 days the samples were analyzed for various chemical attribute studies such as HMF, FFA and Peroxide value in order to elicit the effect of packaging materials and MAP.

3.2.15.2 Storage stability of the ready to cook malted millet based complementary health foods

The best adjudged RTC malted millet based complementary health foods were packed into the MPE pouches and stored at 30±1^{o}C. The overall acceptability and microbial quality of ready-to-cook (RTC) millet based complementary health foods during storage at 30±1^{o}C were assessed during storage. The microbial load with respect to TBC, coliforms and yeast and molds were analyzed at an interval of 15days to adjudge the storage stability of RTC complementary foods.

3.2.15.3 Storage stability of the ready to use millet based complementary health foods

The best adjudged RTU malted white ragi based vacuum dried complementary health food, RTU little millet based extruded complementary health food, best adjudged RTU flakes were packed into the MPE pouches and stored at 30±1°C. The overall acceptability and microbial quality of ready-to-use (RTU) millet based complementary health foods during storage at 30±1°C were assessed at an interval of 30days. The microbial load with respect to TBC, coliforms and yeast and molds were analyzed at an interval of 30days to adjudge the storage stability of RTC complementary foods.

3.2.15.4 The viability of probiotic organisms of the best adjudged RTU millet based honey blended probiotic complementary health food during storage

The viability of probiotic organisms during storage of the best adjudged RTU malted millet based vacuum dried honey blended probiotic complementary health food, RTU millet based extruded honey blended probiotic complementary health food with SMP were packed into the MPE pouches and stored at 30±1°C. The overall acceptability and microbial quality of ready-to-use (RTU) millet based complementary health foods during storage at 30±1°C were assessed at an interval of 30days.

3.3 Analytical techniques used for formulation of millet based complementary food

3.3.1 Measurement of colour of complementary foods

The colour measurement of the products was made using a Spectrophotometer (Make: Konica Minolta Instrument, Osaka, Japan; Model-CM 5) (Plate-3). It is a light weight, compact tri-stimulus colour analyzer for measuring reflected-light colour of a sample. It combines advanced electronics and optical technology to provide high accuracy and complete portability of data. Using an 8 mm diameter (measuring area) diffused illumination and a 0° viewing angle, the chromameter takes accurate colour measurements instantaneously and the readings are displayed.

3.3.2 Moisture content

The moisture content of all the ingredients and samples were estimated as per AOAC (1984).

3.3.3 Estimation of total protein

The total protein content of the dried samples of ingredients as well as final functional weaning food was computed by estimating total nitrogen by the Micro kjeldahl method as per procedure given in IS:SP 18(Part XI), 1981.

3.3.4 Estimation of fat

Fat content was estimated by ether extract method as per the procedure of AOAC (1980).

3.3.5 Estimation of ash

Total ash content of the developed weaning foods was analysed as per the procedure of AOAC (1980).

3.3.6 Estimation of crude fibre

Crude fibre of the sample was estimated by using moisture and fat-free samples and expressed as g/ 100g or per cent of the samples used as per AOAC (1984). Automatic

Fibre analyzer Apparatus (make: Pelican Equipments, Chennai) was used to estimate the fibre content of the ingredients and formulated complementary foods.

3.3.7 Computation of carbohydrate

Carbohydrate content was calculated by differential method as per AOAC (1980).

Carbohydrate (g/100g) = 100-[Protein + Fat +Fibre + Ash + Moisture].

3.3.8 Computation of energy

Energy was computed as per AOAC (1980).

Energy (kcal) = [Protein (g) X 4] + [Carbohydrate (g) X 4] + [Fat (g) x9].

3.3.9 Determination of pH

The pH of reconstituted samples was measured using a digital pH meter.

3.3.10 Water activity

Water activity of the samples were measured using water activity meter of make Rotonac AG**,** installed at the Post Harvest Engeneering and Technology Division of PG centre, GKVK, UHS, Bagalkot.

3.3.11 HMF

Extent of browning was estimated by measuring 5-hydroxy methyl-2 furfural which is the main browning compound. Browning compounds were estimated as HMF by adopting the method specified by Sripad (1988).

3.3.12 Peroxide value

The peroxide values were estimated as per IS: 3508-1966.

3.3.13 Free fatty acids

Free Fatty Acid (FFA) content of samples was determined as per the procedure described by Buma (1971).

3.3.14 Estimation of the amino acid profile of the complementary foods

Amino acid profile of the developed formulations of the complementary foods were estimated using the Matrix-assisted laser desorption/ionization (MALDI) mass spectrometry (MALDI-MS) installed at the Molecular Biophysics Unit (MBU), at the Indian Institute of Science, Bangalore

3.3.15 Sensory evaluation

Sensory evaluation of samples was carried out by a panel of 5 in-house judges by providing 9 point hedonic scale.

3.3.16 Statistical analysis

The results were analyzed statistically for test of significance by using SAS, Design Expert and CRD design as per the requirement of the study to get the best interpretation of the results.

3.3.17 Cost economics

The cost economics of the developed complementary health food products were worked out taking into consideration their fixed and variable costs.

RESULTS

IV. RESULTS

Complementary foods are foods other than breast milk introduced to children to provide nutrients. In developing countries complementary foods are mainly based on cereals like maize, millet and sorghum. Complementary feeding typically covers the period from 6 - 24 months of age. This is a critical period of growth during which nutrient deficiencies and illnesses contribute globally to higher rates of under nutrition among children less than five years of age. A number of successful strategies have been developed to improve complementary feeding practices in low and middle-income countries. But there is an urgent need for developing a suitable complementary food for the 2-5year age group, which is the neglected group as no complementary food is available commercially. Keeping in view of above need in mind, this investigation was undertaken to explore the possibilities of utilization of millets in formulating complementary food. The results of the investigation to formulate millet based complementary health food have been presented in this chapter with suitable tables, graphs figures and plates.

4.1 Composition of ingredients used in formulation of complementary health food

Chemical composition of ingredients used in formulation of complementary health food is presented in Table-1.

4.1.1 Chemical composition of raw flours

Raw flours were used for the preparation of extruded flours and also in preparation of flakes. The chemical composition of the raw flours is depicted in Table-1.

Table 1: Chemical composition of important food ingredients used in the study

Ingredient Name	Moisture (%)	Fat (%)	Protein (%)	CHO (%)	Crude Fibre (%)	Minerals (%)	Energy (kcal/100g)
Raw Wheat Flour	7.06	2.00	10.60	77.30	1.24	1.80	369.60
Raw Green Gram Flour	9.24	1.23	22.70	61.23	2.10	3.50	346.79
Raw Foxtail Millet Flour	8.65	3.90	11.80	64.45	7.80	3.40	340.10
Raw Little Millet Flour	8.04	5.24	10.81	66.71	7.40	1.80	357.24
Raw White Ragi flour	9.67	1.90	12.77	68.06	4.70	2.90	340.42
Raw Sorghum Flour	5.92	2.80	11.98	74.84	2.74	1.72	372.48
Malted Wheat Flour	5.30	1.90	11.35	78.10	1.25	2.10	374.90
Malted Green Gram Flour	5.75	1.21	24.00	63.14	2.30	3.60	359.45
Malted Foxtail Millet Flour	7.86	3.30	12.10	66.27	6.90	3.57	343.18
Malted Little Millet Flour	6.35	5.10	11.45	67.60	7.60	1.90	362.10
Malted White Ragi flour	7.25	1.80	13.56	69.89	4.70	2.80	350.00
Malted Sorghum Flour	4.12	2.65	12.16	76.66	2.81	1.60	379.13
Skim Milk Powder	4.10	0.00	36.20	54.50	0.00	5.20	362.80
Whey Protein Hydrolyzate	5.30	6.80	79.00	6.60	0.00	2.30	403.60
Extruded Wheat Flour	5.69	1.89	13.47	75.63	2.12	1.20	373.41
Extruded Foxtail Millet Flour	4.36	1.81	12.24	71.84	7.10	2.65	352.61
Extruded Little Millet Flour	3.20	1.95	11.68	73.76	7.52	1.89	359.31
Extruded White Ragi Flour	3.08	1.43	13.71	74.26	4.60	2.92	364.75
Extruded Sorghum Flour	3.60	2.11	12.26	77.51	2.71	1.81	378.07

All values are average of three trials

The moisture, fat, protein, carbohydrate, crude fibre, and ash content of the raw wheat flour was observed to be 7.06, 2.00, 10.60, 77.30, 1.80 and 1.24 per cent respectively, with the energy density of 369.60kcal/100g. The respective compositional values in raw green gram flour for moisture, fat, protein, carbohydrate, crude fibre, and ash content were 9.24, 1.23, 22.70, 61.23, 2.10 and 3.50 per cent. The energy density of the raw green gram flour was 346.79 kcal/100g. Raw foxtail millet flour had 8.65, 3.90, 11.8, 64.45, 7.80 and 3.40 per cent of moisture, fat, protein, carbohydrate, crude fibre, and ash content respectively, with the energy density of 340.1kcal/100g. The moisture, fat, protein, carbohydrate, crude fibre, and ash content of the raw little millet flour was observed to be 8.04, 5.24, 10.81, 66.71, 7.40 and 1.80 per cent with the energy density of 357.04 kcal/100g. The respective compositional values in raw white ragi flour for moisture, fat, protein, carbohydrate, crude fibre, and ash content were 9.67, 1.90, 12.77, 68.06, 4.70 and 2.90 per cent. The energy density of the raw white ragi flour was 340.42 kcal/100g. Raw sorghum flour had 5.92, 2.80, 11.98, 74.84, 2.74 and 1.72 per cent of moisture, fat, protein, carbohydrate, crude fibre, and ash content respectively, with the energy density of 372.48 kcal/100g.

4.1.2 Chemical composition of malted flours

Malted flours of small millets, green gram and sorghum were used for the preparation of complementary food. The chemical composition of the malted flours is depicted in Table-1. The moisture, fat, protein, carbohydrate, crude fibre, and ash content of the malted wheat flour was observed to be 5.30, 1.90, 11.35, 78.10, 1.25 and 2.10 per cent respectively with the energy of 374.90kcal/100g. The respective compositional values in malted green gram flour for moisture, fat, protein, carbohydrate, crude fibre, and ash content were 5.75, 1.21, 24.00, 63.14, 2.30 and 3.60. The energy density of the malted green gram flour was 359.45 kcal/100g. Malted foxtail millet flour had 7.86, 3.30, 12.10, 66.27, 6.90 and 3.57 per cent of moisture, fat, protein, carbohydrate, crude fibre, and ash content respectively with the energy density of 343.18 kcal/100g. The moisture, fat, protein, carbohydrate, crude fibre, and ash content of the malted little millet flour was found to be 7.35, 5.10, 11.45, 67.60, 7.60 and 1.90 per cent respectively, with the energy density of 362.10 kcal/100g. The respective compositional values in malted white ragi flour for moisture, fat, protein, carbohydrate, crude fibre, and ash content were 7.25, 1.80, 13.56, 69.89, 4.70 and 2.80 per cent. The energy density of the malted white ragi flour was 350.00 kcal/100g. Malted sorghum flour had 4.12, 2.65, 12.16,76.66, 2.81 and 1.60 per cent of moisture, fat, protein, carbohydrate, crude fibre, and ash content respectively, with the energy density of 379.13 kcal/100g.

4.1.3 Chemical composition of SMP and WPH

SMP used for the preparation of complementary food in the present investigation had the moisture, fat, protein, carbohydrate, crude fibre, and ash content of 4.1, 0.0, 36.2, 54.5, 0 and 5.20 per cent respectively, with the energy density of 362.80kcal/100g. The respective compositional values in WPH for moisture, fat, protein, carbohydrate, crude fibre, and ash content were 5.3, 6.8, 79.0, 6.60, 0.0, and 2.30 per cent. The energy density of the WPH was 403.60 kcal/100g.

4.1.4 Chemical composition of extruded flours

Extruded flours were used in the study for the formulation of RTU extruded complementary health food. The chemical composition of the extruded flours is depicted in Table-1. The moisture, fat, protein, carbohydrate, crude fibre, and ash content of the extruded wheat flour was found to be 5.69, 1.89, 13.47, 75.63, 2.12 and 1.20 per cent respectively with the energy density of 373.41kcal/100g. Extruded foxtail millet flour had 4.36, 1.81, 12.24, 71.84, 7.10 and 2.65 per cent of moisture, fat, protein, carbohydrate, crude fibre, and ash content respectively with the energy density of 352.61 kcal/100g. The moisture, fat, protein, carbohydrate, crude fibre, and ash content of the extruded little millet flour was observed to be 3.20, 1.95, 11.68, 73.76, 7.52 and 1.89 per cent with the energy density of 359.31 kcal/100g. The respective compositional values in extruded white ragi flour for moisture, fat, protein, carbohydrate, crude fibre, and ash content were 3.08, 1.43, 13.71, 74.26, 4.60 and 2.92 per cent. The energy density of the extruded white ragi flour was 364.75 kcal/100g. Extruded sorghum flour had 3.60, 2.11, 12.26, 77.51, 2.71 and 1.81 per cent of moisture, fat, protein, carbohydrate, crude fibre, and ash content respectively with the energy density of 378.07 kcal/100g.

4.2 Formulation of millet based complementary health food

Millet based complementary health food formulated keeping malted wheat based blend as control. In the experimental samples, malted wheat flour used in the formulation was replaced with malted millet flour at various levels. Similarly, malted green gram was replaced with various levels of SMP and WPH. Results obtained in the process of optimization of millet flour, SMP and WPH levels in the formulation are presented here under.

4.2.1 Formulation of foxtail millet based complementary health food

4.2.1.1 Effect of replacement of malted wheat flour with malted foxtail millet flour on sensory attributes of foxtail millet based complementary food

The malted wheat flour used in the standard formulation was replaced with malted foxtail millet flour at 25, 50, 75 and 100 per cent levels. The effect of replacement of malted wheat flour with malted foxtail millet flour on sensory quality of foxtail millet based complementary food is presented in Table-2.

With the increase in the level of foxtail millet malt from 0 to 100 per cent there was decrease in the scores pertaining to color and appearance. The scores for complementary food prepared exclusively with malted wheat was 7.63 whereas it was 7.43, 7.18, 7.17 and 7.39 at 25, 50, 75 and 100 per cent level of incorporation of foxtail millet malt in the formulation. However, the statistically there was no significant difference among the blends in terms of colour and appearance (CD=0.677). With the increase in the level of foxtail millet malt in the formulation, there was slight decrease in the scores pertaining to flavour attributes was observed. The flavor scores awarded for the formulated product were 7.61, 7.17, 7.38, 7.37 and 7.58 at 25, 50, 75 and 100 per cent level of incorporation of foxtail millet malt in the formulation. But the decrease in the flavour scores was insignificant. Body and texture awarded for the complementary food were 7.65, 7.42, 7.43, 7.40 and 7.55 showed decreasing trend upon replacement of wheat with foxtail millet malt. The scores pertaining to overall acceptability attributes were observed to be 7.65, 7.49, 7.30, 7.41 and 7.57 respectively, for control, 25, 50, 75 and 100 per cent levels of foxtail millet malt in the complementary food. However, the

Table 2: Effect of replacing malted wheat flour with malted foxtail millet flour on sensory attributes of foxtail millet based complementary food

Malted Wheat flour : Malted Foxtail Millet flour Ratio	Sensory scores on 9 point Hedonic Scale			
	Colour and Appearance	**Flavour**	**Body and Texture**	**Overall Acceptability**
100:0	7.44	7.61	7.65	7.63
75:25	7.43	7.17	7.42	7.49
50:50	7.18	7.38	7.43	7.30
25:75	7.17	7.37	7.40	7.41
0:100	7.39	7.58	7.55	**7.57**
CD	0.677	0.672	0.601	0.599

All values are average of three trials

decreased score with respect to body and texture and overall acceptability attributes upon increased level of replacement was insignificant. Even though the scores were statistically insignificant, the results revealed that highest sensory scores were awarded for the 100 percent malted foxtail millet in the formulation. Thus, it is inferred that the foxtail millet could be completely replaced in place of wheat in foxtail millet based complementary health food.

4.2.1.2 Effect of replacing malted green gram with SMP on sensory attributes of foxtail millet based complementary health food

The complementary food was formulated by replacing malted green gram flour with SMP at 25, 50, 75 and 100 per cent keeping malted green gram blended complementary food as control. The effects of replacement of green gram protein with SMP on sensory characteristics were evaluated. The results are presented in Table-3.

Upon increase in the incorporation level of SMP in the complementary food there was a consistent increase in the scores with respect to the colour and appearance were observed. The score for green gram based complementary food was 6.92 which were increased to 7.07, 7.23, 7.36 and 7.59 upon incorporating SMP at 25, 50, 75 and 100 per cent respectively. The flavour scores were also increased from 6.53 at 0 per cent to 6.68, 6.79, 6.83 and 7.97 upon replacement of green gram with SMP at 25, 50, 75 and 100 per cent respectively in the complementary food. The score upon 100 percent replacement with SMP was significant (CD=0.33) in comparison with the control. The respective body and texture scores were 6.73, 6.86, 6.92, 7.00 and 7.43 for 0, 25, 50, 75 and 100 per cent level of SMP incorporation in the complementary food and the increase in score

Table 3: Effect of replacing malted Green gram flour with SMP on sensory attributes of foxtail millet based complementary health food

Malted Green Gram flour : SMP Ratio	Sensory scores on 9 point Hedonic Scale			
	Colour and Appearance	Flavour	Body and Texture	Overall Acceptability
100:0	6.92	6.53	6.73	6.58
75:25	7.07	6.68	6.86	6.84
50:50	7.23	6.79	6.92	7.07
25:75	7.36	6.83	7.00	7.23
0:100	7.59	7.97	7.43	**7.93**
CD	0.630	0.330	0.470	0.540

All values are average of three trials

with100 per cent SMP was statistically significant compared to the green gram based complementary food (CD=0.540). As the SMP level in the complementary food increased, sensory scores of overall acceptability attribute were also significantly increased. The overall acceptability scores were 6.58, 6.84, 7.07, 7.23 and 7.93 for 0, 25, 50, 75 and 100 per cent level of SMP incorporation in the complementary food. The results of the study showed that the complementary health food product was best accepted by completely replacing green gram with SMP.

4.2.1.3 Effect of replacement of SMP with WPH on sensory attributes of foxtail millet based complementary health food

The effect of incorporating WPH in place of SMP on various sensory attributes of complementary food is presented in Table-4. As could be observed from the results, with increasing in the level of WPH there was improvement in color and appearance of the product up to a level of 50 per cent replacement. Further increase to 75 per cent level decreased the score with respect to colour and appearance attribute. The scores with respect to the colour attributes were 7.82, 8.04, 7.8, and 7.66 for 0, 50, 75 and 100 per cent level of substitution. It was observed that increase in the level of substitution up to 50 per cent increased the flavour score. But the increase in flavour scores was insignificant as compared to control. However, above 50 per cent level, there was a significant decrease in the scores awarded to the flavour attribute of the complementary food was observed. The flavour score for the control sample was 7.54 whereas it was 7.68, 7.23 and 7.04 respectively, for 50, 75 and 100 per cent level of substitution of SMP with WPH in the foxtail millet based complementary food. It was evident from the result that the body and texture scores improved upon substitution of SMP with WPH up to 50

Table 4: Effect of replacing SMP with WPH on sensory attributes of foxtail millet based complementary health food

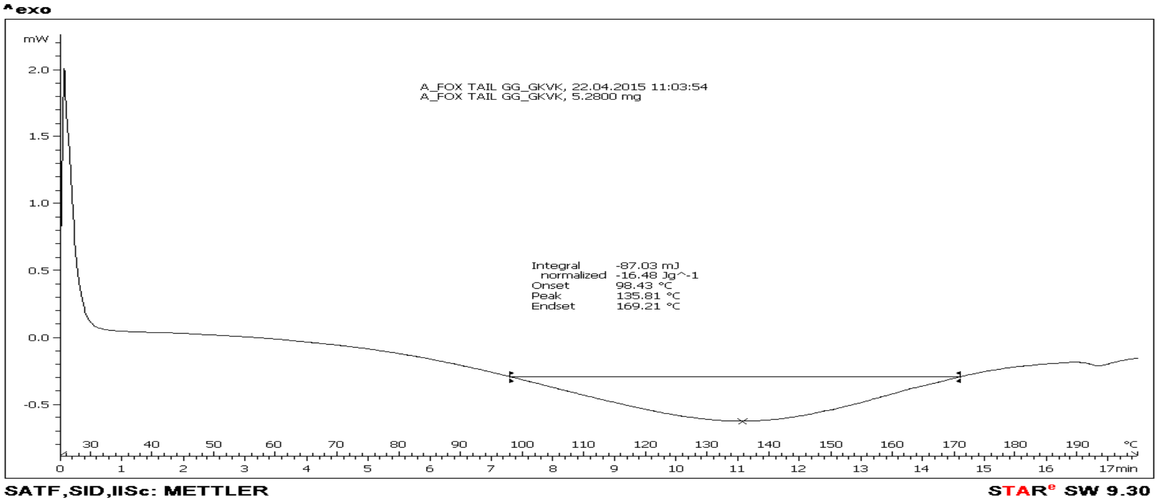
SMP: WPH Ratio	**Sensory scores on 9 point Hedonic Scale**			
	Colour and Appearance	**Flavour**	**Body and Texture**	**Overall Acceptability**
100:0	7.82	7.54	7.68	7.71
50:50	8.04	7.68	7.86	**7.83**
25:75	7.80	7.23	7.63	7.60
0:100	7.66	7.04	7.23	7.54
CD	0.490	0.30	0.12	0.19

All values are average of three trials

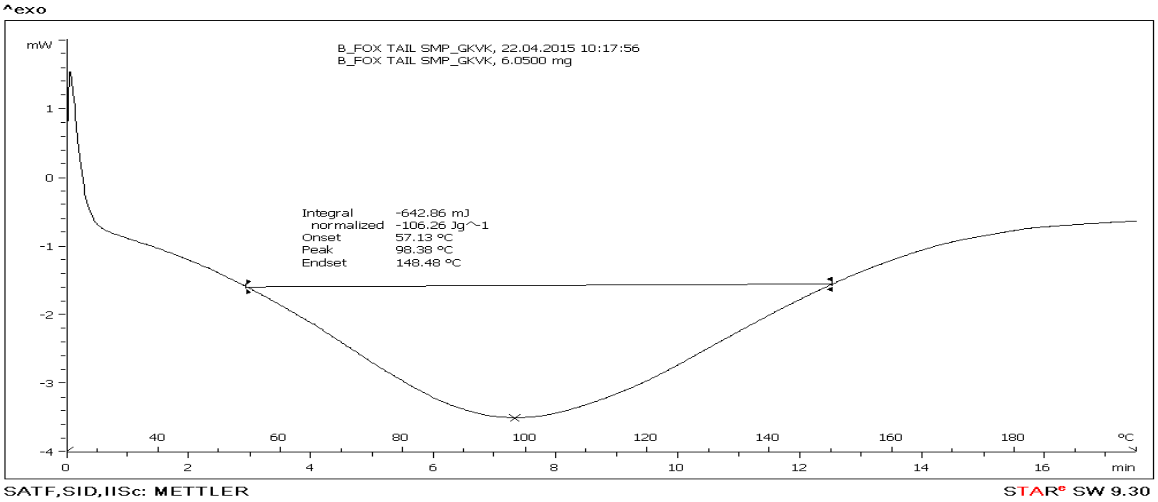
per cent level, thereafter the scores for body and texture attribute decreased. The respective scores at 0, 50, 75 and 100 per cent level of substitution were 7.68, 7.86, 7.63 and 7.23. The scores awarded for overall acceptability attributes followed similar pattern as that of other sensory attributes. Substitution of SMP with WPH had increased the overall acceptability attribute from 7.71 for control to 7.83 at 50 per cent. However, incorporation of WPH above 50 per cent level resulted in significantly decreased scores with respect to overall acceptability attribute of the complementary food in comparison with the control. Thus, it was inferred that the foxtail millet complementary health food with added WPH can be prepared by adding SMP and WPH in equal proportion of 50 per cent each in WPH containing product without much compromise on the sensory acceptability of the product.

4.2.1.4 Gelatinization studies

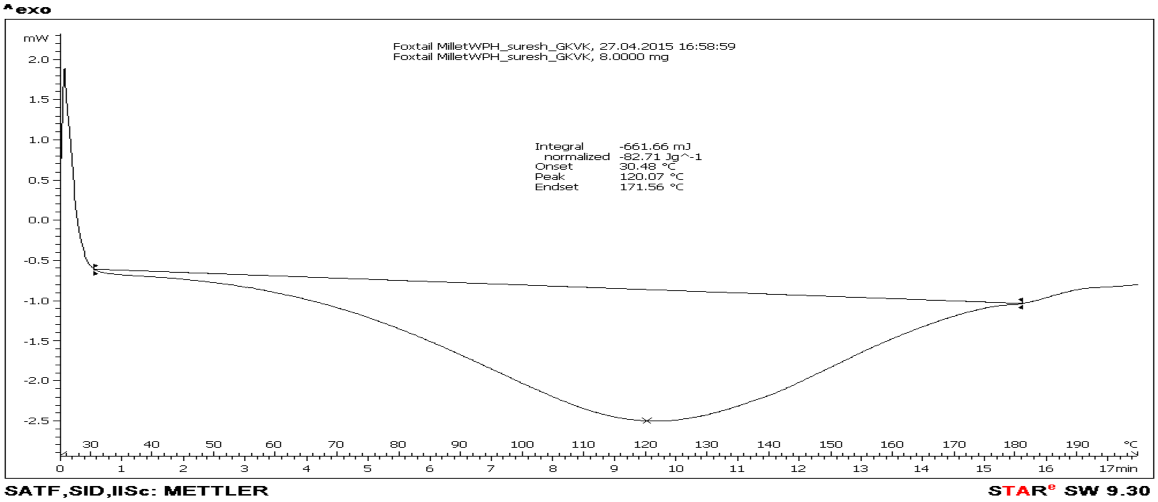
The Gelatinization of the starch present in the product influences the body and texture of the product and the consistency in porridge. The results of the study are depicted in Figure-1. The onset of gelatinization was at a temperature of 99.43°C and peaked at 135.81°C and had endset temperature of 169.21°C as measured by DSC (Figure-1a) for foxtail millet based formulation with green gram. However, the onset temperature in the product with SMP decreased to 57.13°C, peaked at 98.38°C and endset was at 148.48°C (Figure-1b). In the product with WPH an early on set of gelatinization was observed at 30.48°C but it peaked at 120.07°C and had endset at 171.56°C (Figure-1c). From the results, it was inferred that no single time temperature combination can be fixed for cooking time to prepare porridge and the cooking



a) **Foxtail millet based formulation with green gram**



b) **Foxtail millet based formulation with SMP**



c) **Foxtail millet based formulation with WPH**

Fig. 1: Identification of gelatinization temperature of foxtail millet based complementary health food using differential scaning colorimetry (DSC)

conditions could be stated as bring down to boil and wait till the development of viscosity.

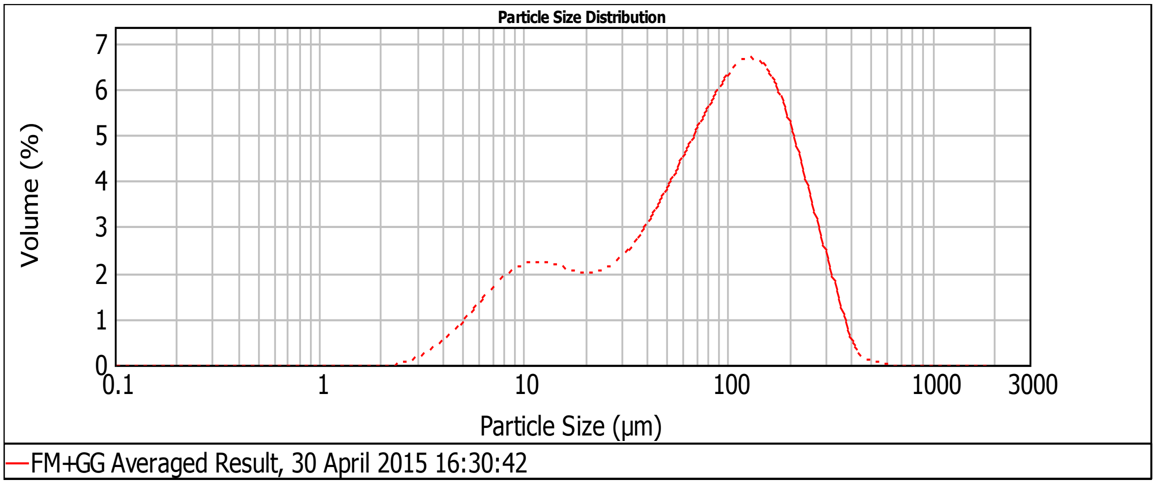
4.2.1.5 Physico-chemical and microbiological quality of the optimized blends of foxtail millet based complementary health foods

The optimized blends of foxtail millet based complementary health foods with green gram, SMP and WPH were analyzed for various physical, chemical and microbiological parameters. The results of the study are depicted in Table-5 and Fig. 2. As it could be seen from the Fig. 2a, 2b and 2c, the particle size distribution was observed to be ranging from 2µ to 632µ for foxtail millet complementary food containing green gram, 2µ to 502µ for foxtail millet complementary food with SMP and the particle size was 2µ to 447µ for the product with WPH. However, the maximum per cent (80 volume %) of the particles are below 200µ in all the three types of foxtail millet based complementary health foods. The colour (L*, a* and b*) values for green gram added foxtail millet based complementary food was 76.73*, 2.37* and 19.98*. It was 76.90*, 2.41* and 19.91* for the complementary food with SMP and 76.15*, 2.53* and 20.41* for the product with WPH depicting not much difference in the colour and appearance of the developed foxtail millet complementary food. The respective pH of the green gram, SMP and WPH complementary foods were 6.43, 6.58 and 6.84 which indicated there was slight increase of pH upon addition of SMP but upon blending WPH pH increase was more which is mainly due to the higher pH content of the added WPH. The water activity of the optimized complementary foods was 0.417 for green gram blended, 0.418 for the product with SMP and 0.423 for the product with WPH. This water activity even though can prevent the growth of the microorganisms but enzymatic activity at this level of water

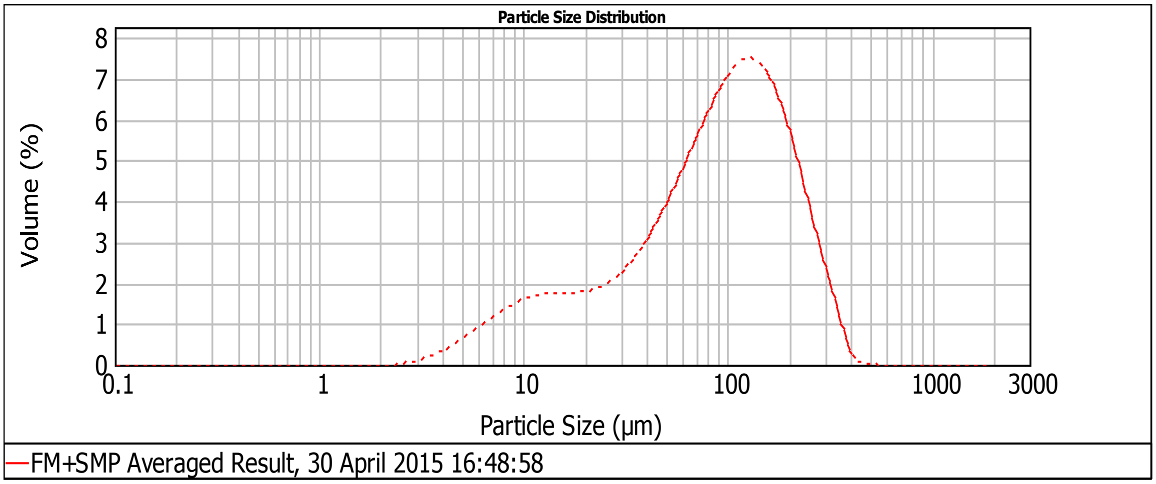
Table 5: Physical properties, chemical composition and microbiological quality of optimized formulations of foxtail millet based complementary health food

Foxtail millet based complementary health food	**Green gram**	**SMP**	**WPH**
Physical attributes			
Colour (L* a* b*)	76.73* 2.37* 19.98*	76.90* 2.41* 19.91*	76.15* 2.53* 20.41*
pH	6.43	6.58	6.84
Water Activity	0.417	0.418	0.423
Chemical Composition			
Moisture (%)	6.83	6.27	6.80
Fat (%)	2.48	2.34	2.96
Protein (%)	11.31	12.63	15.12
Carbohydrates (%)	71.51	70.52	67.21
Crude fibre (%)	5.07	4.81	4.78
Ash (%)	2.80	3.43	3.13
Energy density (K.cal/100g)	353.60	353.66	355.96
Microbiological quality counts in log cfu/gm			
TBC	4.50	4.36	4.27
Coliforms	NIL	NIL	NIL
Yeast and moulds	0.7	0.3	0

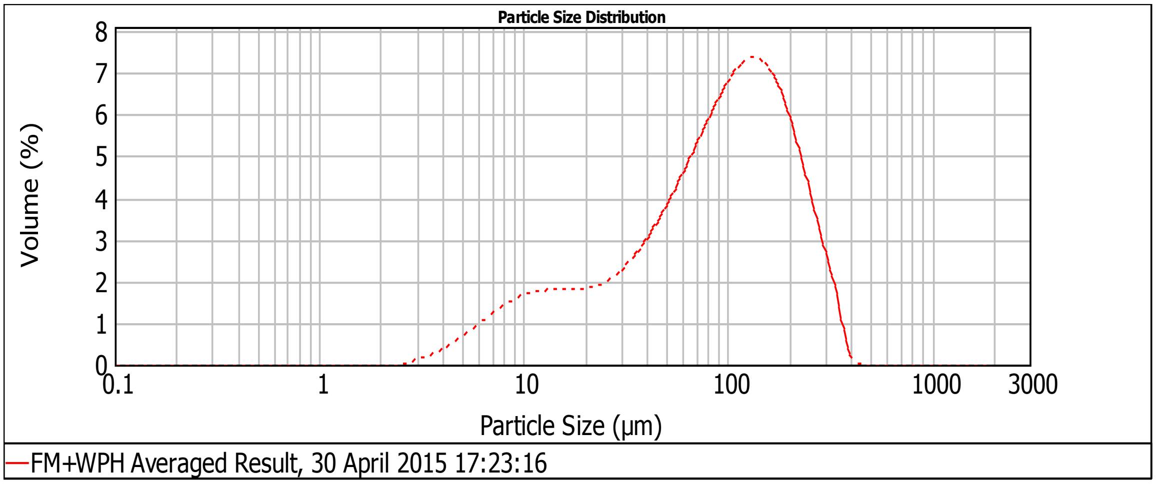
All values are average of three trials



a) Foxtail millet based formulation with green gram



b) Foxtail millet based formulation with SMP



c) Foxtail millet based formulation with WPH

Fig. 2: Particle size distribution of the optimized formulations of foxtail millet based complementary health food

activity could bring changes to the developed product during storage. The results of the chemical composition of the optimized formulations of foxtail millet based complementary food are depicted in Table-5. The moisture content of green gram based product was 6.83 per cent, SMP containing product was 6.27 per cent and in the product with WPH, moisture content was found to be 6.80 per cent. Higher levels of the moisture content in all the three forms are attributed to the higher moisture content of the malted foxtail millet flour. The fat content of the optimized formulations of green gram, SMP and WPH were 2.48, 2.34 and 2.96 per cent respectively. The respective protein content of complementary food with green gram, SMP and WPH was 11.31, 12.63 and 15.12 per cent depicting increased level of substitution of SMP and WPH increased the protein content of the resultant complementary food than that of the green gram containing product. Carbohydrate content in the green gram, SMP and WPH added complementary foods were observed to be 71.51, 70.52 and 67.21 per cent, respectively. In contrast to protein, there was a decreased carbohydrate content with increased level of WPH in the blend. The complementary food crude fibre content was decreased with increased level of SMP and WPH. The crude fibre content of green gram containing complementary food was 5.07 per cent whereas it was 4.81 per cent upon blending SMP and 4.78 per cent upon adding WPH. Increased level of substitution of SMP and WPH led to increased ash content of the complementary food. The ash content observed was 2.8, 3.43 and 3.13 per cent for green gram, SMP and WPH containing complementary food respectively. The energy density of foxtail millet based complementary health food was 353.60, 353.66 and 355.96 for green gram, SMP and WPH containing complementary foods respectively.

Microbial analysis results revealed that TBC of green gram, SMP and WPH containing complementary foods was 4.5log cfu/gm, 4.36 log cfu/gm and 4.27 log cfu/gm, respectively. Yeast and mould count was 0.7 log cfu/gm for green gram containing product and 0.3 log cfu/gm for SMP incorporated product. However the WPH containing product was free of yeast and moulds. Coliforms were absent in all the three samples of foxtail millet based complementary health foods indicating the developed products were safe.

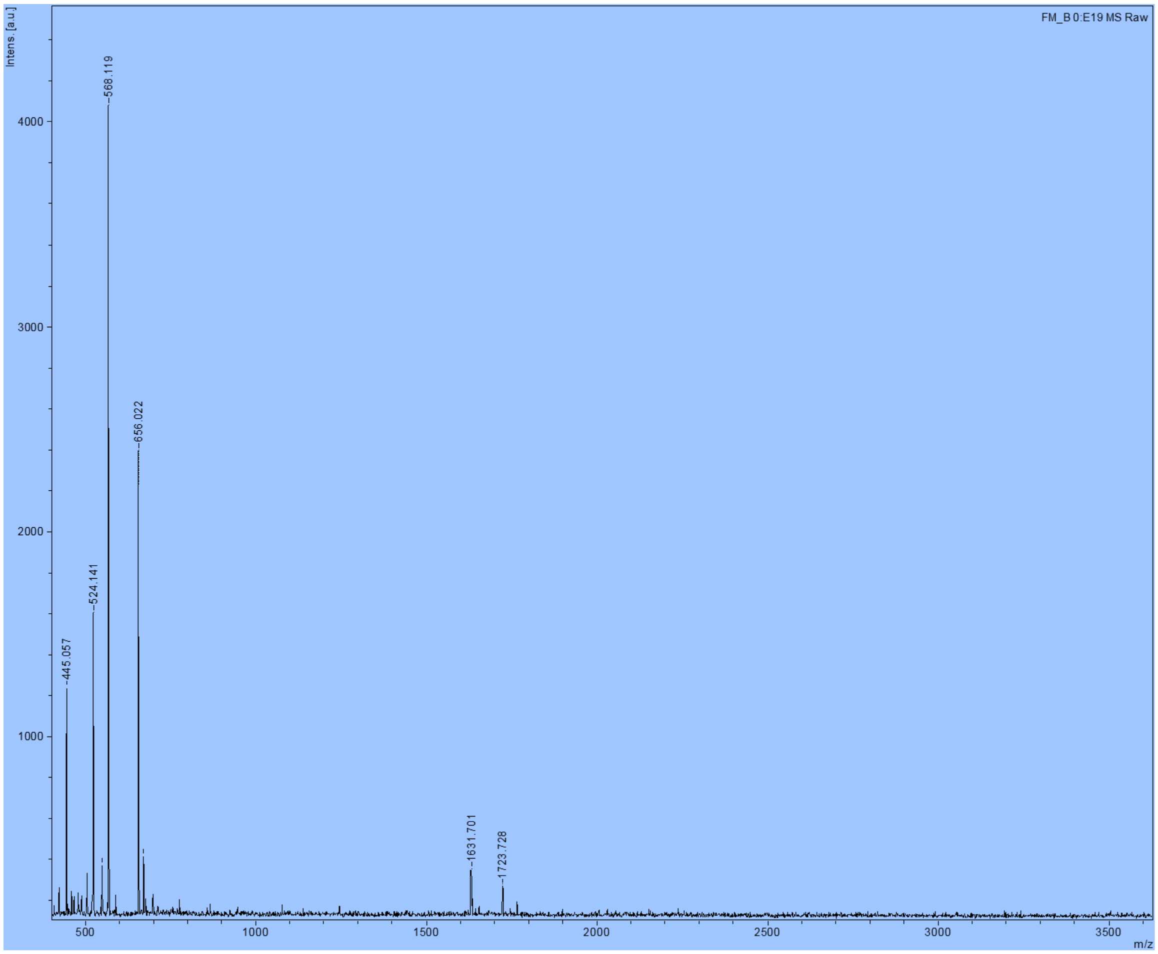
4.2.1.6 Amino acid profile of foxtail millet based complementary health food

The amino acid profile in the form of amino acid sequences obtained in MALDY-MS is shown in Figure 3a, 3b and 3c. The complementary food containing green gram has very few amino acids in the formulated product. The same was true with the SMP containing complementary food but more essential amino acids. However, the product with WPH had almost all the essential amino acids in the product.

4.2.2 Formulation of little millet based complementary health food

4.2.2.1 Effect of replacement of malted wheat flour with malted little millet flour on sensory attributes of little millet based complementary food.

The malted wheat flour used in the standard formulation was replaced with malted little millet flour at 25, 50, 75 and 100 per cent levels. The effect of replacement of malted wheat flour with malted little millet flour on sensory acceptability of little millet based complementary food is depicted in Table-6. Increase in the level of malted little millet flour from 0 to 100 per cent increased scores pertaining to color and appearance. The scores for complementary food with malted wheat were 7.48 increased steadily to



AMINO ACID SEQUENCES

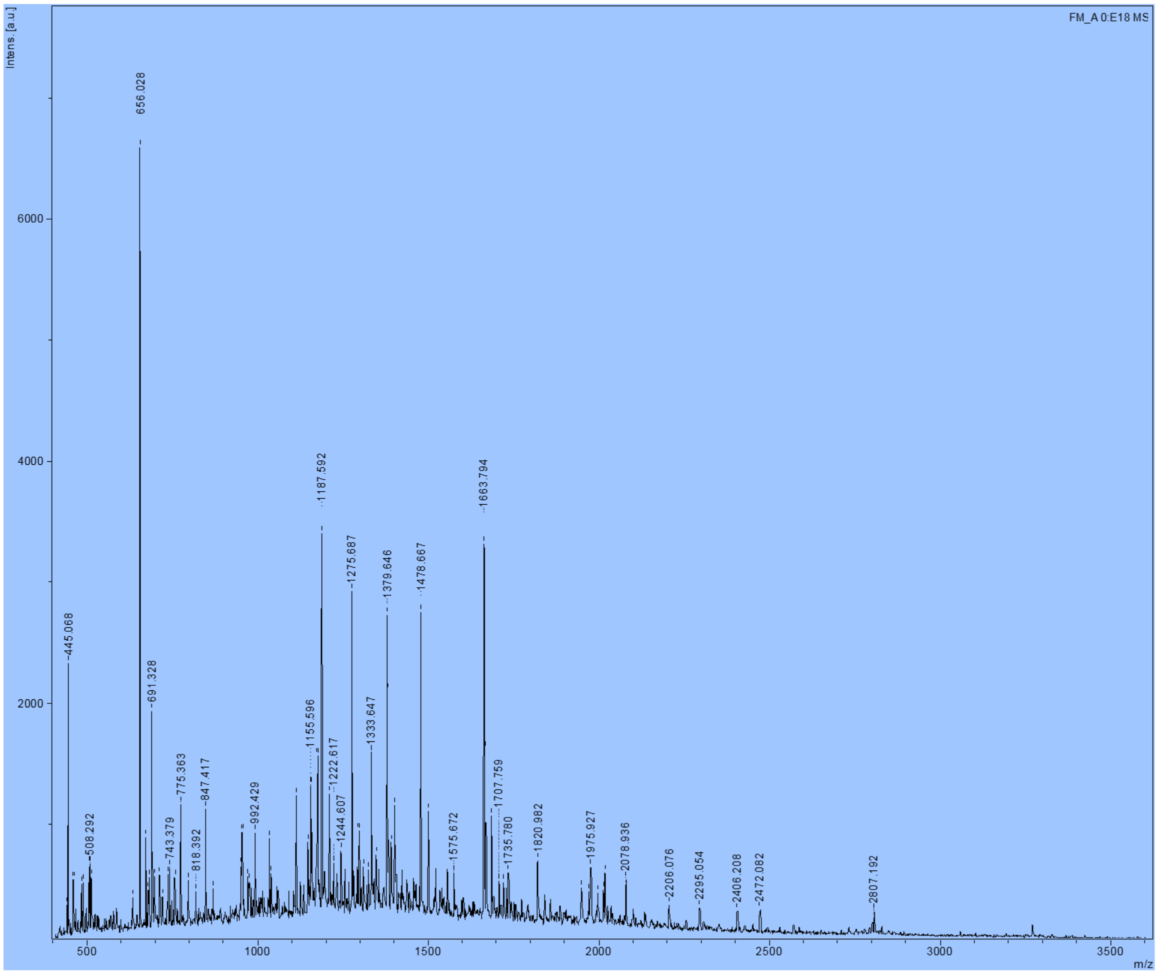
1 MEFTTAMFGT SLIFTTSTQS KHNLVNNCCC SSSTSESSMP ASCACTK**CGC**

51 **KTCKC**

AMINO ACID CODES

G	A	L	M	F	W	K	Q	E	S
Glycine	Alanine	Leucine	Methionine	Phenylalanine	Tryptophan	Lysine	Glutamine	Glutamic Acid	Serine
P	V	I	C	Y	H	R	N	D	T
Proline	Valine	Isoleucine	Cysteine	Tyrosine	Histidine	Arginine	Asparagine	Aspartic Acid	Threonine

Fig. 3a: Amino acid profile of foxtail millet based complementary food containing green gram



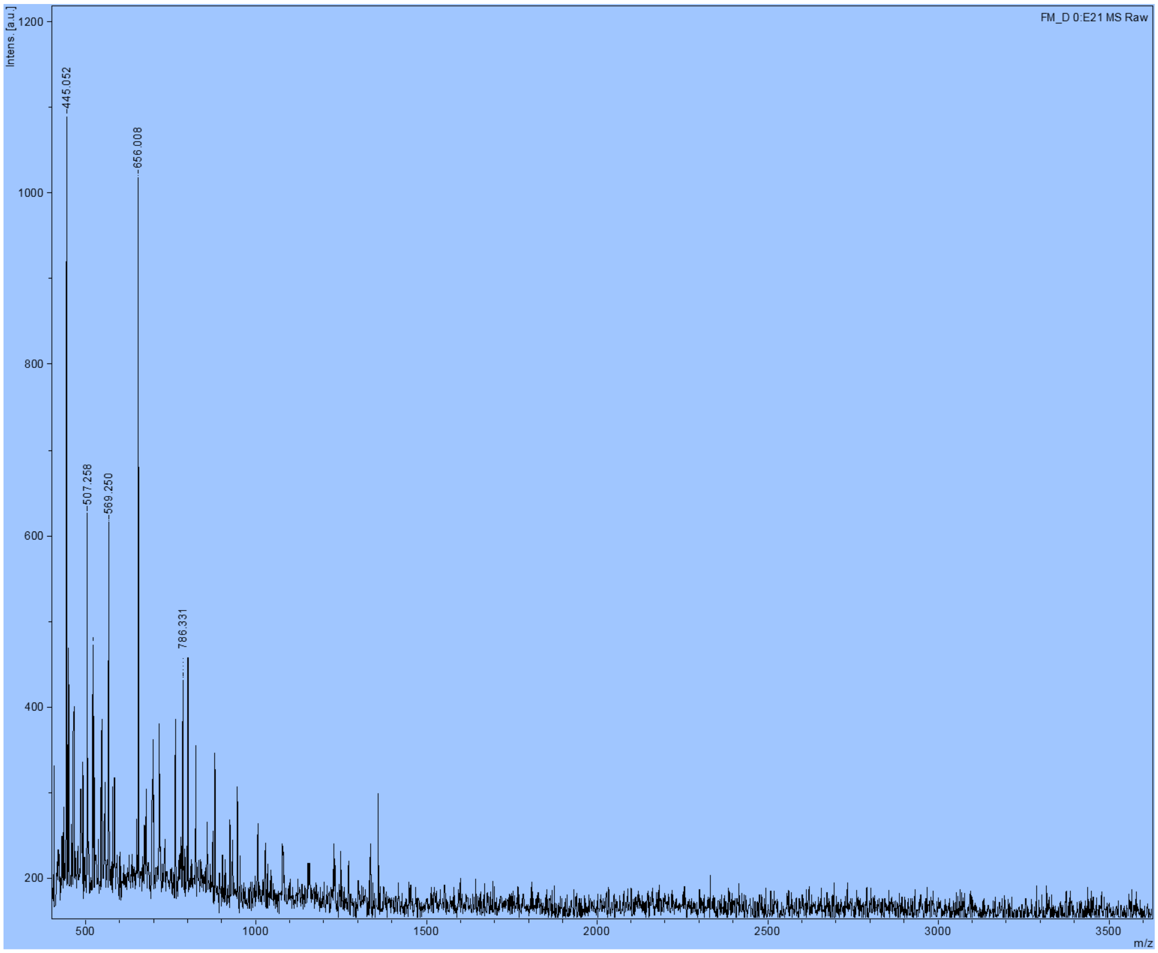
AMINO ACID SEQUENCES

1	MRRVVRQSK**F**	**RHVFGQAVK**N	DQCYDDIRVS	RVTWDSSFCA	VNPRFVAIII
51	EASGGGAFLV	LPLHKTGRID	KSYPTVCGHT	GPVLDIDWCP	HNDQVIASGS
101	EDCTVMVWQI	PENGLTLSLT	EPVVILEGHS	KRVGIVAWHP	TARNVLLSAG
151	CDNAIIIWNV	GTGEALINLD	DMHSDMIYNV	SWNRNGSLIC	TASKDKKVRV
201	IDPRKQEIVA	EK**EKAHEGAR**	**PMR**AIFLADG	NVFTTGFSRM	SERQLALWNP
251	KNMQEPIALH	EMDTSNGVLL	PFYDPDTSII	YLCGK**GDSSI**	**R**YFEITDESP
301	YVHYLNTFSS	K**EPQRGMGYM**	**PKR**GLDVNKC	EIAR**FFKLHE**	**RK**CEPIIMTV
351	PRKSDLFQDD	LYPDTAGPEA	ALEAEEWFEG	KNADPILISL	KHGYIPGKNR
401	DLKVVKKNIL	DSKPTANKKC	DLISIPK**KTT**	**DTASVQNEAK**	**LDEILK**EIKS
451	IK**DTICNQDE**	**RISKLEQQMA**	**K**IAA		

AMINO ACID CODES

G	A	L	M	F	W	K	Q	E	S
Glycine	Alanine	Leucine	Methionine	Phenylalanine	Tryptophan	Lysine	Glutamine	Glutamic Acid	Serine
P	V	I	C	Y	H	R	N	D	T
Proline	Valine	Isoleucine	Cysteine	Tyrosine	Histidine	Arginine	Asparagine	Aspartic Acid	Threonine

Fig. 3b: Amino acid profile of foxtail millet based complementary food containing SMP



AMINO ACID SEQUENCES

1 M**ALPSSRR**FK SPTTLAFFLV GVTLVVLNQW FLQEHRQEKA KGPVATRRSL
51 AAVVQRSPLF QVPPCVANAS ANLLTGFQLL PARIQDFLRY RHCRRFPQLW
101 DAPPKCAGPR GVFLLLAVKS SPAHYERREL IRRTWGQER**S** **YSGR**QVLRLF
151 LVGTSPPEEA AREPQLADLL SLEAREYGDV LQWDFSDTFL NLTLKHLHLL
201 DWTAEHCPGV SFLLSCDDDV FVHTANVLSF LEVQSPEHHL FTGQLMVGSV
251 PVR**ESGSK**YF VPPQIFPGVA YPAYCSGGGF LLSRYTVRNL RSAAHHVPLF
301 PIDDAYMGMC LQQAGLAPSS HQGIRPFGVQ LPNVQRLSLD PCMYRELLLV
351 HRFAPYEMLL MWKALHNPAL HCSHKQVAGS PTAGEQNPDA H

AMINO ACID CODES

G	A	L	M	F	W	K	Q	E	S
Glycine	Alanine	Leucine	Methionine	Phenylalanine	Tryptophan	Lysine	Glutamine	Glutamic Acid	Serine
P	V	I	C	Y	H	R	N	D	T
Proline	Valine	Isoleucine	Cysteine	Tyrosine	Histidine	Arginine	Asparagine	Aspartic Acid	Threonine

Fig. 3c: Amino acid profile of foxtail millet based complementary food containing WPH

Table 6: Effect of replacing malted wheat flour with malted little millet flour on sensory attributes of little millet based complementary food

Malted Wheat flour : Malted Little Millet flour Ratio	**Sensory scores on 9 point Hedonic Scale**			
	Colour and Appearance	**Flavour**	**Body and Texture**	**Overall Acceptability**
100:0	7.48	7.20	7.40	7.21
75:25	7.49	7.21	7.26	7.28
50:50	7.58	7.35	7.31	7.30
25:75	7.74	7.41	7.48	7.54
0:100	7.94	7.56	7.69	**7.61**
CD	0.338	0.253	0.146	0.354

All values are average of three trials

7.49, 7.58, 7.74 and 7.94 respectively, upon incorporating 25, 50, 75 and 100 per cent level of little millet flour. There was significant difference between the 100 per cent little millet flour blend in terms of colour and appearance with that of the control. With increase in the level of malted little millet flour in the product significantly increased the flavor attribute scores. The flavour score was 7.2 for the control was increased to 7.21, 7.35, 7.41 and 7.56 respectively, at 25, 50, 75 and 100 per cent level of malted little millet flour incorporation into the complementary food. The body and texture scores of the complementary food showed decreasing trend initially to 7.26 from 7.40 upon 25 per cent replacement of wheat with little millet malted flour however the extent of decrease was insignificant. Upon increase in the flour blend further to 50, 75 per cent and 100 per cent level, the body and texture showed increasing trend with the respective scores of 7.31, 7.48 and 7.69 reflecting the improvement in the consistency of the porridge with the incorporation of malted little millet flour in the product. The scores awarded to overall acceptability attribute were 7.21, 7.28, 7.30, 7.54 and 7.61 respectively, for 0, 25, 50, 75 and 100 per cent malted little millet flour in the product. The improvement in the overall acceptability was significant (0.354) upon complete replacement of the wheat flour with little millet flour in the complementary food.

4.2.2.2 Effect of replacing malted green gram by adding SMP on sensory attributes of little millet based complementary health food.

The complementary food was formulated by adding SMP in place of malted green gram flour at 25, 50, 75 and 100 per cent keeping malted green gram blended complementary food as control. The effects of replacement of green gram protein with SMP on sensory characteristics were evaluated. The results are presented in Table-7. As

Table 7: Effect of replacing malted Green gram flour with SMP on sensory attributes of little millet based complementary health food

Malted Green Gram flour : SMP Ratio	**Sensory scores on 9 point Hedonic Scale**			
	Colour and Appearance	**Flavour**	**Body and Texture**	**Overall Acceptability**
100:0	6.55	6.42	6.53	6.59
75:25	7.25	6.74	6.85	7.08
50:50	7.42	6.86	7.14	7.21
25:75	7.60	7.12	7.17	7.37
0:100	8.13	7.94	7.88	**8.02**
CD	0.438	0.213	0.236	0.414

All values are average of three trials

the incorporation level of SMP in the complementary food increased, there was a consistent increase in the scores with respect all the sensory characteristics of the resultant product. Colour and appearance of SMP incorporated little millet malt based complementary food increased from 6.55 in green gram based complementary food to 7.25, 7.42, 7.60 and 8.13 respectively, upon incorporation of 25, 50, 75 and 100 per cent SMP in place of green gram. The flavour scores awarded were 6.42, 6.74, 6.86, 7.12 and 7.94 respectively, for 0, 25, 50, 75 and 100 per cent SMP containing little millet malt based complementary food showing significant increase in the flavor scores at all the levels of incorporation (CD=0.213). The body and texture scores were also significantly increased (0.414) upon addition of SMP and the scores awarded were 6.53, 6.85, 7.14, 7.17 and 7.88 respectively, for 0, 25, 50, 75 and 100 per cent SMP containing little millet malt based complementary food. As the SMP level in the complementary food increased, sensory scores of overall acceptability attribute were also significantly increased. The overall acceptability scores were 6.59, 7.08, 7.21, 7.37 and 8.02 for 0, 25, 50, 75 and 100 per cent level of SMP incorporation in the little millet based complementary food containing SMP. The results of the study inferred that best product could be obtained by incorporating SMP completely in place of green gram.

4.2.2.3 Effect of replacement of SMP with WPH on sensory attributes of little millet based complementary health food

The effect of replacement of SMP with WPH on sensory attributes of complementary food is presented in Table-8. Increase in the level of WPH in the blend slight decrease in the colour and appearance scores was observed. The scores awarded for colour and appearance were 8.00, 7.85, 7.79, 7.82 for 0, 50, 75 and 100 per cent WPH

Table 8: Effect of replacing SMP with WPH on sensory attributes of little millet based complementary health food

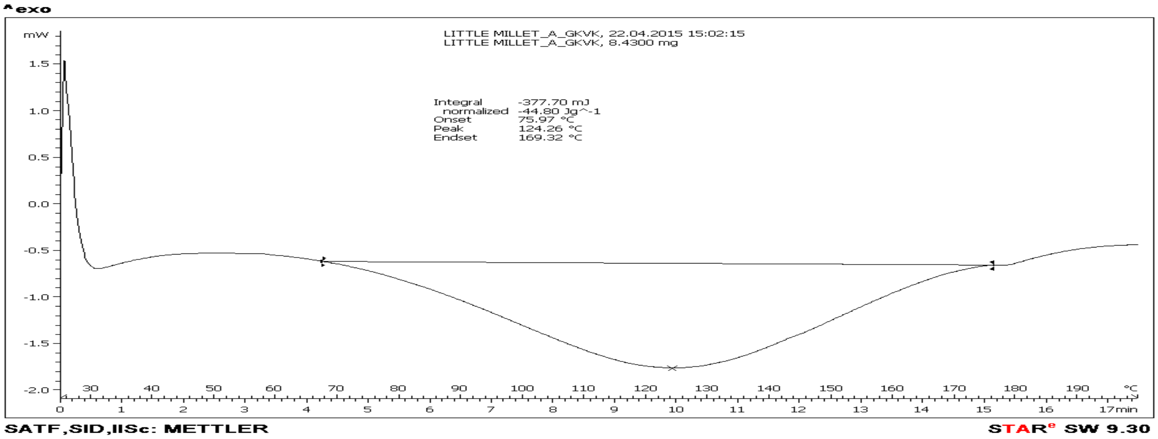
SMP: WPH Ratio	Sensory scores on 9 point Hedonic Scale			
	Colour and Appearance	**Flavour**	**Body and Texture**	**Overall Acceptability**
100:0	8.00	7.85	7.95	8.00
50:50	7.85	7.65	7.70	7.72
25:75	7.79	7.81	7.65	7.78
0:100	7.82	7.83	7.85	7.88
CD	0.331	0.453	0.431	0.354

All values are average of three trials

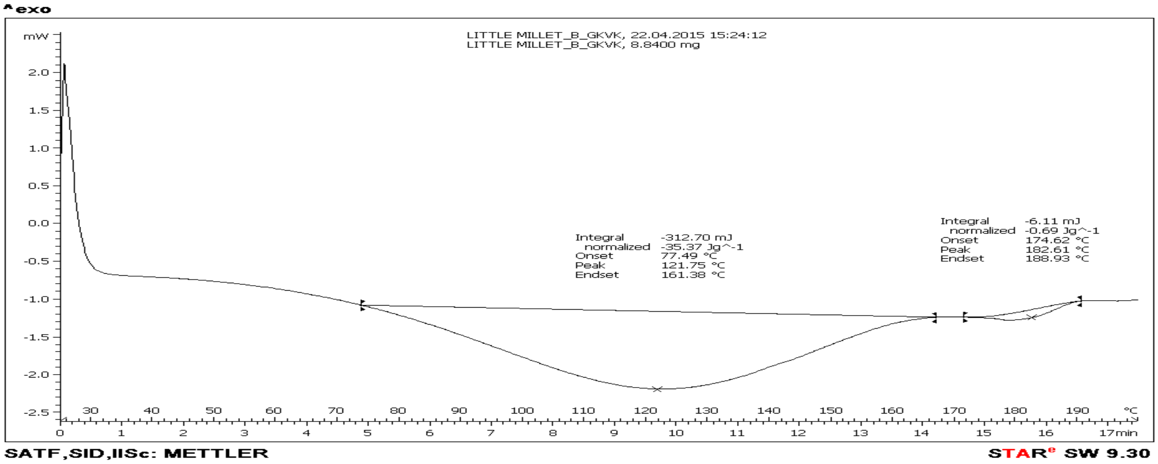
containing product. However, the extent of reduction was insignificant suggesting no difference among the different blends. It is observed that increase in the level of substitution did not have the significant influence on the flavour of the resultant product. The flavour score for the control sample was 7.85 whereas it was 7.65, 7.81 and 7.81 respectively, for 50, 75 and 100 per cent level of substitution SMP incorporating WPH. It was evident from the result that, body and texture did not significantly wary upon substitution of SMP with WPH. The respective scores at 0, 50, 75 and 100 per cent level of substitution were 7.95, 7.70, 7.65 and 7.85. The scores awarded for overall acceptability attributes followed similar pattern as that of other sensory attributes. Complete replacement of SMP with WPH had no effect on the overall acceptability attribute in comparison with control. The awarded overall acceptability scores at 0, 50, 75 and 100 per cent level of WPH were 8.0, 7.72, 7.78 and 7.85 respectively. From the study, it was opined that SMP could be completely replaced with WPH to have the benefit of the protein enhancement.

4.2.2.4 Gelatinization studies

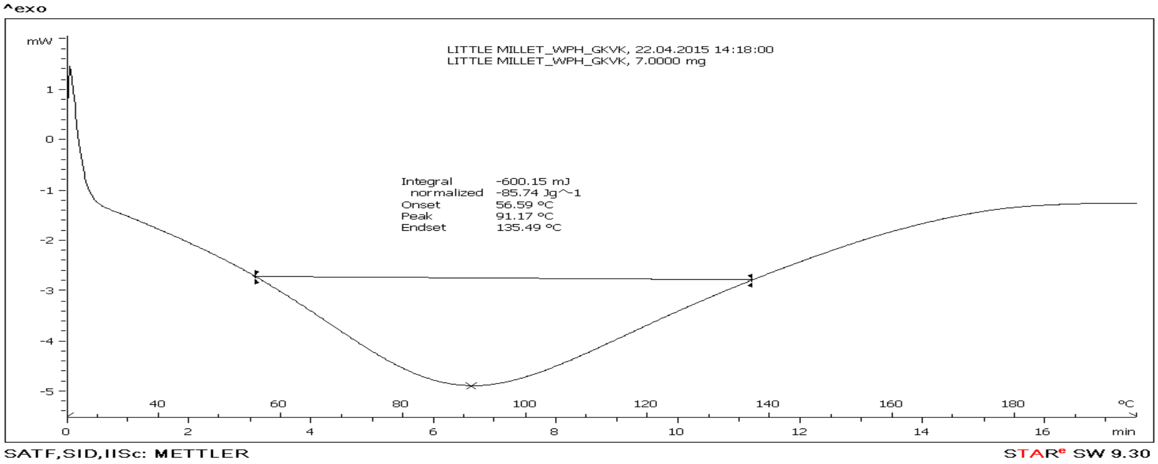
The Gelatinization of the starch present in the product influences the body and texture of the product and the consistency in porridge. The results of the study are depicted in Figure-4. The onset of gelatinization was at a temperature of 75.97°C and peaked at 124.26°C and had endset temperature of 169.32°C as measured by DSC (Figure-4a) for little millet based formulation with green gram. However, the onset temperature in the product with SMP was 77.49°C, peaked at 121.75°C and endset was at 161.38°C (Figure-4b). The product with WPH started gelatinizing early with onset of gelatinization 56.59°C and peaked at 91.17°C and its endset was observed at 135.49°C



a) Little millet based formulation with green gram



b) Little millet based formulation with SMP



c) Little millet based formulation with WPH

Fig. 4: Identification of gelatinization temperature of little millet based complementary health food using differential scanning colorimetry (DSC)

(Figure-4c). From the results, it was inferred that no single time temperature combination can be fixed for cooking time to prepare porridge and the cooking conditions could be stated as bring down to boil and wait till the development of viscosity.

4.2.2.5 Rheological studies

The Rheological characteristics of the best adjudged little millet based complementary food containing SMP using Anton paar rheometer are depicted in the Figure 5. The viscosity of the porridge was 33821mPa.s initially and decreased further upon increase in the shear rate. This viscosity could have influenced the body and texture scores difference (Table-8) upon increasing the level of replacement of type of protein as general and incorporation of SMP in particular.

4.2.2.6 Physico-chemical and microbiological quality of the optimized blends of little millet based complementary health foods

The optimized blends of little millet based complementary health foods with green gram, SMP and WPH were analyzed for various physical, chemical and microbiological parameters. The results of the study are depicted in Table-9 and Fig.6. It could be seen from the Fig.6a, 6b and 6c, the particle size distribution was observed to be ranging from 0.7µ to 632µ for green gram, 3.5µ to 563µ for SMP and 2.8µ to 502µ for WPH containing complementary food. However, the maximum per cent of the particles are below 288µ for the product with WPH containing little millet based complementary health foods.

The colour (L*, a* and b*) values for green gram added little millet based complementary food was 82.37*, 2.21* and 16.18*. It was 82.88*, 2.30* and 15.79* for

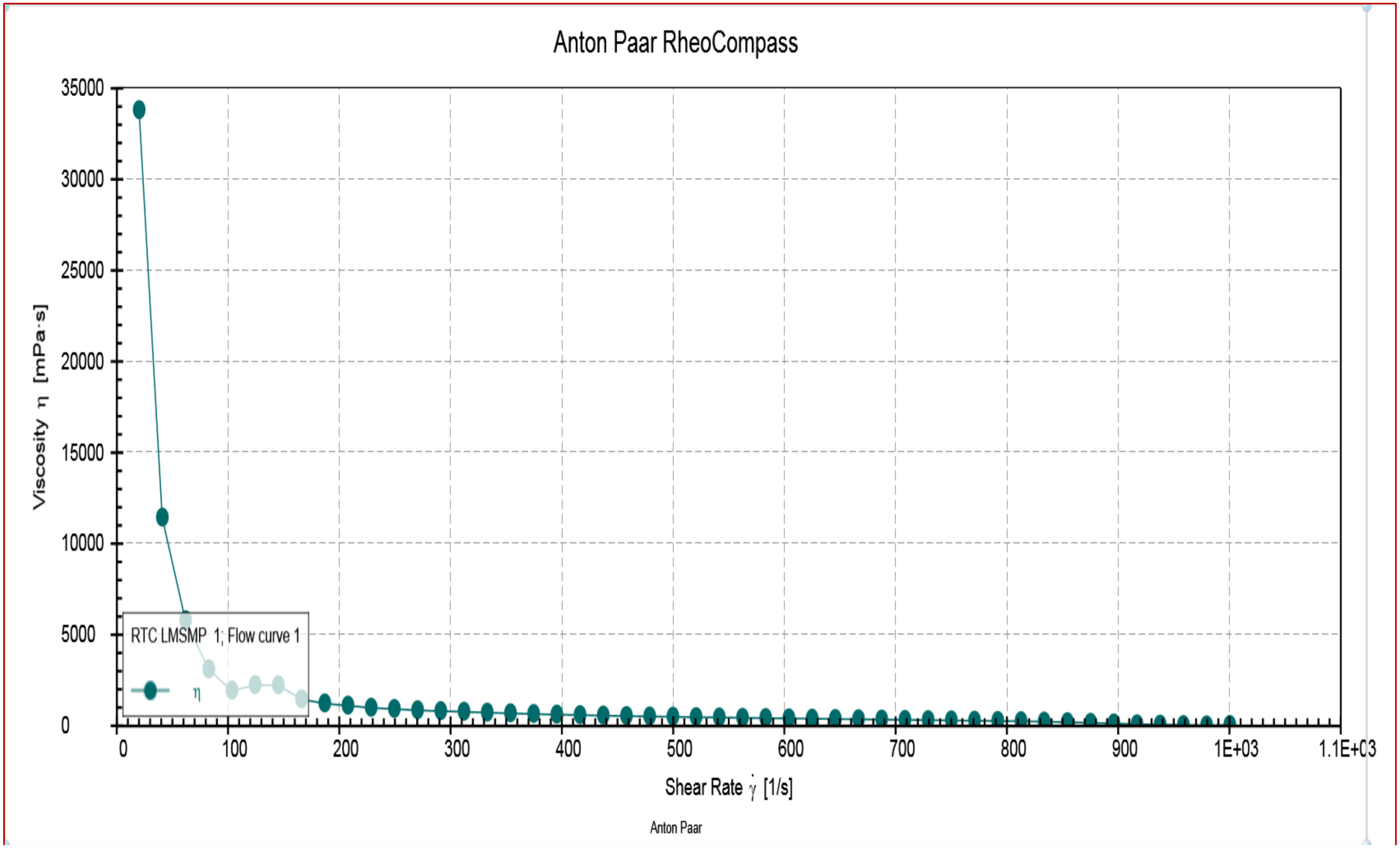
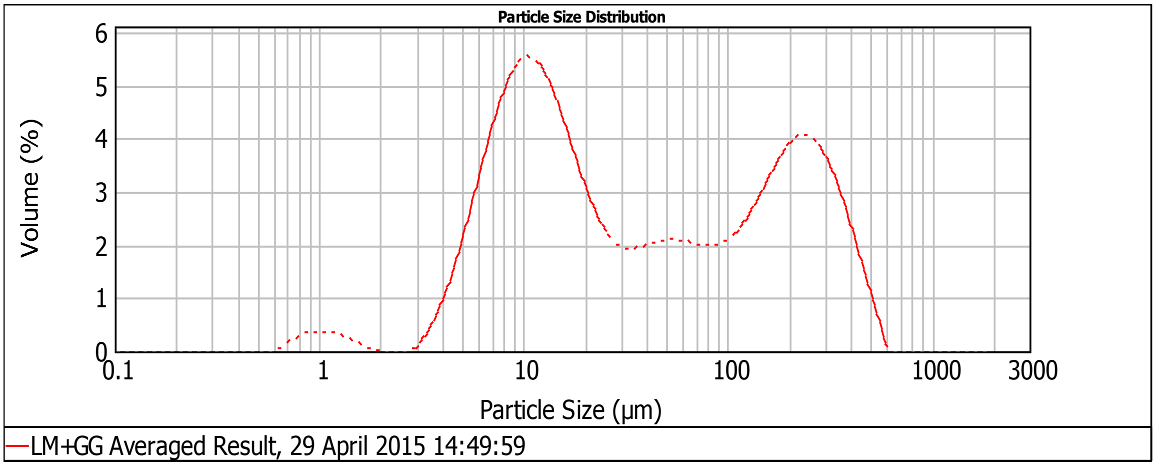


Fig. 5: Rheological parameters of ready to cook malted little millet based complementary health food

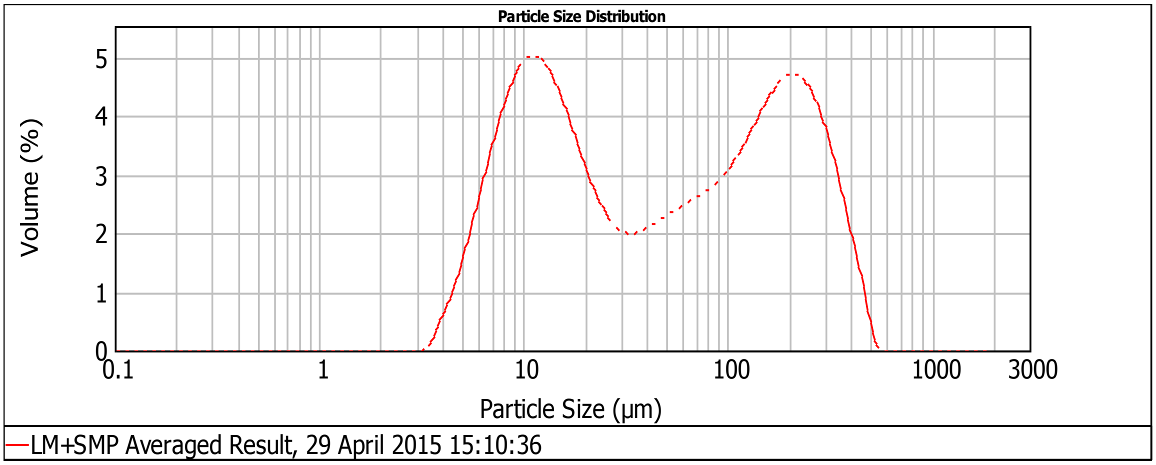
Table 9: Physical properties, chemical composition and microbiological quality of optimized formulations of little millet based complementary health food.

Little millet based complementary health food	**Green gram**	**SMP**	**WPH**
Physical attributes			
Colour	82.37* 2.21* 16.18*	82.88* 2.30* 15.79*	82.25* 2.41* 16.14*
pH	6.27	6.37	6.75
Water Activity	0.392	0.410	0.425
Chemical Composition			
Moisture (%)	6.31	6.08	6.32
Fat (%)	4.48	4.12	5.24
Protein (%)	10.81	12.23	17.15
Carbohydrates (%)	71.90	70.94	65.09
Crude fibre (%)	5.42	5.21	5.18
Ash (%)	1.08	1.42	1.09
Energy density (K.cal/100g)	371.16	369.76	376.12
Microbiological quality counts in log cfu/gm			
TBC	4.10	3.96	3.78
Coliforms	NIL	NIL	NIL
Yeast and moulds	0.21	0.17	0.11

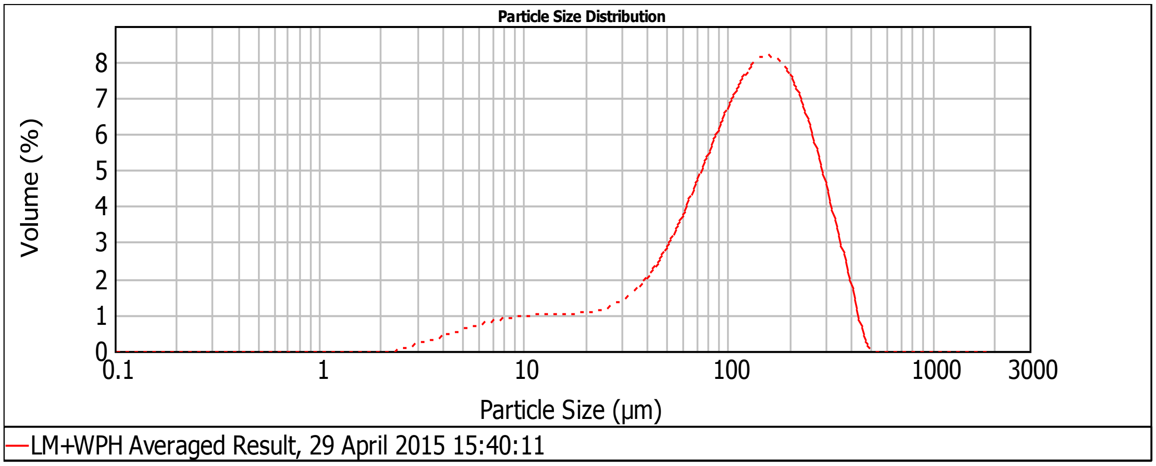
All values are average of three trials



a) Little millet based formulation with green gram



b) Little millet based formulation with SMP



c) Little millet based formulation with WPH

Fig. 6: Particle size distribution of the optimized formulations of little millet based complementary health food

the complementary food with SMP and 82.25*, 2.41* and 16.14* for the product with WPH. The respective pH of the green gram, SMP and WPH complementary foods were 6.27, 6.37 and 6.75. The water activity of the optimized complementary foods was 0.392 for green gram blended, 0.410 for the product with SMP and 0.425 for the product with WPH. The results of the chemical composition of the optimized formulations of little millet based complementary food are depicted in Table-9. The moisture content of green gram, SMP and WPH based products were 6.31, 6.08 and 6.32 per cent respectively. The fat content of the optimized formulations of green gram, SMP and WPH were 4.48, 4.12 and 5.24 per cent respectively. The respective protein content of complementary food with green gram, SMP and WPH was 10.81, 12.23 and 17.25 per cent depicting increased level of substitution of SMP and WPH has enhancement effect on the protein content of complementary food. Carbohydrate content in the green gram, SMP and WPH added complementary foods were observed to be 71.90, 70.94 and 65.09 per cent, respectively. The crude fibre content decreased with increased level of SMP and WPH. The crude fibre content of green gram, SMP and WPH containing complementary food was 5.42, 5.21 and 5.18 per cent respectively. The respective ash content of green gram, SMP and WPH containing little millet based complementary food was 1.08, 1.42 and 1.09. Increased level of substitution of SMP and WPH led to increased ash content of the complementary food. The energy density of little millet based complementary health food was 371.16, 369.76 and 376.12 respectively for green gram, SMP and WPH containing complementary food.

Microbial analysis results revealed that TBC of green gram, SMP and WPH containing little millet malt based complementary foods was 4.1log cfu/gm, 3.96 log cfu/gm and 3.78 log cfu/gm, respectively. Coliforms were absent in all the three samples of little millet based complementary health foods. Yeast and mould count was 0.21, 0.17 and 0.11 log cfu/gm for green gram, SMP and WPH incorporated product.

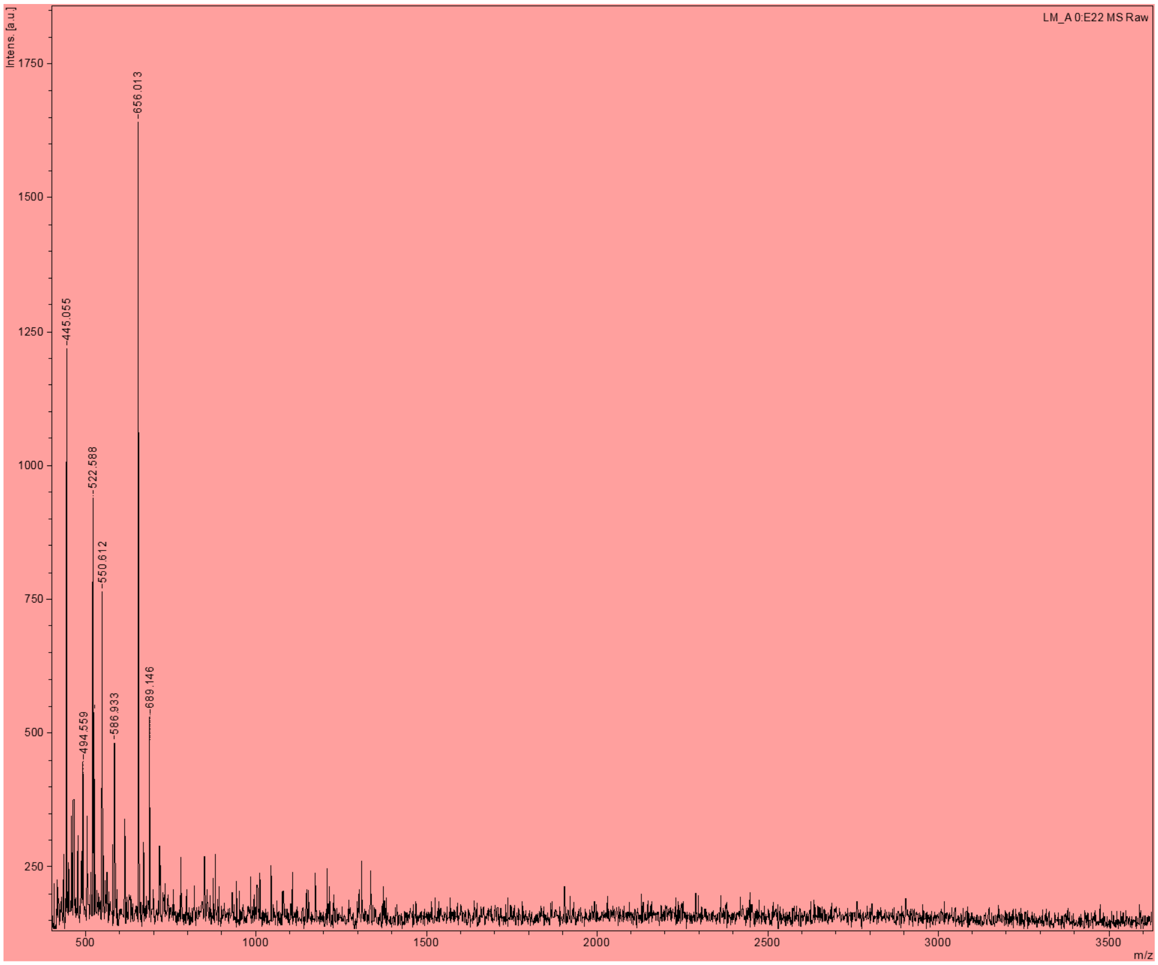
4.2.2.7 Amino acid profile of little millet based complementary health food

The amino acid profile in the form of amino acid sequences obtained in MALDY-MS is shown in Figure 7a, 7b and 7c. The complementary food containing green gram has very few amino acids in the formulated product. The same was true with the SMP containing complementary food but more essential amino acids. However, the product with WPH had almost all the essential amino acids in the product.

4.2.3 Formulation of sorghum based complementary health food

4.2.3.1 Effect of replacement of malted wheat flour with malted sorghum flour on sensory attributes of Sorghum based complementary food.

The malted wheat flour used in the standard formulation was replaced with malted sorghum flour at 25, 50, 75 and 100 per cent levels. The effect of replacement of malted wheat flour with malted sorghum flour on sensory acceptability of sorghum based complementary food is depicted in Table-10. Increase in the level of malted sorghum flour from 0 to 100 per cent increased scores pertaining to color and appearance however the extent of increase was insignificant. The scores for colour and appearance of complementary food were 7.32, 7.71, 7.81, 7.73, and 7.58 at 0, 25, 50, 75 and 100 per cent level of sorghum flour. The flavour scores were increased initially up to 50 per cent with increase in the level of malted sorghum flour and started decreasing when the sorghum flour level. The observed scores were 7.13, 7.26, 7.30, 7.15 and 7.05. The



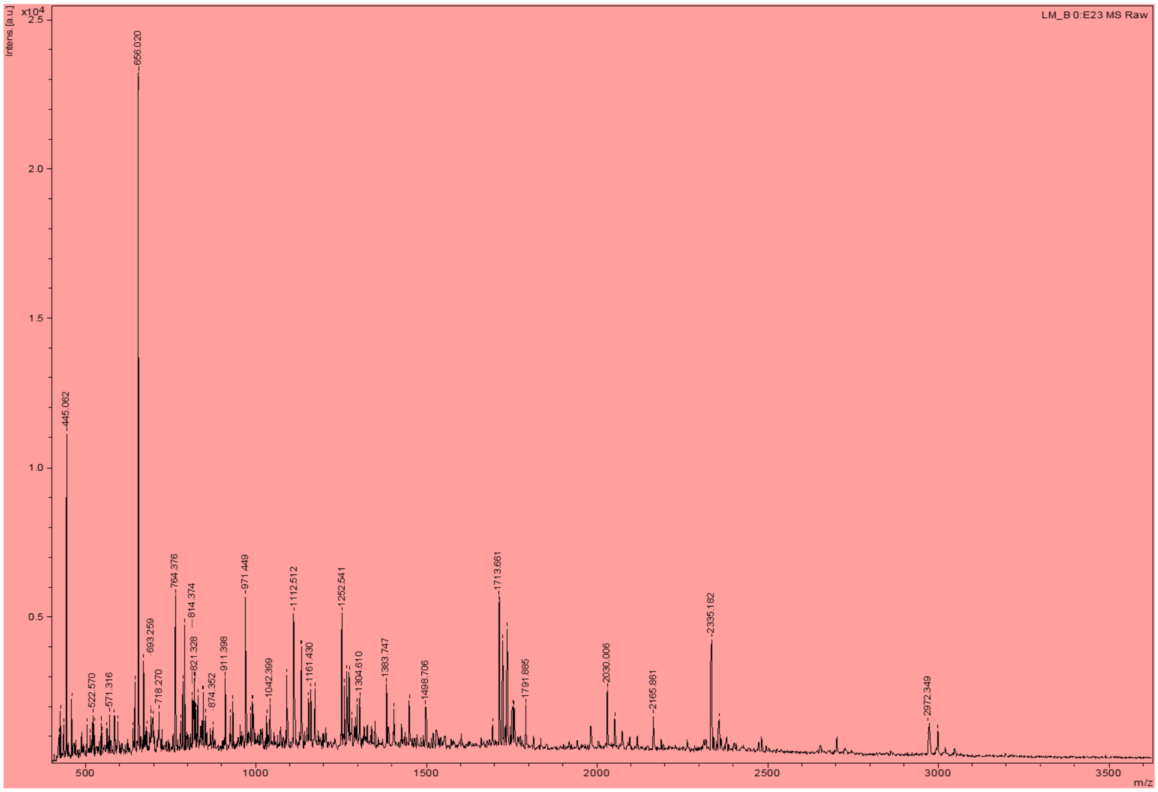
AMINO ACID SEQUENCES

1 MSETIEDRLL NKQVCMRCNA RNPTDAESCR K**CGYK**NLRTK ASERRSA

AMINO ACID CODES

G	A	L	M	F	W	K	Q	E	S
Glycine	Alanine	Leucine	Methionine	Phenylalanine	Tryptophan	Lysine	Glutamine	Glutamic Acid	Serine
P	V	I	C	Y	H	R	N	D	T
Proline	Valine	Isoleucine	Cysteine	Tyrosine	Histidine	Arginine	Asparagine	Aspartic Acid	Threonine

Fig. 7a: Amino acid profile of little millet based complementary food containing green gram



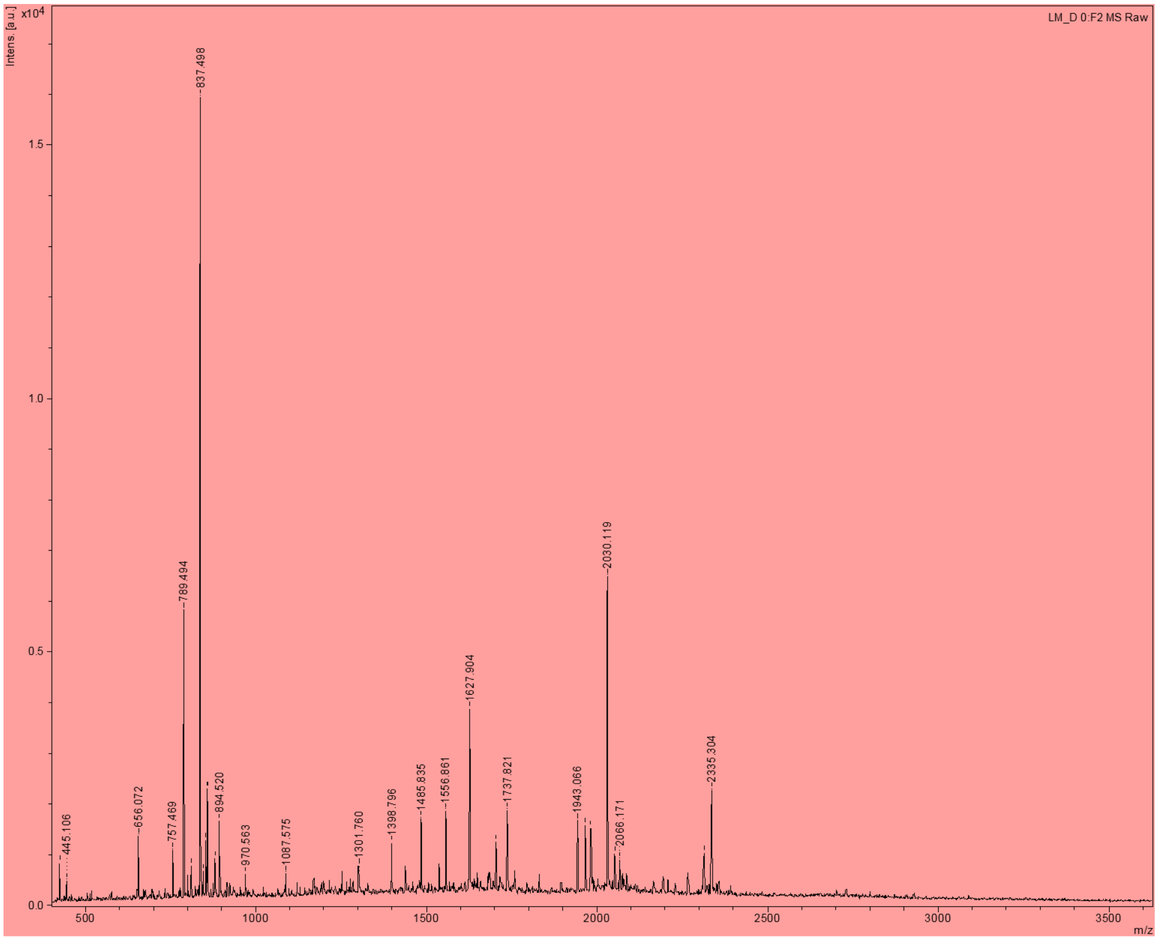
AMINO ACID SEQUENCES

1	MSASSSGGSP	RFPSCGKNGV	TSLTQK**KVLR**	TPCGAPSVTV	TKSHK**RGMKG**
51	**DTVNVR**RSVR	VKTK**VPWMPP**	**GK**SSARHVGC	NWENPPHCLE	ITPPSSEKLV
101	SVMRLSDLST	EDDDSGHCKM	NRYDKKIDSL	MNAVGCLKSE	VK**MQKGER**QM
151	AKR**FLEERK**E	ELEEVAQELA	ETEHENTVLR	HNIER**IKEEK**	**DYTMLQKK**HL
201	QQEKECLMSK	LVEAEMDGAA	AAKQVMALKD	TIGKLKSEKQ	MTCSDINTLT
251	RQKELLLQKL	STFEETNRTL	RDLLREQHCK	EDSERLMEQQ	GTLLKRLAEA
301	DSEKARLLLL	LQDKDKEVEE	LLQEIQCEK**A**	**QAKTASELSK**	**SMETMR**GHLQ
351	AQLR**CKEAEN**	**SRLCMQIKNL**	**ER**SGNQHKAE	VEAIMEQLKE	LKQKGERDKE
401	SLKKAIRAQK	ERAEKSEEYA	EQLHVQLADK	**DLYVAEALST**	**LESWR**SRYNQ
451	VVKDK**GDLEL**	**EIIVLNDR**VT	DLVNQQQTLE	EKMREDR**DSL**	**VERLHRQTAE**
501	**YSAFK**LENER	**LKASFAPMED**	**K**LNQAHIEVQ	QLKASVKNYE	GMIDNYKSQV
551	MKTRLEADEV	AAQLERCDKE	NK**ILKDEMNK**	EIEAARRQFQ	SQLADLQQLP
601	DILKITEAK**L**	**AECQDQLQGY**	**ERK**NIDLTAI	ISDLRSRVRD	WQKGSHELAR
651	AGARLPR				

AMINO ACID CODES

G	A	L	M	F	W	K	Q	E	S
Glycine	Alanine	Leucine	Methionine	Phenylalanine	Tryptophan	Lysine	Glutamine	Glutamic Acid	Serine
P	V	I	C	Y	H	R	N	D	T
Proline	Valine	Isoleucine	Cysteine	Tyrosine	Histidine	Arginine	Asparagine	Aspartic Acid	Threonine

Fig. 7b: **Amino acid profile of little millet based complementary food containing SMP**



AMINO ACID SEQUENCES

1 **MLTPYGR**STI LKTTIFASAI AVTGLFFPPV SRAVLILSAA AILGFAFWFF
51 RDPERTPAET GRVILAPADG R**VILVEER**DH PFTGSRSTLI SIFMSPLNVH
101 VNRIPQSGRI R**HLQYHPGSF** **KMAFDHKSME** **ENER**MDIGIE SDSLKIFFSQ
151 VSGFIARR**IV** **CPLRMDEAVE** **AGK**RFGMIKF GSRVDIIIPQ GSTPAVTIGG

201 KTRAGETVIA RW

AMINO ACID CODES

G	A	L	M	F	W	K	Q	E	S
Glycine	Alanine	Leucine	Methionine	Phenylalanine	Tryptophan	Lysine	Glutamine	Glutamic Acid	Serine
P	V	I	C	Y	H	R	N	D	T
Proline	Valine	Isoleucine	Cysteine	Tyrosine	Histidine	Arginine	Asparagine	Aspartic Acid	Threonine

Fig. 7c: Amino acid profile of little millet based complementary food containing WPH

Table 10: Effect of replacing malted wheat flour with malted sorghum flour on sensory attributes of sorghum based complementary food

Malted Wheat flour : Malted Sorghum flour Ratio	Sensory scores on 9 point Hedonic Scale			
	Colour and Appearance	Flavour	Body and Texture	Overall Acceptability
100:0	7.32	7.13	7.27	7.40
75:25	7.71	7.26	7.57	7.30
50:50	7.81	7.30	7.65	**7.36**
25:75	7.73	7.15	7.45	7.21
0:100	7.58	7.05	7.50	7.23
CD	0.538	0.673	0.646	0.734

All values are average of three trials

change in the score was insignificant (CD=0.646) between the levels even though the best score was at 50 per cent levels. Body and texture of the complementary food were also showed increasing trend upon replacement of wheat with sorghum malted flour however the extent of increase was insignificant. The scores pertaining to body and texture attribute were 7.27, 7.57, 7.65, 7.45 and 7.50 for 0, 25, 50, 75 and 100 per cent level of malted sorghum flour reflecting the consistency of the porridge for control were increased with the incorporation up to 50 per cent level of malted sorghum flour and decreased slightly beyond 50 per cent. The scores pertaining to overall acceptability were 7.40, 7.30, 7.36, 7.21 and 7.23 for 0, 25, 50, 75 and 100 per cent level of malted sorghum flour 50 per cent replacement of the wheat flour with sorghum flour in the complementary food. The slight decrease in the overall acceptability scores beyond 50 per cent level was observed. The results of the study showed that best acceptable sorghum based complementary food could be prepared from incorporation of sorghum only up to 50 percent in place of wheat.

4.2.3.2 Effect of incorporating SMP replacing malted green gram on sensory attributes of sorghum based complementary health food.

The malted sorghum based complementary food was formulated by replacing malted green gram flour with SMP at 25, 50, 75 and 100 per cent keeping malted green gram blended complementary food as control. The effects of replacement of green gram protein with SMP on sensory characteristics were evaluated. The results are presented in Table-11. As the incorporation level of SMP in the complementary food increased, there was a consistent increase in the scores with respect all the sensory characteristics of the resultant product. Colour and appearance scores increased from 7.71 in green gram based

Table 11: Effect of replacing malted Green gram flour with SMP on sensory attributes of sorghum based complementary health food

Malted Green Gram flour : SMP Ratio	Sensory scores on 9 point Hedonic Scale			
	Colour and Appearance	Flavour	Body and Texture	Overall Acceptability
100:0	7.71	7.06	7.24	7.13
75:25	7.32	7.19	7.21	7.20
50:50	7.54	7.39	7.54	7.36
25:75	7.73	7.40	7.57	7.61
0:100	8.07	7.89	7.96	**7.97**
CD	0.636	0.640	0.737	0.756

All values are average of three trials

complementary food to 7.32, 7.54, 7.73 and 8.07 respectively upon incorporating SMP at 25, 50, 75 and 100 per cent. However the extent of increase was not significant and all the blends were having same colour and appearance. The flavour scores were increased upon replacing green gram with SMP. The scores awarded for flavor of malted sorghum based complementary food were 7.06, 7.19, 7.39, 7.40 and 7.89 for 0, 25, 50, 75 and 100 per cent SMP containing product. The score (7.89) upon 100 percent replacement with SMP was significant in comparison with the control (7.06). The body and texture scores were improved upon addition of SMP with the scores of 7.24, 7.21, 7.54, 7.57 and 7.96 at 0, 25, 50, 75 and 100 per cent incorporation of SMP. As the SMP level in the complementary food increased, sensory scores of overall acceptability attribute were also significantly increased. The overall acceptability scores were 7.13, 7.20, 7.36, 7.61 and 7.97 for 0, 25, 50, 75 and 100 per cent level of SMP incorporation in the sorghum based complementary food containing SMP. The study confirmed that the acceptability of the malted sorghum based complementary food could be significantly improved by incorporating SMP in place of green gram.

4.2.3.3 Effect of replacement of SMP with WPH on sensory attributes of sorghum based complementary health food

The effect of replacing SMP by incorporating WPH on sensory attributes of sorghum based complementary food is presented in Table-12. The colour and appearance scores awarded were 8.03, 8.10, 7.78 and 7.51 respectively for 0, 50, 75 and 100 per cent WPH containing product. Increase in the level of WPH in the blend did not significantly affect the colour and appearance scores of the product. However, the scores did decrease when the WPH level in the blend increased beyond 50 per cent. It was observed that

Table 12: Effect of replacing SMP with WPH on sensory attributes of sorghum based complementary health food

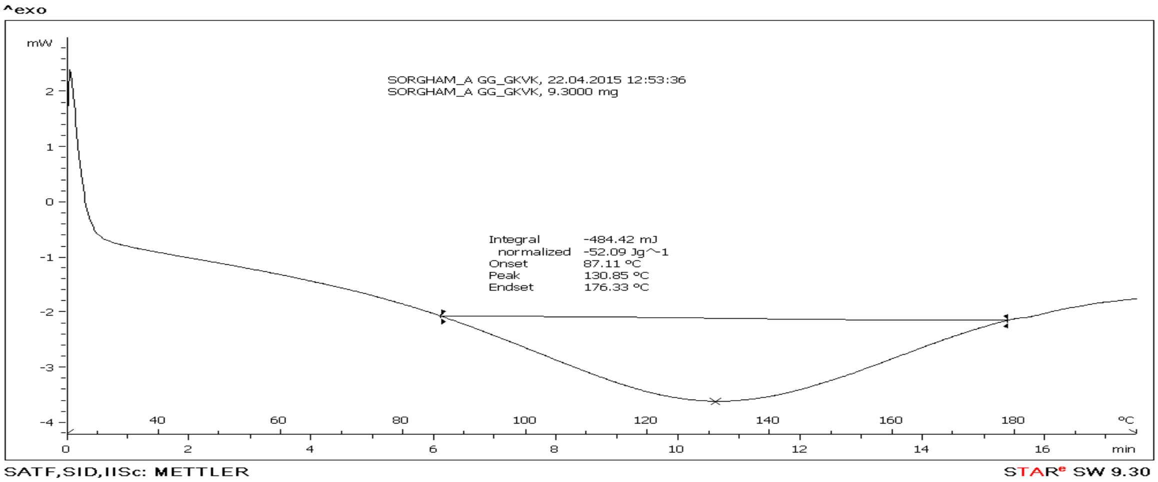
SMP: WPH Ratio	Sensory scores on 9 point Hedonic Scale			
	Colour and Appearance	Flavour	Body and Texture	Overall Acceptability
100:0	8.03	8.11	7.98	8.06
50:50	8.10	7.75	7.74	**7.99**
25:75	7.78	7.79	7.55	7.75
0:100	7.51	6.95	6.85	7.10
CD	0.566	0.763	0.634	0.753

All values are average of three trials

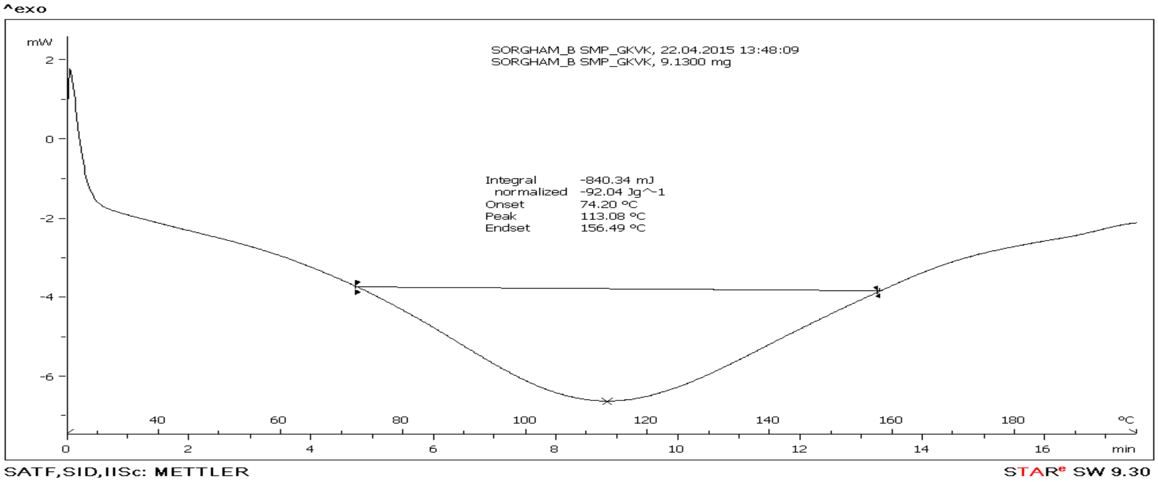
increase in the level of substitution did have the significant influence on the flavour of the resultant product. The flavour score for the control sample was 8.15 whereas it was 7.75, 7.79 and 6.95 for 50, 75 and 100 per cent level of substitution respectively. It was evident from the result that, body and texture did not significantly wary upon substitution of SMP with WPH up to 75 per cent. Further increase in the substitution significantly affected the body and texture scores. The respective scores at 0, 50, 75 and 100 per cent level of substitution were 7.98, 7.74, 7.55 and 6.85. Replacement of SMP with WPH had no effect on the overall acceptability attribute in comparison with control at 50 per cent level. However, 75 per cent has resulted in decrease in overall acceptability scores and upon blending 100 per cent WPH resulted in significant decrease in the scores awarded for overall acceptability. The scores at 0, 50, 75 and 100 per cent level of WPH were 8.06, 7.99, 7.75 and 7.10 respectively. The 50 per cent blend had the sensory scores near to that of the control. Thus, 50 per cent was taken as the best among the blends.

4.2.3.4 Gelatinization studies

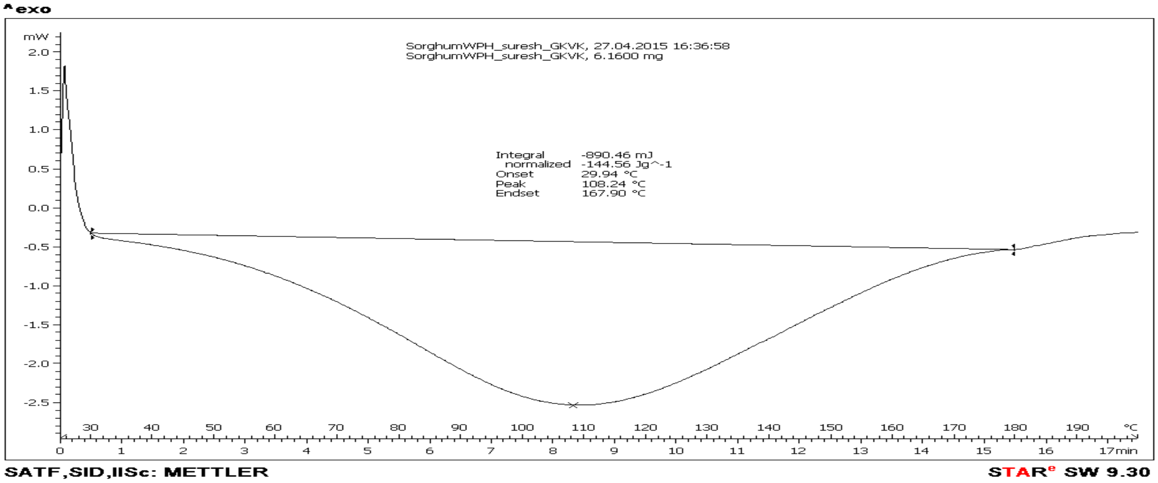
The Gelatinization of the starch influences the body and texture of the complementary food and the consistency in porridge. The results of the study are depicted in Figure-8. The onset of gelatinization was at a temperature of 87.11°C, peaked at 130.85°C and had endset at 176.33°C as measured by DSC (Figure-8a) for malted sorghum based formulation with green gram. The onset temperature in the product with SMP was 74.20°C, peaked at 113.08°C and endset was at 156.49°C (Figure-8b). The product with WPH started gelatinizing early at 29.94°C but peaked at 120.07°C and had endset at 167.90°C (Figure-8c). From the results, it was opined that no single time temperature combination can be fixed for cooking time to prepare porridge and the



a) Sorghum based formulation with green gram



b) Sorghum based formulation with SMP



c) Sorghum based formulation with WPH

Fig. 8: Identification of gelatinization temperature of sorghum based complementary health food using differential scanning colorimetry (DSC)

cooking conditions could be stated as bring down to boil and wait till the development of viscosity.

4.2.3.5 Rheological studies

The Rheological characteristics using Anton paar rheometer are depicted in the Figure-9. The viscosity of the porridge was 28000mPa.s initially decreased upon increase in the shear rate. This viscosity resulted in decreasing scores for body and texture and scores difference upon increasing the level of replacement of type of protein. However, complete replacement of green gram by incorporating SMP did affect the body and texture of the complementary food.

4.2.3.6 Physico-chemical and microbiological quality of the optimized blends of sorghum based complementary health foods

The optimized blends of sorghum based complementary health foods with green gram, SMP and WPH were analyzed for various physical, chemical and microbiological parameters. The results of the study are depicted in Table-13 and Figure.10. It could be seen from the Figure.10a, 10b and 10c, the particle size distribution was observed to be ranging from 0.8µ to 447µ for all the three types of complementary foods with green gram, SMP and WPH. However, the maximum per cent (90 volume %) of the particles are below 260µ in all the three sorghum based complementary health food. The colour (L*, a* and b*) values for green gram, SMP and WPH added sorghum based complementary food were 83.91*, 1.93* and 15.41*; 84.60*, 1.98* and 15.40*; 84.33*, 2.05* and 15.38* respectively, for complementary foods with green gram, SMP and WPH. The respective pH of the green gram, SMP and WPH complementary foods were

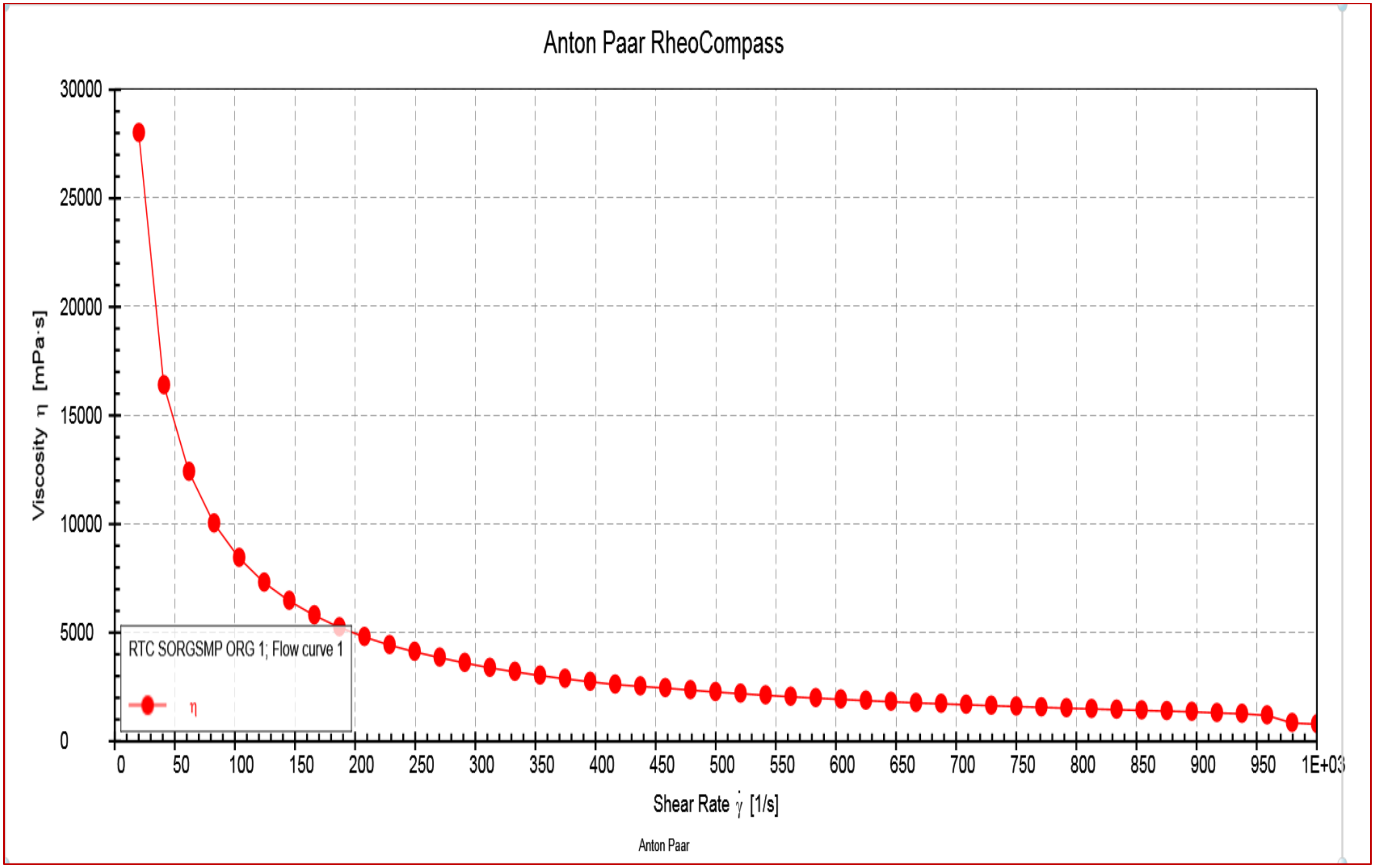
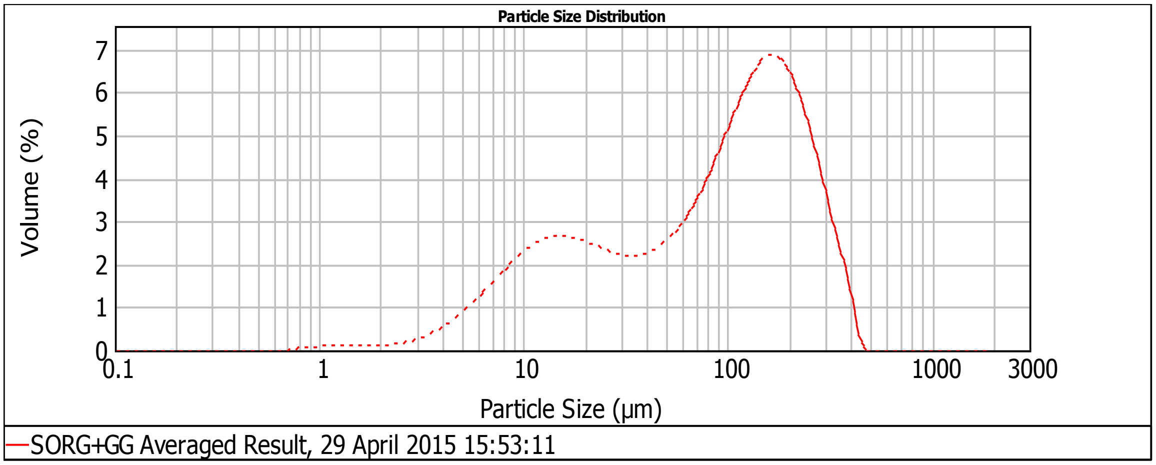


Fig. 9: Rheological parameters of ready to cook malted sorghum based complementary health food

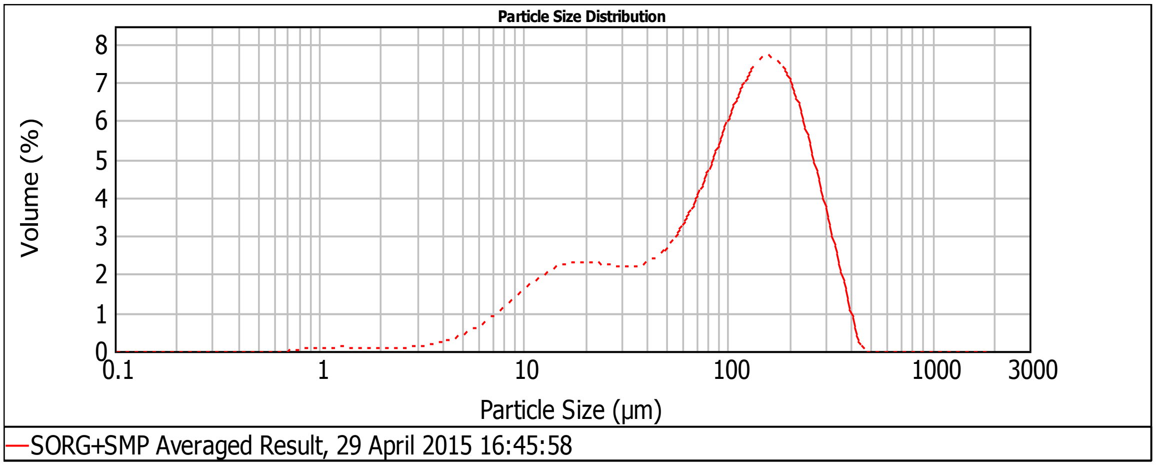
Table 13: Physical properties, chemical composition and microbiological quality of optimized formulations of sorghum based complementary health food

Sorghum based complementary health food	Green gram	SMP	WPH
Physical attributes			
Colour	83.91* 1.93* 15.41*	84.60* 1.98* 15.40*	84.33* 2.05* 15.38*
pH	6.03	6.19	6.56
Water Activity	0.224	0.237	0.251
Chemical Composition			
Moisture (%)	5.70	4.34	3.95
Fat (%)	2.55	2.37	2.82
Protein (%)	11.26	12.16	14.41
Carbohydrates (%)	76.44	77.09	75.23
Crude fibre (%)	2.20	1.94	1.89
Ash (%)	1.85	2.10	1.70
Energy density (K.cal/100g)	373.75	378.33	383.94
Microbiological quality counts in log cfu/gm			
TBC	3.40	3.25	3.12
Coliforms	NIL	NIL	NIL
Yeast and moulds	NIL	NIL	NIL

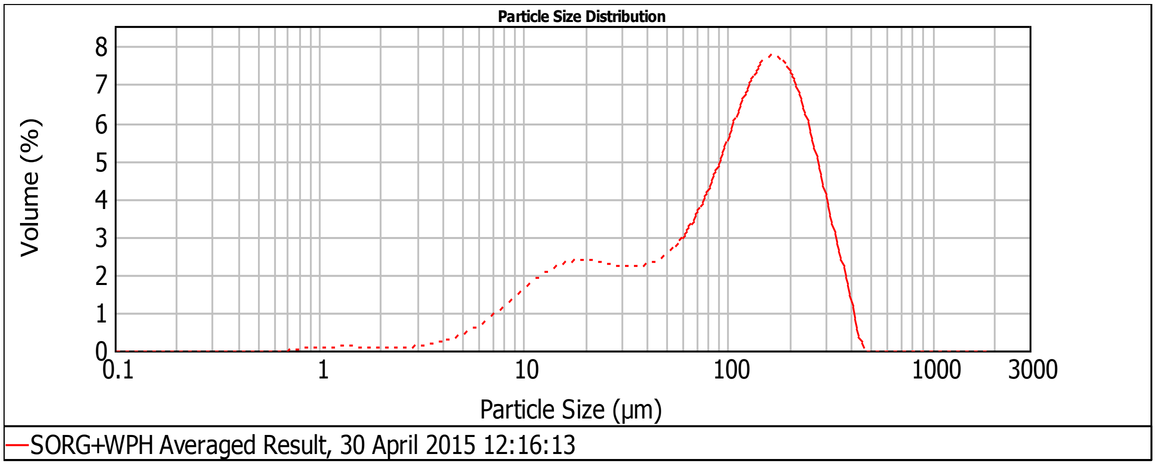
All values are average of three trials



a) Sorghum based formulation with green gram



b) Sorghum based formulation with SMP



c) Sorghum based formulation with WPH

Fig. 10: Particle size distribution of the optimized formulations of sorghum based complementary health food

6.03, 6.19 and 6.56. The water activity of the optimized complementary foods was 0.224 for green gram blended, 0.237 for the product with SMP and 0.251 for the product with WPH. The results of the chemical composition of the optimized formulations of sorghum based complementary food are depicted in Table-13. The moisture content of green gram, SMP and WPH based products were 5.7, 4.34 and 3.95 per cent respectively. The fat content of the optimized formulations of green gram, SMP and WPH were 2.55, 2.37 and 2.82 per cent respectively. The respective protein content of complementary food with green gram, SMP and WPH was 11.26, 12.16 and 14.41 per cent depicting increased level of substitution of SMP and WPH has increasing effect on the protein content of complementary food. Carbohydrate content in the green gram, SMP and WPH added complementary foods were observed to be 76.44, 77.09 and 75.23 per cent, respectively. The crude fibre content decreased with increased level of SMP and WPH. The crude fibre content of green gram, SMP and WPH containing complementary food was 2.2, 1.94 and 1.89 per cent respectively. Increased level of substitution of SMP and WPH led to increased ash content of the complementary food. The energy density of sorghum based complementary health food was 373.75, 378.33 and 383.94 respectively for green gram, SMP and WPH containing complementary food.

Microbial analysis results revealed that TBC of green gram, SMP and WPH containing complementary foods was 3.4 log cfu/gm, 3.25 log cfu/gm and 3.12 log cfu/gm, respectively. Coliforms and yeast and moulds were absent in all the three samples of sorghum based complementary health foods.

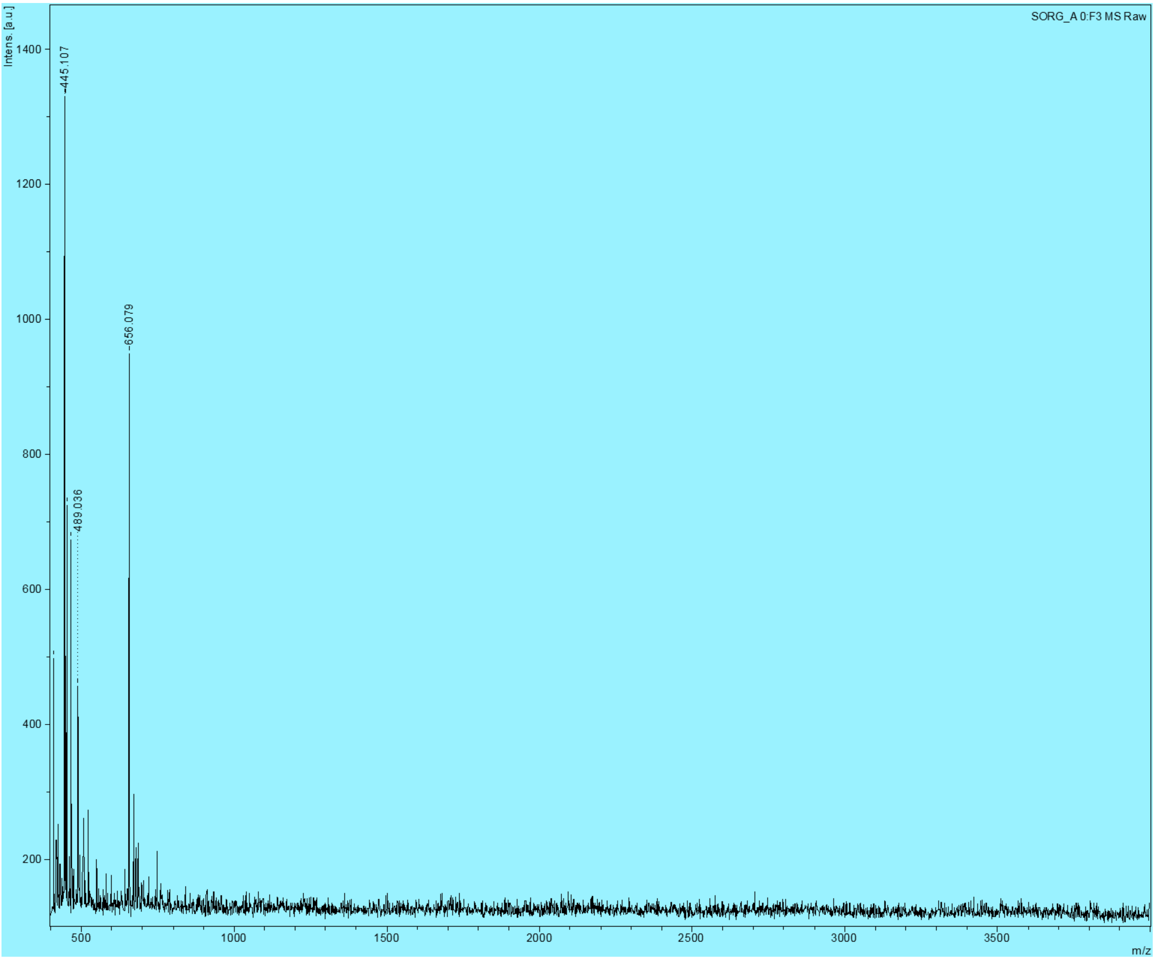
4.2.3.7 Amino acid profile of sorghum based complementary health food

The amino acid profile in the form of amino acid sequences obtained in MALDY-MS is shown in Figure 11a, 11b and 11c. The complementary food containing green gram has very few amino acids in the formulated product. The same was true with the SMP containing complementary food but more essential amino acids. However, the product with WPH had almost all the essential amino acids in the product.

4.2.4 Formulation of white ragi based complementary health food

4.2.4.1 Effect of replacement of malted wheat flour with malted white ragi flour on sensory attributes of white ragi based complementary food.

The malted wheat flour used in the standard formulation was replaced with malted white ragi flour at 25, 50, 75 and 100 per cent levels. The effect of replacement of malted wheat flour with malted white ragi flour on sensory acceptability of white ragi based complementary food is depicted in Table-14. Increase in the level of malted white ragi flour from 0 to 100 per cent increased scores pertaining to color and appearance. The colour and appearance scores for complementary food with malted wheat were 7.46 for control and 7.31, 7.32, 7.64 and 7.73 respectively, for malted white ragi incorporated complementary food at the levels of 25, 50, 75 and 100 per cent. There was significant difference between the 100 per cent white ragi flour blend in terms of colour and appearance with that of the control. With increase in the level of malted white ragi flour significantly improved the flavor attribute scores. The flavour scores were 7.17, 7.33, 7.41, 7.51 and 7.71 respectively, for 0, 25, 50, 75 and 100 per cent incorporation of malted white ragi into the complementary food. Increase in flavour scores at 75 and 100



AMINO ACID SEQUENCES

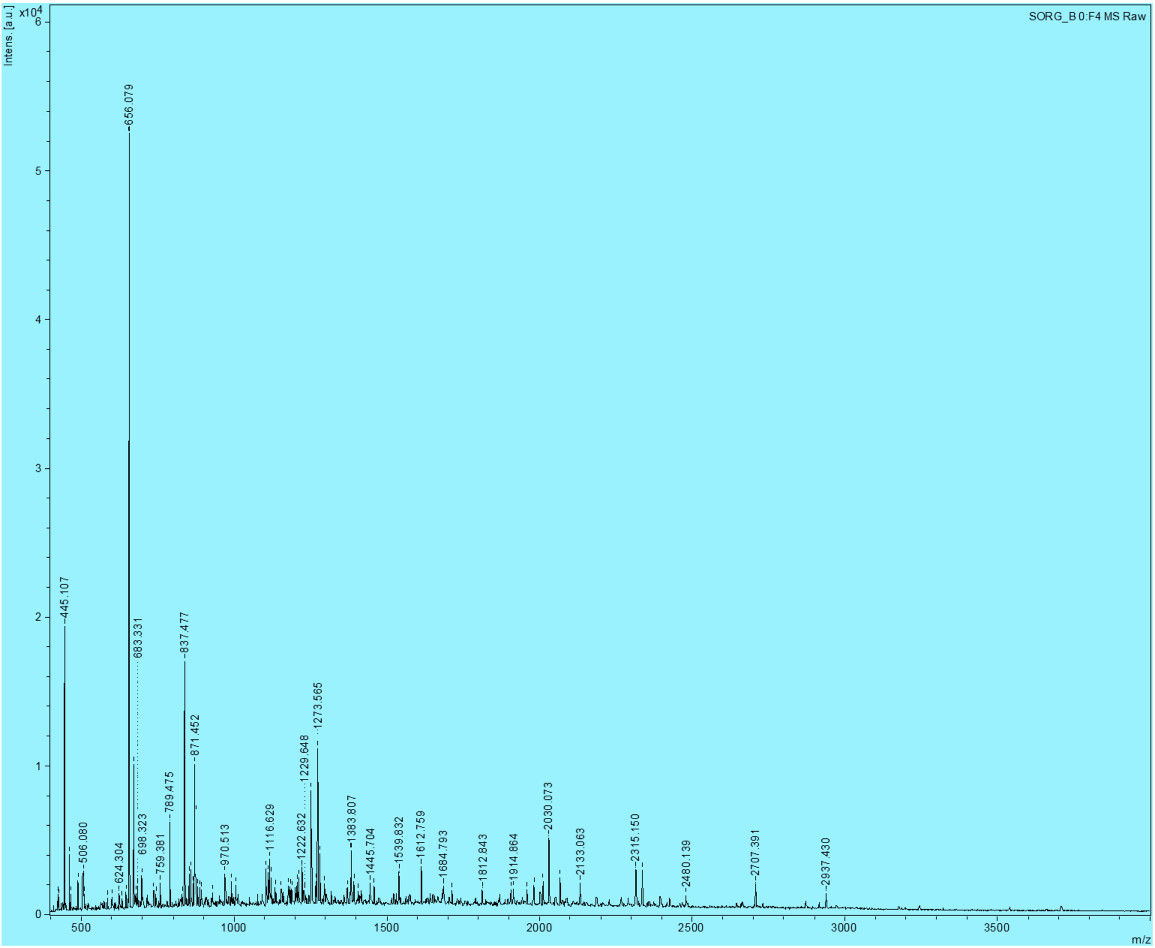
1 MVKLGNNFAE KGTKQPLLED GFDTIPLMTP LDVNQLQFPP PDKVVVKTKT
51 EYEPDRKKGK ARPPQIAEFT VSITEGVTER FKVSVLVLFA LAFLTCVVFL
101 VVYK**VYKYDR** ACPDGFVLKN TQCIPEGLES YYAEQDSSAR EKFYTVINHY

151 NLAKQSITRS VSPWMSVLSE EKLSEQETEA AEKSA

AMINO ACID CODES

G	A	L	M	F	W	K	Q	E	S
Glycine	Alanine	Leucine	Methionine	Phenylalanine	Tryptophan	Lysine	Glutamine	Glutamic Acid	Serine
P	V	I	C	Y	H	R	N	D	T
Proline	Valine	Isoleucine	Cysteine	Tyrosine	Histidine	Arginine	Asparagine	Aspartic Acid	Threonine

Fig. 11a: Amino acid profile of sorghum based complementary food containing green gram



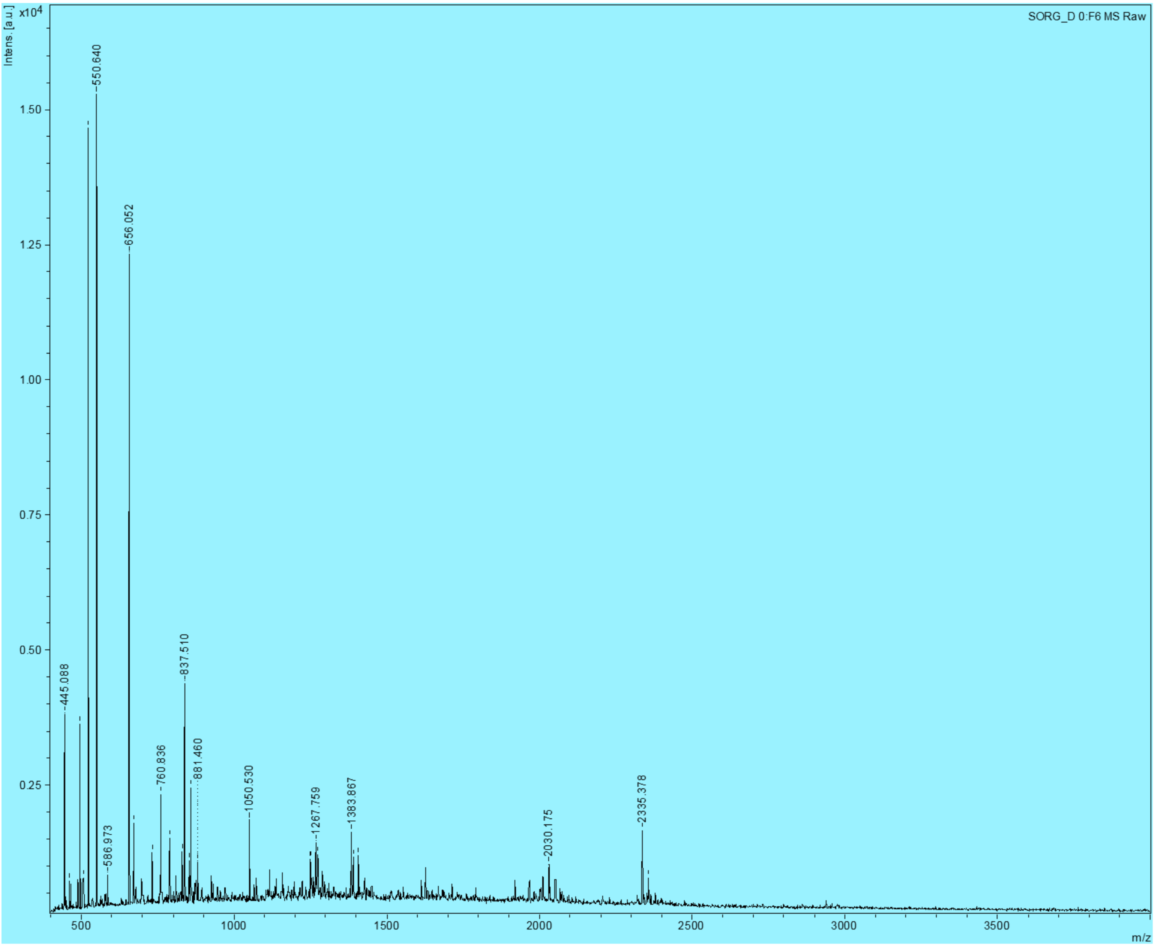
AMINO ACID SEQUENCES

1 **MINDIINDSK** **SRMEK**SLGSL K**TELAKLRTG** **RAHPSLLEHI** **K**VDYYNVETP
51 LSQVASIAIE NPR**TLSITPW** **EKNMVGPIEK** AIQKADLGLN PATVGMVIRV
101 PLPPLTEERR KELARVVR**EE** **AEHARVAIR**N IRREANNDLK ELMKEK**EISE**
151 **DEER**R**AQTAI** **QK**LTDAQIAE VDKMASQKEA DLMAV

AMINO ACID CODES

G	A	L	M	F	W	K	Q	E	S
Glycine	Alanine	Leucine	Methionine	Phenylalanine	Tryptophan	Lysine	Glutamine	Glutamic Acid	Serine
P	V	I	C	Y	H	R	N	D	T
Proline	Valine	Isoleucine	Cysteine	Tyrosine	Histidine	Arginine	Asparagine	Aspartic Acid	Threonine

Fig.11b: Amino acid profile of sorghum based complementary food containing SMP



AMINO ACID SEQUENCES

1 MLILTRRVGE TLMIGDEVTV TVLGVK**GNQV** **RIGVNAPKEV** **SVHREEIYQR**

51 IQSEK**TGSPE** **GGNY**

AMINO ACID CODES

G	A	L	M	F	W	K	Q	E	S
Glycine	Alanine	Leucine	Methionine	Phenylalanine	Tryptophan	Lysine	Glutamine	Glutamic Acid	Serine
P	V	I	C	Y	H	R	N	D	T
Proline	Valine	Isoleucine	Cysteine	Tyrosine	Histidine	Arginine	Asparagine	Aspartic Acid	Threonine

Fig. 11c: Amino acid profile of sorghum based complementary food containing WPH

Table-14: Effect of replacing malted wheat flour with malted white ragi flour on sensory attributes of white ragi based complementary food

Malted Wheat flour : Malted white ragi flour Ratio	Sensory scores on 9 point Hedonic Scale			
	Colour and Appearance	**Flavour**	**Body and Texture**	**Overall Acceptability**
100:0	7.46	7.17	7.11	7.13
75:25	7.31	7.33	7.37	7.32
50:50	7.32	7.41	7.58	7.51
25:75	7.64	7.51	7.71	7.65
0:100	7.73	7.71	7.80	**7.74**
CD	0.288	0.253	0.296	0.244

All values are average of three trials

per cent level of malted white ragi flour incorporation were statistically significant (CD=0.253). Body and texture of the complementary food were also showed increasing trend upon replacement of wheat with white ragi malted flour and the extent of rise in the scores was significant. Upon increase in the flour blend level, the body and texture showed increasing trend. The scores pertaining to body and texture attribute for control were 7.11, 7.37, 7.58, 7.71 and 7.80 respectively, with the incorporation of 0, 25, 50, 75 and 100 per cent level of malted white ragi flour into the product. The scores pertaining to overall acceptability attribute were 7.13, 7.32, 7.51, 7.65 and 7,.74 respectively for 0, 25, 50, 75 and 100 per cent replacement of the wheat flour with white ragi flour in the complementary food. The increase in the overall acceptability scores at 100 per cent level was significant (CD=0.244).

4.2.4.2 Effect of replacing malted green gram with SMP on sensory attributes of white ragi based complementary health food

The complementary food was formulated by replacing malted green gram flour blending SMP at 25, 50, 75 and 100 per cent keeping malted green gram blended complementary food as control. The effects of replacement of green gram protein with SMP on sensory characteristics were evaluated. The results are presented in Table-15. As the incorporation level of SMP in the complementary food increased, there was a consistent increase in the scores with respect all the sensory characteristics of the resultant product. The colour and appearance scores were 7.60, 7.40, 7.79, 7.90 and 8.18 respectively for 0, 25, 50, 75 and 100 per cent level of malted white ragi flour in the formulation. Colour and appearance scores significantly increased to 8.18 from the 7.60 in green gram based complementary food. The flavor scores were 7.33, 7.35, 7.64, 7.84

Table 15: Effect of replacing malted Green gram flour with SMP on sensory attributes of white ragi based complementary health food

Malted Green Gram flour : SMP Ratio	Sensory scores on 9 point Hedonic Scale			
	Colour and Appearance	**Flavour**	**Body and Texture**	**Overall Acceptability**
100:0	7.60	7.33	7.34	7.46
75:25	7.40	7.35	7.61	7.57
50:50	7.79	7.64	7.58	7.76
25:75	7.90	7.84	7.81	7.87
0:100	8.18	8.27	8.11	**8.17**
CD	0.235	0.341	0.291	0.312

All values are average of three trials

and 8.27 upon incorporating malted white ragi flour at 0, 25, 50, 75 and 100 per cent levels. The flavour score (8.27) upon 100 percent replacement with SMP was significant in comparison with the control (7.33). The body and texture scores were 7.34, 7.61, 7.58, 7.81 and 8.11 respectively at 0, 25, 50, 75 and 100 per cent incorporation of SMP. The body and texture scores significantly increased upon addition of SMP. As the SMP level in the complementary food increased, sensory scores of overall acceptability attribute were also significantly increased. The overall acceptability scores were 7.46, 7.57, 7.76, 7.87 and 8.17 for 0, 25, 50, 75 and 100 per cent level of SMP incorporation in the white ragi based complementary food containing SMP. The study revealed that by incorporating SMP replacing green gram completely could improve the acceptability of the resultant product to a greater extent and is the best way to prepare the malted white ragi based complementary food.

4.2.4.3 Effect of replacement of SMP with WPH on sensory attributes of white ragi based complementary health food

The complementary food was formulated by replacing SMP with WPH at 0, 50, 75 and 100 per cent levels. The results of the study are shown in Table-16. The colour and appearance scores awarded were 8.11, 7.95, 8.01 and 7.71 respectively for 0, 50, 75 and 100 per cent WPH in the product. Increase in the level of WPH in the blend did not affect the sensory acceptability with respect to colour and appearance. It was observed that increase in the level of substitution did not have the significant influence on the flavour of the resultant product up to 75 per cent incorporation of WPH and decreased thereafter. The flavour score for the control sample was 8.20 whereas it was 7.99, 7.98 and 7.72 respectively at 50, 75 and 100 per cent level of incorporation of WPH

Table 16: Effect of replacing SMP with WPH on the sensory attributes of white ragi based complementary health food

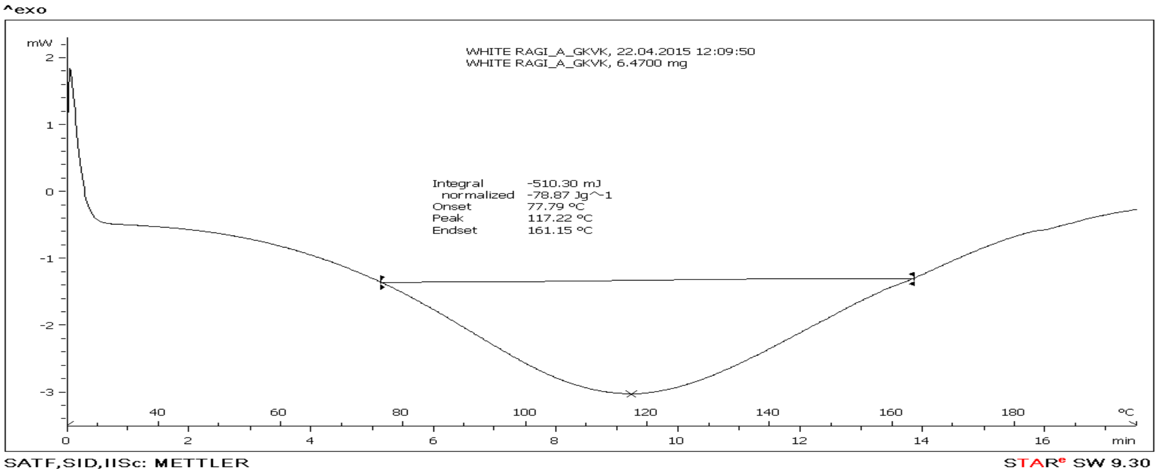
SMP: WPH Ratio	Sensory scores on 9 point Hedonic Scale			
	Colour and Appearance	**Flavour**	**Body and Texture**	**Overall Acceptability**
100:0	8.11	8.20	8.08	8.15
50:50	7.95	7.99	7.93	7.97
25:75	8.01	7.98	8.00	**7.99**
0:100	7.71	7.72	7.65	7.67
CD	0.312	0.234	0.271	0.314

All values are average of three trials

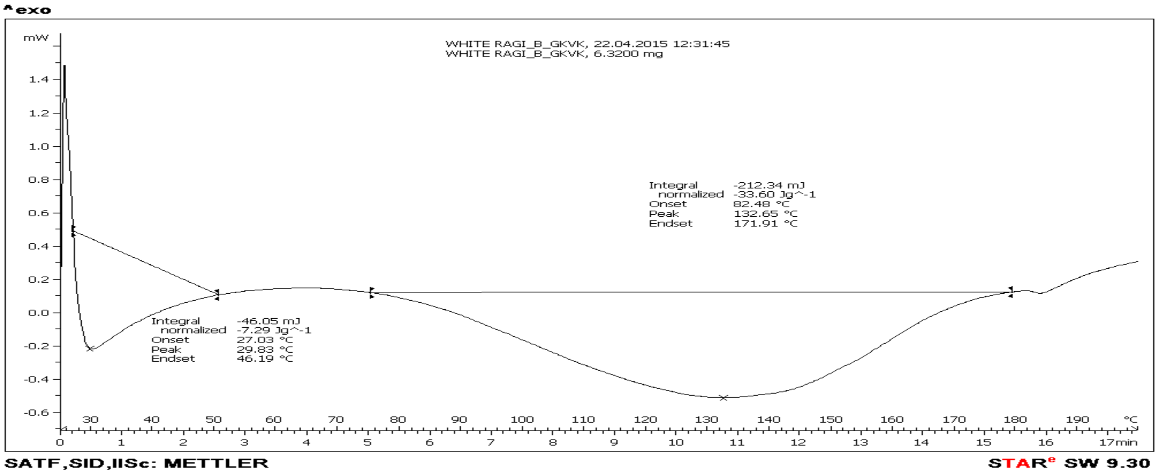
(Table-16). It was evident from the result that, body and texture did not significantly wary upon substitution of SMP with WPH up to 75 per cent level. Further incorporation significantly decreased the body and texture scores. The respective scores at 0, 50, 75 and 100 per cent level of substitution were 8.08, 7.93, 8.00 and 7.65 respectively. The scores awarded for overall acceptability attributes at 0, 50, 75 and 100 per cent level of WPH 8.15, 7.97, 7.99 and 7.67 followed similar patterns as that of other sensory attributes. Complete replacement of SMP with WPH had significantly decreasing effect on the overall acceptability attribute in comparison with control. The results revealed that WPH could be incorporated up to the level of 75 percent replacing the SMP in the formulated product to harness the benefit of higher protein content.

4.2.4.4 Gelatinization studies

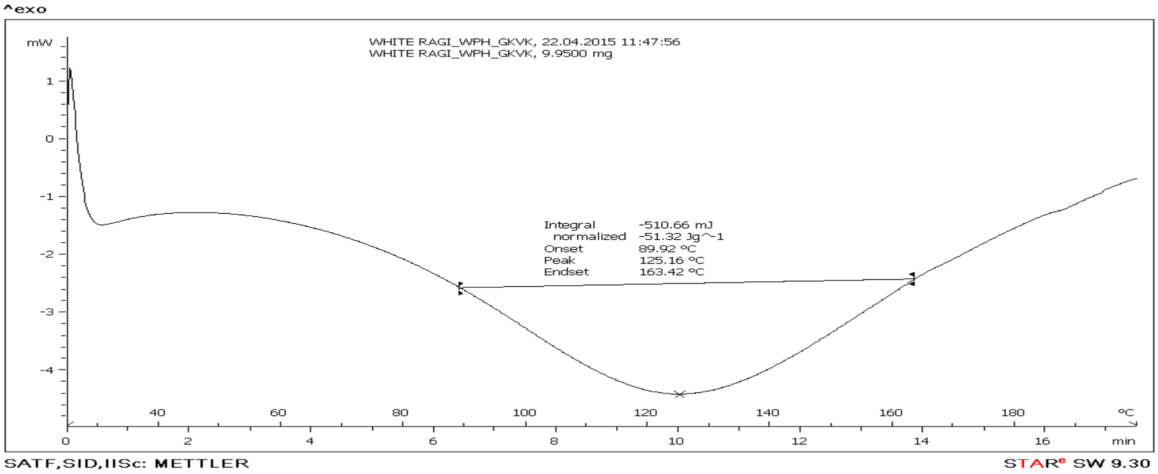
The Gelatinization of the starch influences the body and texture of the complementary food and the consistency in porridge. The results of the study are depicted in Fig. 12. The onset of gelatinization was at a temperature of 77.79°C, peaked at 117.22°C and had endset at 161.15°C as measured by DSC (Figure-8a) for malted white ragi based formulation with green gram. The onset temperature in the product with SMP was 82.48°C, peaked at 132.65°C and endset was at 171.90°C (Figure-8b). The product with WPH started gelatinizing at 89.92°C, peaked at 125.16°C and had endset at 163.42°C (Figure-8c). From the results, it was confirmed that no single time temperature combination can be fixed for cooking time to prepare porridge and the cooking conditions could be stated as bring down to boil and wait till the development of viscosity.



a) White ragi based formulation with green gram



b) White ragi based formulation with SMP



c) White ragi based formulation with WPH

Fig. 12: Identification of gelatinization temperature of white ragi based complementary health food using differential scaning colorimetry (DSC)

4.2.4.5 Rheological studies

The Rheological characteristics of formulated malted white ragi based complementary foods studied using Anton paar rheometer are depicted in the Fig. 13 and 14. The Rheological study revealed that the viscosity was 6700 mPa.s initially and decreased steadily on applying of shear rate in the SMP containing malted white ragi based complementary food. This steady decrease was mainly attributed to the nature of white ragi based formulations where in the viscosity decreased after preparation of porridge and the formulations were becoming thin after some time resulting in decreased sensory acceptability. The viscosity of the porridge of malted white ragi based complementary food containing WPH was observed to be 3000mPa.s. However, it decreased upon increase in the shear rate. This viscosity reduction was observed when the porridge slurry was prepared and kept for few minutes. This could be the reason for the slightly reduced scores for body and texture scores and also the difference (Table-16) upon increasing the level of replacement of type of protein in white ragi based food.

4.2.4.6 Physico-chemical and microbiological quality of the optimized blends of white ragi based complementary health foods

The optimized blends of white ragi based complementary health foods with green gram, SMP and WPH were analyzed for various physical, chemical and microbiological parameters. The results of the study are depicted in Table-17 and Figure.15.

It could be seen from the Figure.15a, 15b and 15c, the particle size distribution was observed to be ranging from 0.80µ to 709µ, for the product with green gram, 2.8µ to 502µ for product containing SMP and 3µ to 563µ for product with WPH. However, the

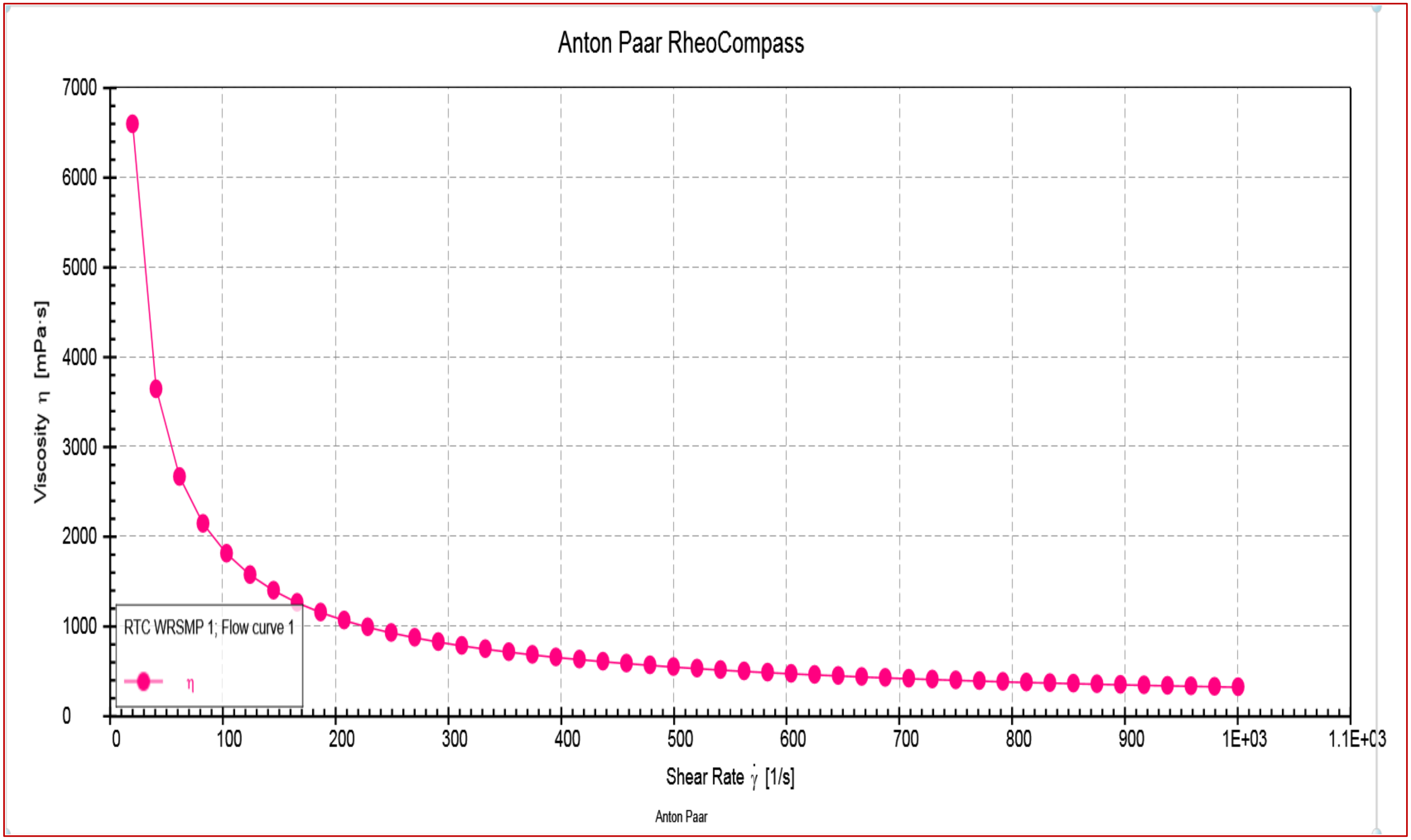


Fig. 13: Rheological characteristics of ready to cook white ragi based complementary health food with SMP

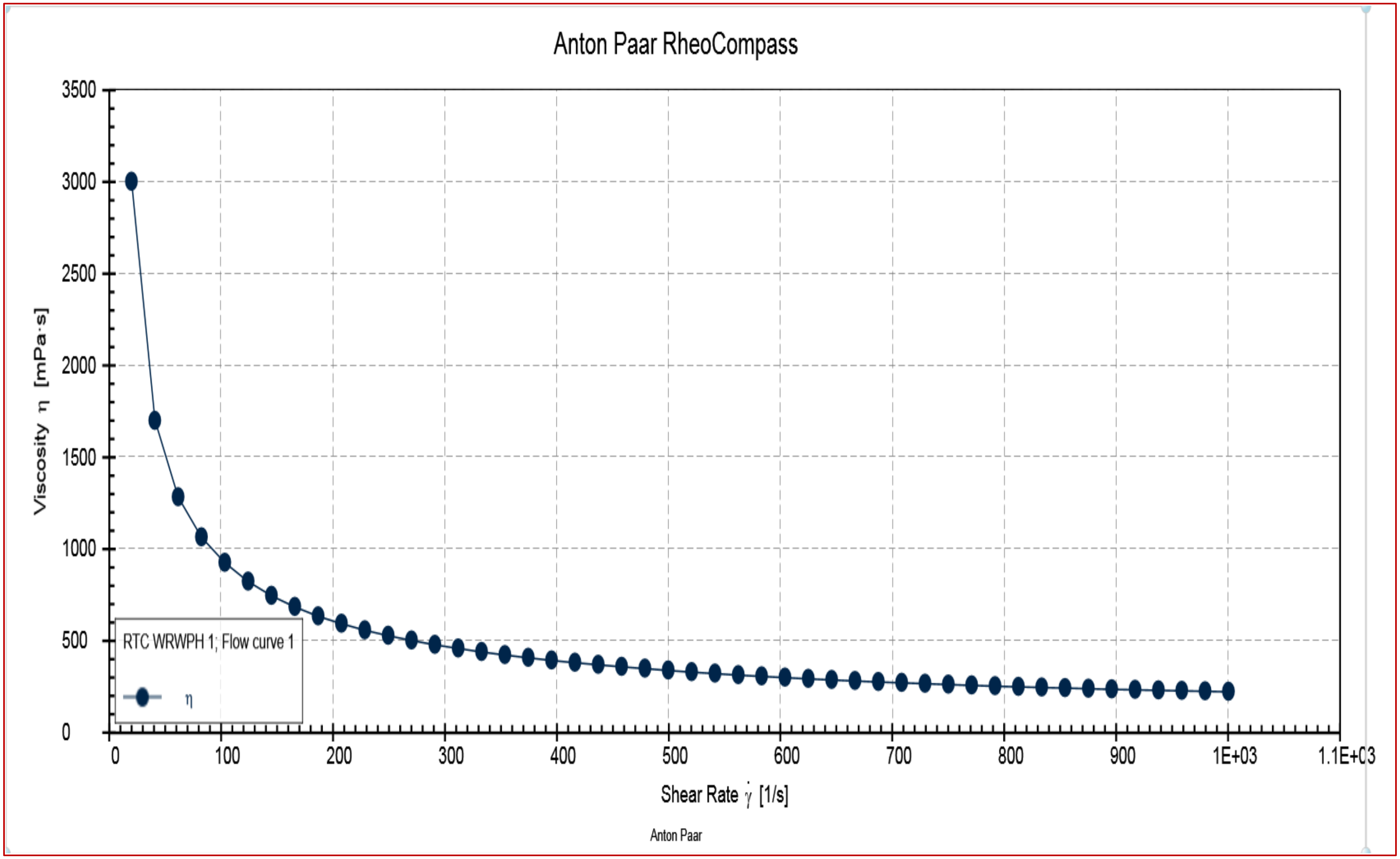
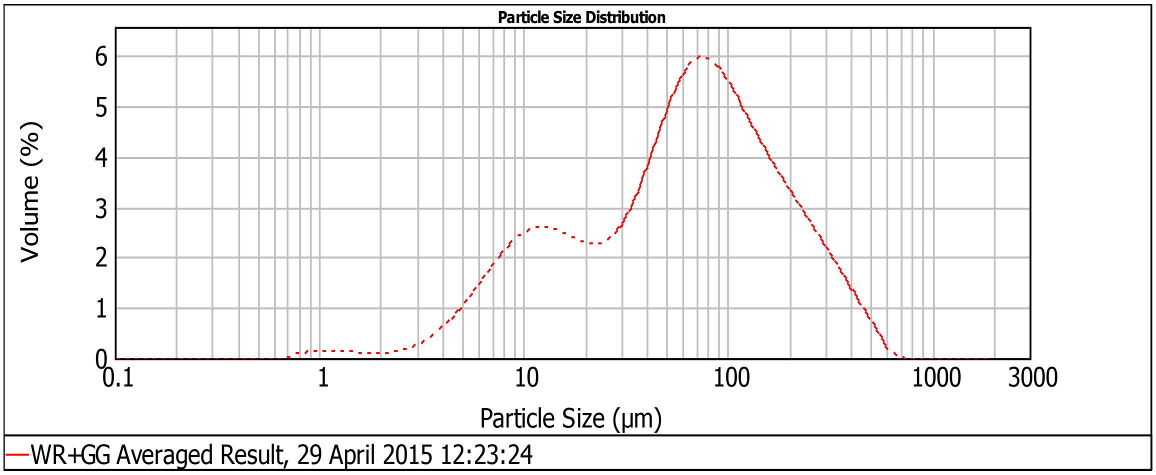


Fig. 14: Rheological characteristics of ready to cook white ragi based complementary health food with WPH

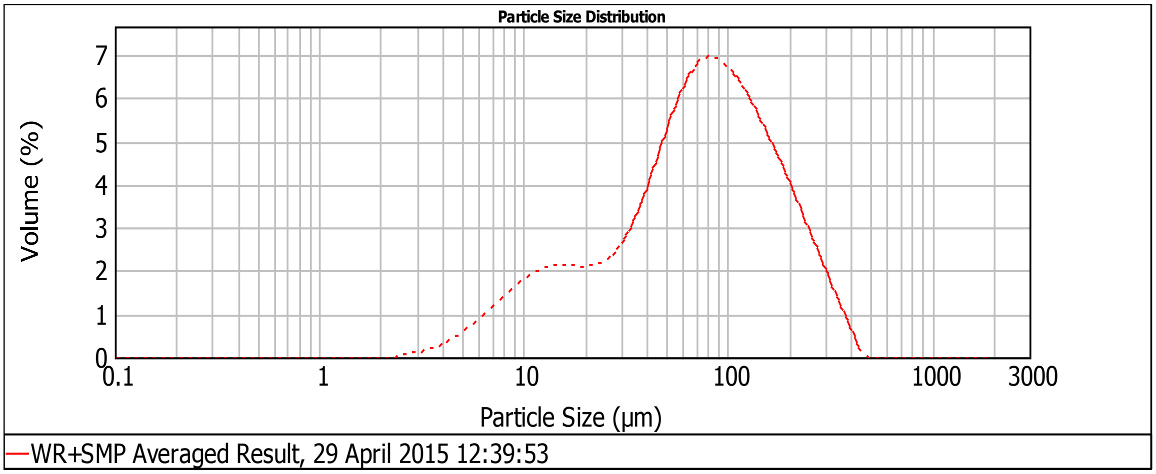
Table 17: Physical properties, chemical composition and microbiological quality of optimized formulations of white ragi based complementary health food.

White Ragi based complementary health food	Green gram	SMP	WPH
Physical attributes			
Colour	84.12* 2.19* 13.62*	84.25* 1.96* 13.46*	84.69* 2.09* 13.30*
pH	6.15	6.44	6.69
Water Activity	0.269	0.263	0.258
Chemical Composition			
Moisture (%)	6.22	6.18	6.15
Fat (%)	2.16	2.00	2.42
Protein (%)	12.23	13.61	17.34
Carbohydrates (%)	74.51	73.61	69.32
Crude fibre (%)	2.97	2.89	2.81
Ash (%)	1.91	2.21	1.96
Energy density (K.cal/100g)	366.40	364.88	368.42
Microbiological quality counts in log cfu/gm			
TBC	3.5	3.05	2.95
Coliforms	NIL	NIL	NIL
Yeast and moulds	NIL	NIL	NIL

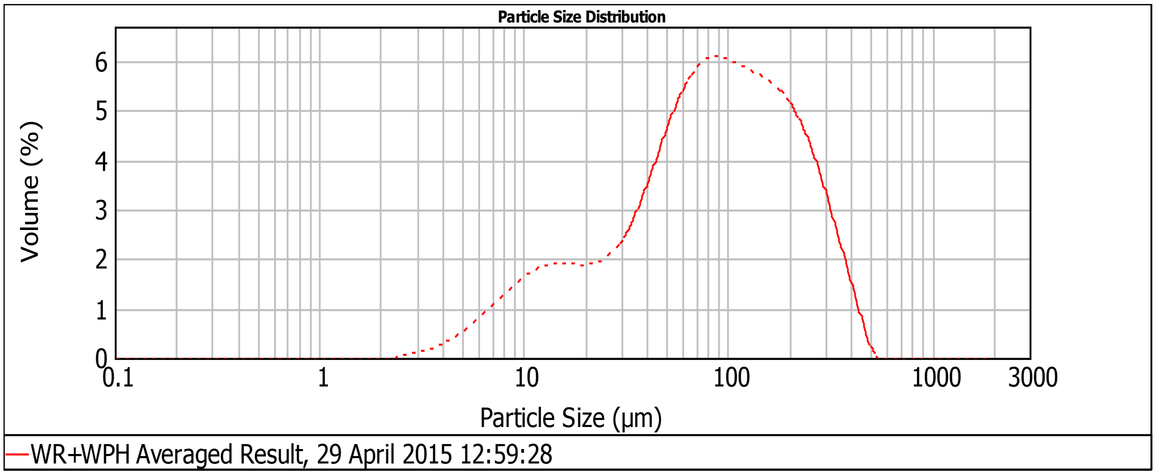
All values are average of three trials



a) White ragi based formulation with green gram



b) White ragi based formulation with SMP



c) White ragi based formulation with WPH

Fig. 15: Particle size distribution of the optimized formulations of white ragi based complementary health food

maximum per cent (74 volume %) of the particles were below 150µ in the first two types and below 200µ for the product with WPH containing white ragi based complementary health food.

The colour (L*, a* and b*) values were 84.12*, 2.19* and 13.62* for product with green gram. However, these colour values were 84.25*, 1.96* and 13.46*; 84.69*, 2.09* and 13.30* for SMP and WPH added white ragi based complementary food indicating lighter colour of the SMP and WPH containing product than the product with green gram. The respective pH of the green gram, SMP and WPH complementary foods were 6.15, 6.44 and 6.69. The water activity of the optimized complementary foods was 0.269 for green gram blended, 0.263 for the product with SMP and 0.258 for the product with WPH. The results of the chemical composition of the optimized formulations of white ragi based complementary food are depicted in Table-17. The moisture content of green gram, SMP and WPH based products were 6.22, 6.18 and 6.15 per cent respectively for the complementary food with green gram, SMP and WPH. The fat content of the optimized formulations of green gram, SMP and WPH were 2.16, 2.0 and 2.42 per cent respectively. The respective protein content of complementary food with green gram, SMP and WPH was 12.23, 13.61 and 17.34 per cent depicting increased level of incorporation of SMP and WPH has increasing effect on the protein content of complementary food. Carbohydrate content in the green gram, SMP and WPH added complementary foods were observed to be 74.51, 73.11 and 69.32 per cent, respectively. The crude fibre content of green gram, SMP and WPH containing complementary food was 2.97, 2.89 and 2.81 per cent respectively. The ash content of green gram, SMP and

WPH containing complementary food was found to be 1.91, 2.21 and 1.96 respectively. The energy density of white ragi based complementary health food was 366.40, 364.88 and 368.42 respectively, for green gram, SMP and WPH containing complementary food.

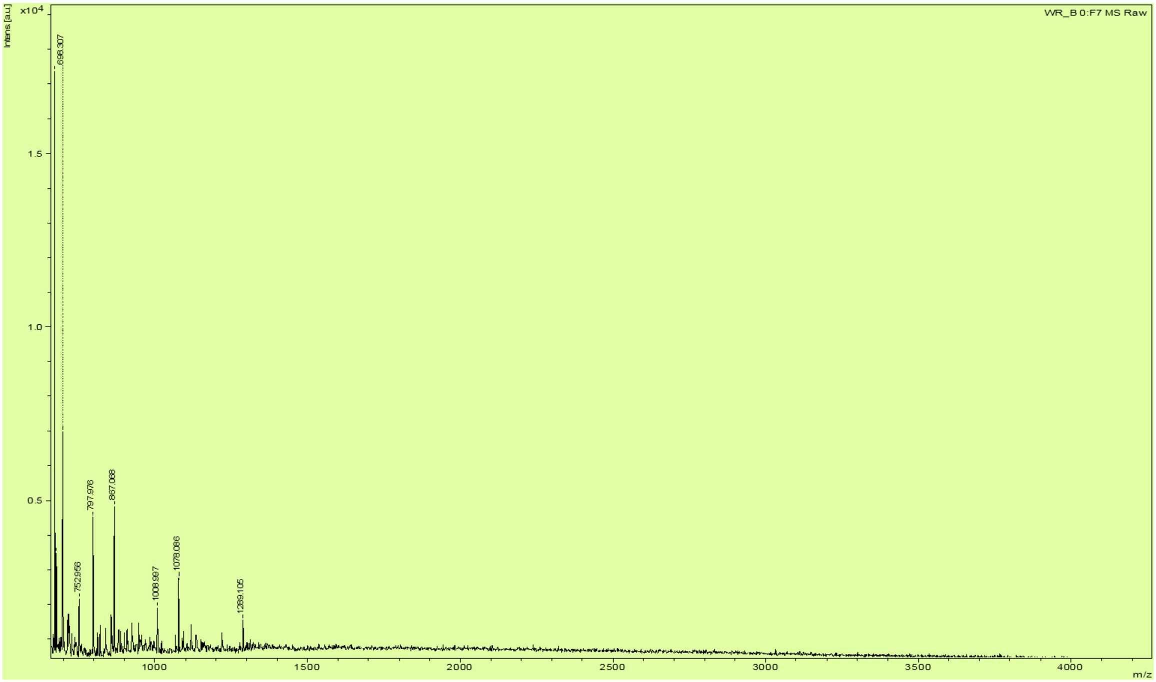
Microbial analysis results revealed that TBC of green gram, SMP and WPH containing complementary foods was 3.5log cfu/gm, 3.05 log cfu/gm and 2.95 log cfu/gm, respectively. Coliforms and yeast and moulds were absent in all the three samples of white ragi based complementary health foods.

4.2.3.7 Amino acid profile of white based complementary health food

The amino acid profile in the form of amino acid sequences obtained in MALDY-MS is shown in Figure 16a, 16b and 16c. The complementary food containing green gram has very few amino acids in the formulated product. The same was true with the SMP containing complementary food but more essential amino acids. However, the product with WPH had almost all the essential amino acids in the product.

4.2.5 Comparison of sensory and rheological characteristics of the best adjudged millet based complementary health foods

The best adjudged complementary food prepared from foxtail millet, little millet, sorghum and white ragi were subjected to the sensory acceptability keeping wheat based complementary food product as control. The effect of type of the complementary food on sensory characteristics was evaluated. The results are presented in Table-18 and Figure-17. From among the millets based complementary food formulated, malted white ragi based complementary food was adjudged as best followed by the complementary food



AMINO ACID SEQUENCES

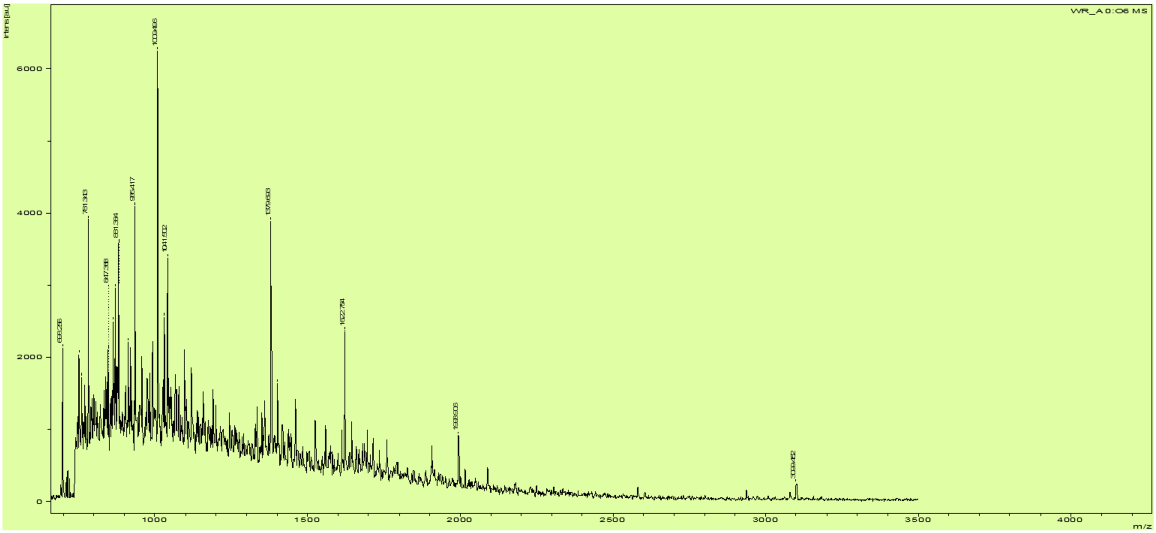
1 MEMKKIACGV LFAAASMTAV MAAEEVGAPA PGPASAASAA LPALGSLVGA

51 SLVSLFSYYL H

AMINO ACID CODES

G	A	L	M	F	W	K	Q	E	S
Glycine	Alanine	Leucine	Methionine	Phenylalanine	Tryptophan	Lysine	Glutamine	Glutamic Acid	Serine
P	V	I	C	Y	H	R	N	D	T
Proline	Valine	Isoleucine	Cysteine	Tyrosine	Histidine	Arginine	Asparagine	Aspartic Acid	Threonine

Fig. 16a: Amino acid profile of white ragi based complementary food containing green gram



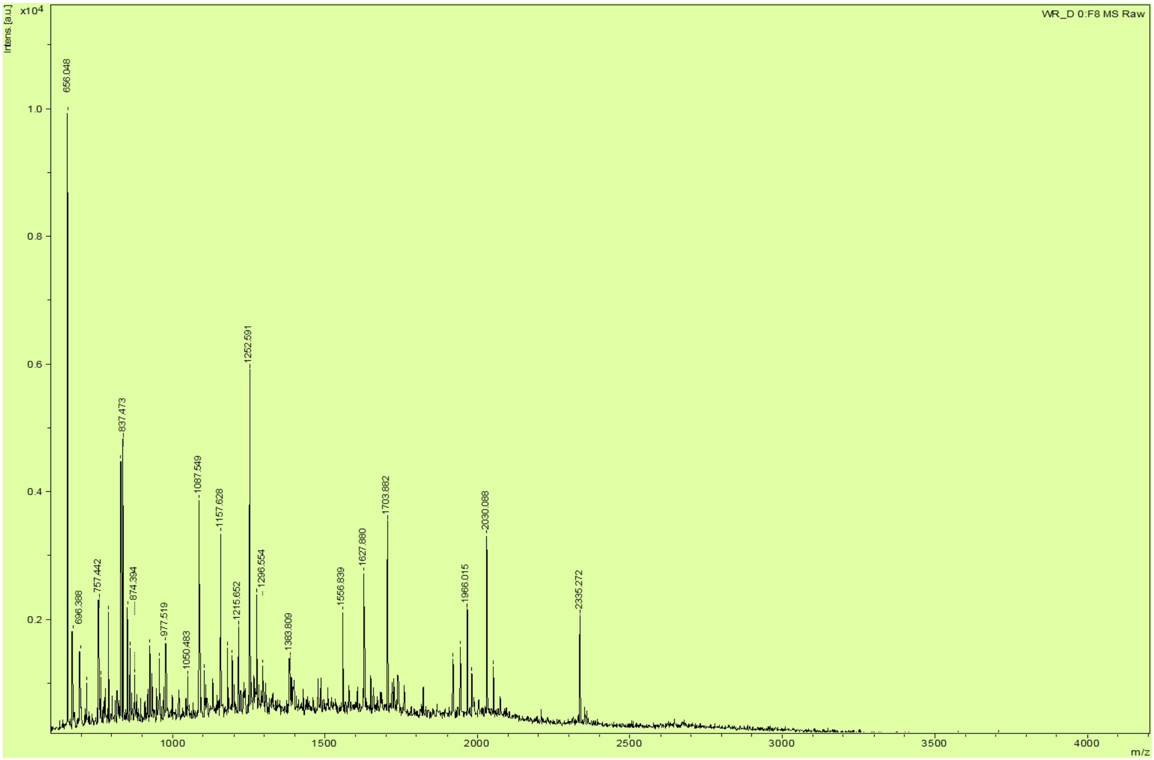
AMINO ACID SEQUENCES

1	MTVVRLPDGT	DKVFDYPVTV	LDVAESIGPG	LARVALAGKL	NGRLVDLSEP
51	IEIDSDLVLI	TNK**DPEGLEI**	**IR**HSCAHLLA	HAVKELFPSA	QVTIGPVIED
101	GFYYDFSYER	PFTPEDLAAI	EKR**MQEISRR**	NLKIERKVWD	RSKAIGFFKD
151	LGEHYKAQII	ASIPNDEPVS	LYSQGDFTDL	CRGPHVPYTS	RIK**VFKLMK**I
201	AGAYWRGDSK	NEMLQRIYGT	AWVSSEEQNN	YLRRLEEAEK	RDHRKLGKQL
251	DLFHMQEEAP	GMVYWHPKGW	AIWQQIEQYM	RQVLAKNGYV	EIRTPQVLDI
301	SLWEKSGHWE	NFRENMFITE	SESRHYAIKP	MNCPGHVQVF	NHGLRSYRDL
351	PLRLAEFGSC	HRNEASGALH	GLMRVRSFTQ	DDAHIFCTED	QVLEEVTKFI
401	DLLNQVYIDF	GFHENLIKLS	TRPAQRVGTE	EQWDRAEAAL	AAALNQKELN
451	WELQPGEGAF	YGPKIEFTLK	DSLGRKWQCG	TLQLDFSMPA	R**LGAGYIAED**
501	**NTKKIPVMLH**	**R**AILGSMERF	IGILIEHHAG	ALPVWLSPDQ	VVVLNISR**NQ**
551	**ADYVQSITNE**	**LK**QNDIRVSS	DLR**NEKISYK**	IREHSLQKVP	YLIVVGDKEV
601	ENQTVTVRGR	SNHDHGAMSL	EGFVTLIRKE	MAERV	

AMINO ACID CODES

G	A	L	M	F	W	K	Q	E	S
Glycine	Alanine	Leucine	Methionine	Phenylalanine	Tryptophan	Lysine	Glutamine	Glutamic Acid	Serine
P	V	I	C	Y	H	R	N	D	T
Proline	Valine	Isoleucine	Cysteine	Tyrosine	Histidine	Arginine	Asparagine	Aspartic Acid	Threonine

Fig. 16b: Amino acid profile of white ragi based complementary food containing SMP



AMINO ACID SEQUENCES

1	MAHVGDCTQT	PWLPVLVVSL	MCSARAEYSN	CGENEYYNQT	TGLCQECPPC
51	GPGEEPYLSC	GYGTKDEDYG	CVPCPAEK**FS**	**KGGYQICR**R**H**	**KDCEGFFR**AT
101	VLTPGDMEND	AECGPCLPGY	YMLENRPRNI	YGMVCYSCLL	APPNTKECVG
151	ATSGASANFP	GTSGSSTLSP	FQHAHKELSG	QGHLATALII	AMSTIFIMAI
201	AIVLIIMFYI	LKTKPSAPAC	CTSHPGKSVE	AQVSK**DEEK**K	**EAPDNVVMFS**
251	**EKDEFEK**LTA	TPAKPTKSEN	DASSENEQLL	SRSVDSDEEP	APDKQGSPEL
301	CLLSLVHLAR	EKSATSNK**SA**	**GIQSRR**KKIL	DVYANVCGVV	EGLSPTELPF
351	DCLEKTSR**ML**	**SSTYNSEKAV**	**VKTWRHLAES**	**FGLKR**DEIGG	MTDGMQLFDR
401	ISTAGYSIPE	LLTK**LVQIER**	LDAVESLCAD	ILEWAGVVPP	ASQPHAAS

AMINO ACID CODES

G	A	L	M	F	W	K	Q	E	S
Glycine	Alanine	Leucine	Methionine	Phenylalanine	Tryptophan	Lysine	Glutamine	Glutamic Acid	Serine
P	V	I	C	Y	H	R	N	D	T
Proline	Valine	Isoleucine	Cysteine	Tyrosine	Histidine	Arginine	Asparagine	Aspartic Acid	Threonine

Fig. 16c: Amino acid profile of white ragi based complementary food containing WPH

Table 18: Sensory acceptability of the best adjudged millet based complementary health food

Type of Cereal/Millet	Sensory scores on the 9 point Hedonic Scale			
	Colour and Appearance	Flavour	Body and Texture	Overall Acceptability
Wheat	7.89	8.04	8.06	8.03
Foxtail Millet	7.59	7.97	7.43	7.93
Little Millet	8.13	7.94	7.88	8.02
Sorghum	8.07	7.89	7.96	7.97
White Ragi	8.18	8.27	8.11	8.17
CD	0.204	0.213	0.284	0.252

All values are average of three trials

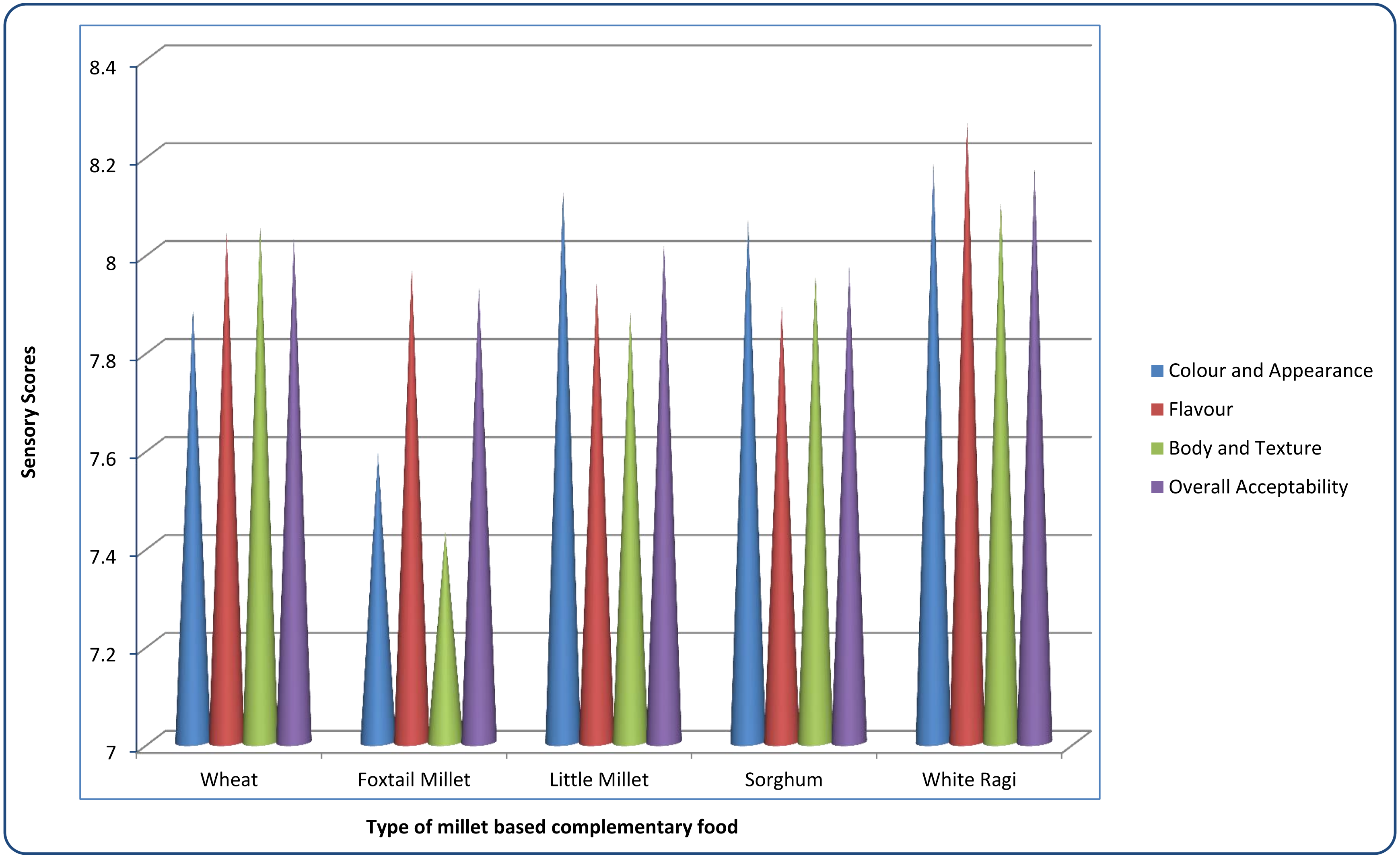
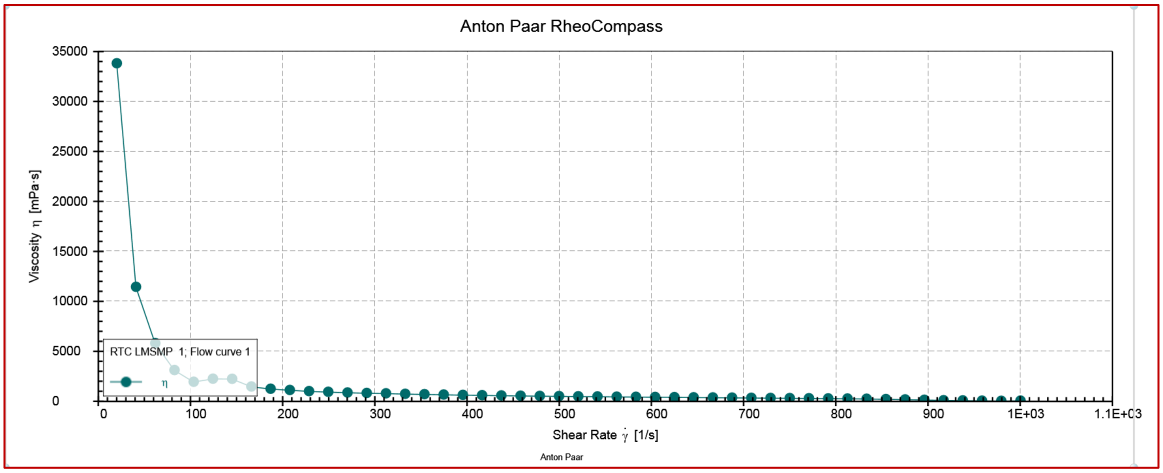


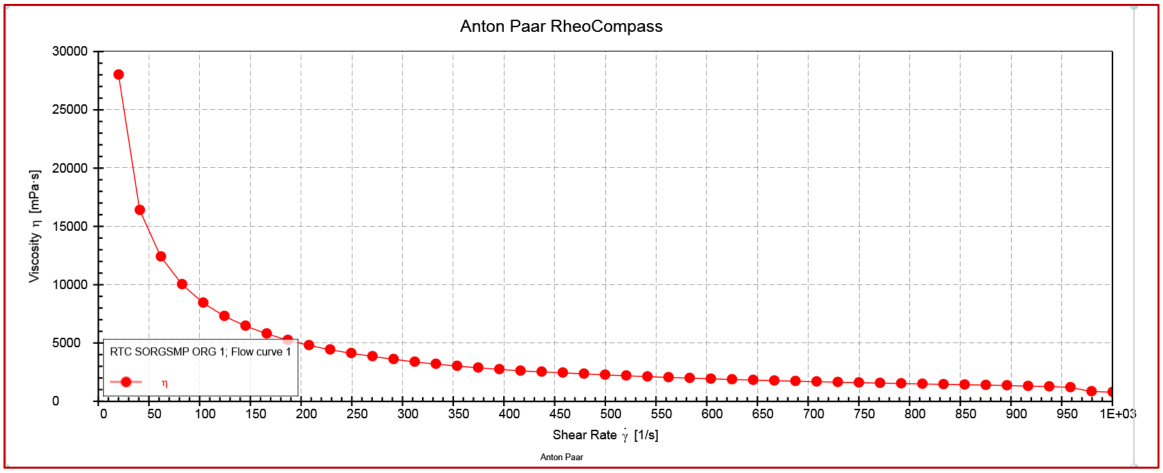
Fig. 17: Sensory characteristics of best adjudged malted white ragi based complementary health food

with wheat, little millet, sorghum and foxtail millet. The colour and appearance scores were 7.89, 7.59, 8.13, 8.07, 8.18 for the formulation containing malted wheat, malted foxtail millet, malted little millet, malted sorghum and malted white ragi respectively. Colour and appearance scores significantly increased for malted white ragi in comparison with control and the colour and appearance scores were decreased significantly for complementary food containing malted foxtail millet. The flavor scores were 8.04, 7.97, 7,94, 7.89 and 8.27 respectively, for the complementary food product containing malted wheat, malted foxtail millet, malted little millet, malted sorghum and malted white ragi. The increase in the flavor scores for white ragi was highest and was significantly higher compared to all the other formulations including wheat. The body and texture scores were 8.06, 7.43, 7.88, 7.96 and 8.11 respectively, for the formulation with malted wheat, malted foxtail millet, malted little millet, malted sorghum and malted white ragi. The body and texture scores were highest for white ragi and were at par with that of the malted wheat formulation. Sensory scores awarded for overall acceptability attribute were 8.03, 7.93, 8.02, 7.97 and 8.17 for the complementary food product containing malted wheat, malted foxtail millet, malted little millet, malted sorghum and malted white ragi. The study revealed that using malted white ragi was the best way to prepare the malt based complementary food even though the complementary foods with malted foxtail millet, malted little millet and malted sorghum could also be prepared.

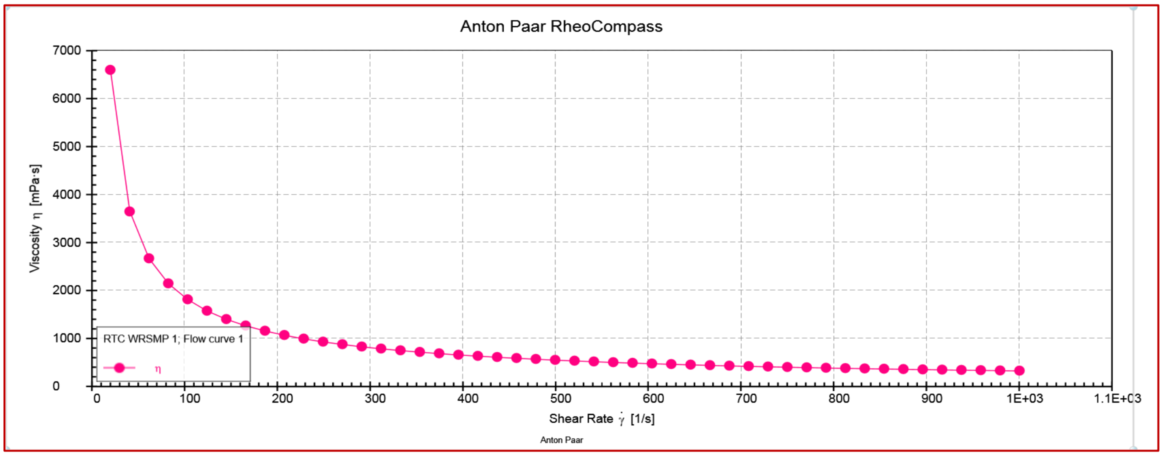
The Rheological characteristics using Anton paar rheometer are depicted in the Figure-18. The viscosity of the porridge of little millet based, sorghum based and white ragi were 33.821, 28000, 6700 mPa.s respectively. However, it decreased upon increase in the shear rate in all the three cases. The viscosity reduction when the porridge slurry



a) Little millet based complementary health food



b) Sorghum based complementary health food



c) White ragi based complementary health food

Fig. 18: Comparison of Rheological properties of ready to cook complementary health foods

was prepared and after keeping it for few minutes. This resulted in body and texture scores difference upon increasing the level of replacement of type of protein in white ragi based food.

4.2.6 Optimization of sugar level in honey blended white ragi based complementary health food

The results in respect of optimizing the level of sugar level in the honey blended white ragi based complementary health food are presented in Table-19. At a fixed level of honey of 5 per cent, as the sugar level decreased the scores did not affect the sensory scores significantly up to the level of sugar at 16.5. The scores awarded for colour and appearance were 8.12, 8.15, 8.14, 8.16 and 8.09 respectively, at sugar level of 18.5, 17.5, 16.5, 15.5 and 14.5 per cent. From among the different levels of sugar, the flavor scores awarded were 8.22, 8.26, 8.21, 7.91, 7.74 respectively, 18.5, 17.5, 16.5, 15.5 and 14.5 per cent sugar in the product. The respective body and texture scores awarded for 18.5, 17.5, 16.5, 15.5 and 14.5 per cent sugar containing products was 8.10, 8.07, 8.05, 7.83, 7.65. The overall acceptability scores awarded for the product were 8.15, 8.13, 8.20, 7.89 and 7.70 respectively, for 18.5, 17.5, 16.5, 15.5 and 14.5 per cent sugar containing complementary food. The sensory evaluation study revealed that the sugar level to be added to the honey blended malted white ragi based complementary health food was 16.5 per cent that adjudged as best and was comparable to the control.

Table 19: Optimization of sugar level in honey blended white ragi based complementary health food

Sugar : Honey (%)	**Sensory scores on the 9 point Hedonic Scale**			
	Colour and Appearance	**Flavour**	**Body and Texture**	**Overall Acceptability**
18.5 : 0	8.12	8.22	8.10	8.15
17.5 : 5	8.15	8.26	8.07	8.13
16.5 : 5	8.14	8.21	8.05	**8.20**
15.5: 5	8.16	7.91	7.83	7.89
14.5: 5	8.09	7.74	7.65	7.70
CD	0.152	0.354	0.327	0.267

All values are average of three trials

4.2.7 Malted white ragi based honey blended probiotic complementary health food

4.2.7.1 Sensory and rheological characteristics of honey blended white ragi based probiotic complementary health food

The RTC blend of best adjudged honey blended malted white ragi based complementary health food was added with the probiotic organisms. Honey was added to the porridge and probiotic organisms were dry blended into the complementary food porridge after preparation, cooking and cooling. The prepared products were subjected to sensory evaluation. The sensory acceptability of the products is depicted in Table-20. The colour and appearance scores awarded for malted white ragi complementary food with sugar, honey blended complementary food, probiotic complementary food with *B.bifidum* and probiotic complementary food with *L.acidophilus* were 8.12, 8.15, 8.14 and 8.16 respectively, depicting no difference between the different formulations of complementary foods. The respective flavor scores were 8.22, 8.26, 8.21 and 8.24 for malted white ragi complementary food with sugar, honey blended complementary food, probiotic complementary food with *B.bifidum* and probiotic complementary food with *L.acidophilus*. The body and texture and overall acceptability scores were 8.10 and 8.15; 8.07 and 8.20; 8.11 and 8.17; 8.18 and 8.14 for malted white ragi complementary food with sugar, honey blended complementary food, probiotic complementary food with *B.bifidum* and probiotic complementary food with *L.acidophilus*. From the above results, it was inferred that sensory scores in respect of all the characteristics for all the tried complementary foods were almost similar and the scores did not differ much even after blending of the probiotic organisms. All the blends were highly acceptable.

Table 20: Sensory characteristics of honey blended white ragi based probiotic complementary health food

Type of complementary health food	**Sensory scores on the 9 point Hedonic Scale**			
	Colour and Appearance	**Flavour**	**Body and Texture**	**Overall Acceptability**
Malted White ragi with SMP and Sugar	8.12	8.22	8.10	8.15
Malted White ragi with SMP and Honey	8.15	8.26	8.07	8.20
Malted White ragi with SMP, Honey and *Bifidobacterium bifidum*	8.14	8.21	8.11	8.17
Malted White ragi with SMP, Honey and *Lactobacillus acidophilus*	8.16	8.24	8.18	8.14
CD	0.152	0.124	0.185	0.164

All values are average of three trials

The Rheological characteristics of the RTC white ragi based honey blended probiotic complementary food with SMP and WPH were analyzed using Anton paar rheometer and the results are depicted in the Figure 19 and 20. The viscosity of the porridge of white ragi based product with SMP was 3000mPa.s. The viscosity of the porridge of white ragi based product with WPH was 2100 mPa.s. In both the cases the viscosity decreased upon increase in the shear rate over a period of time. This decrease in the viscosity has the relation to the viscosity reduction of the porridge slurry after keeping it for few minutes. However, the extent of decrease in the viscosity was relatively higher in the WPH containing malted white ragi based honey blended probiotic complementary health food. This resulted in body and texture scores difference especially whenever the product was not consumed completely.

4.2.7.2 Physico-chemical and microbiological quality of white ragi based honey blended probiotic complementary health foods

The honey blended white ragi based complementary health foods were analyzed for various physical, chemical and microbiological parameters. The results of the study are depicted in Table-21 and Figure.21. It could be seen from the Fig.21a and 21b, the particle size distribution was observed to be ranging from 0.8µ to 709µ and 0.8µ to 796µ for white ragi based probiotic complementary food with *B.bifidum* and probiotic complementary food with *L.acidophilus* respectively. However, the maximum per cent (74 volume %) of the particles were below 100µ in both the types of malted white ragi based honey blended probiotic complementary health food. The colour (L* a* b*) values were 84.76*, 2.08* and 13.28*; 83.46*, 2.26* and 13.99*; 83.54*, 2.28* and 13.97* for white ragi based complementary food with honey, complementary food with probiotic

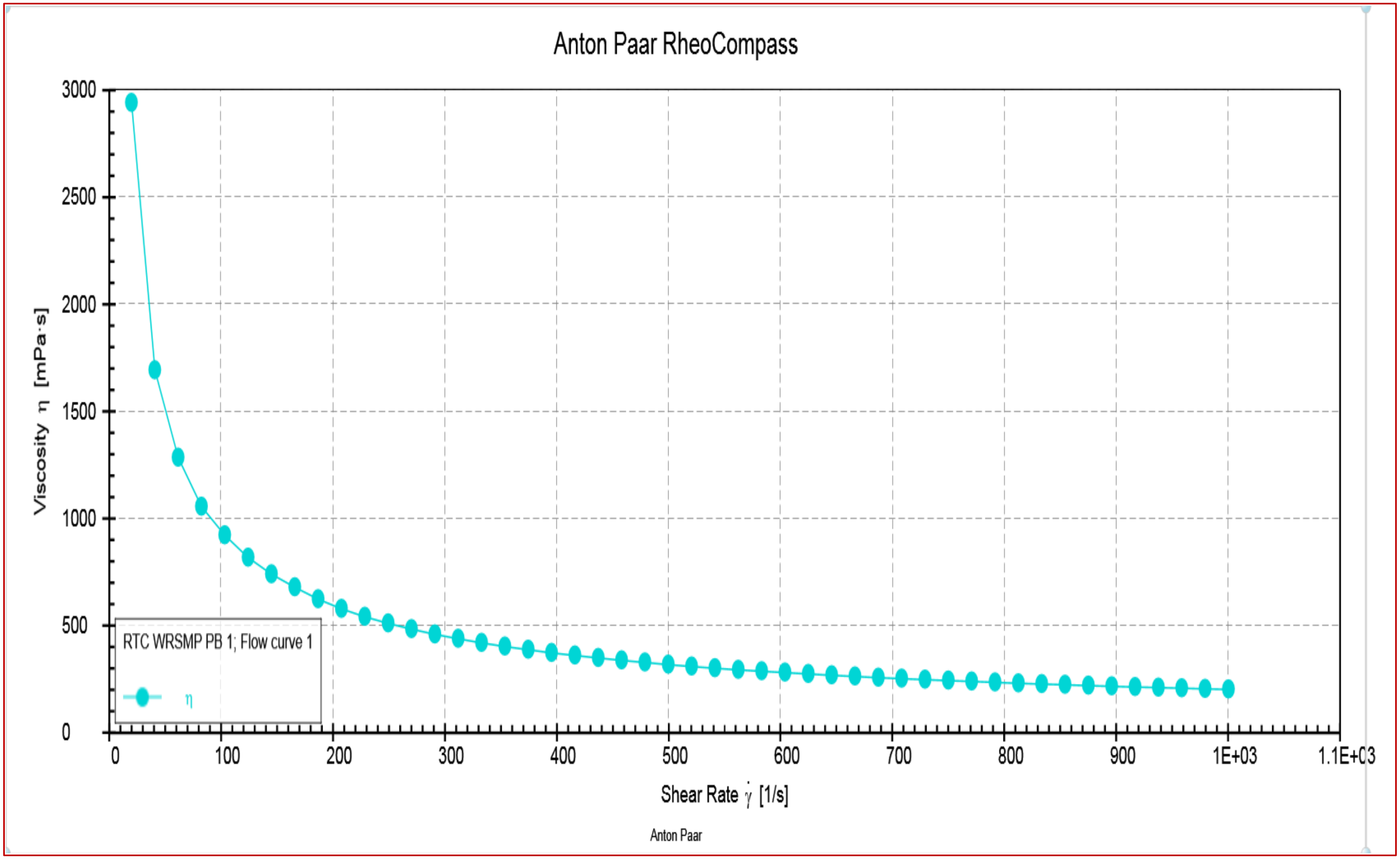


Fig. 19: Rheological characteristics of ready to cook white ragi based probiotic complementary health food

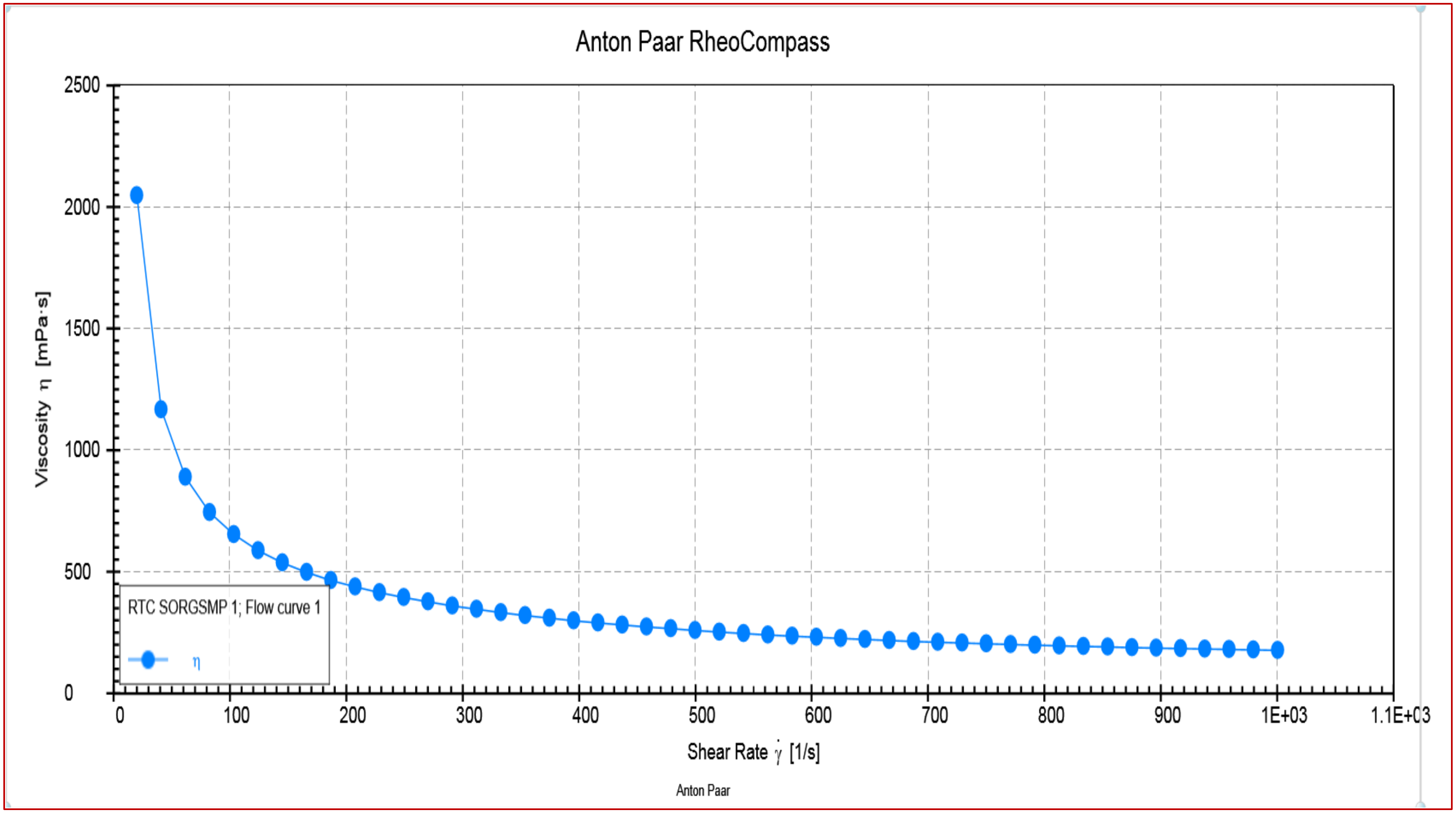
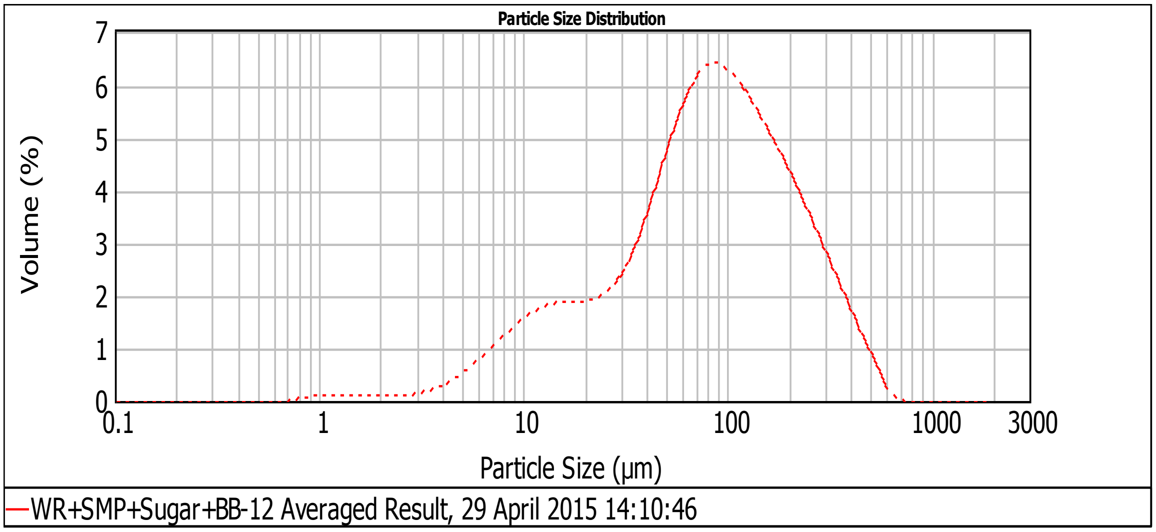


Fig. 20: **Rheological characteristics of ready to cook white ragi based complementary health food with honey and probiotic bacteria**

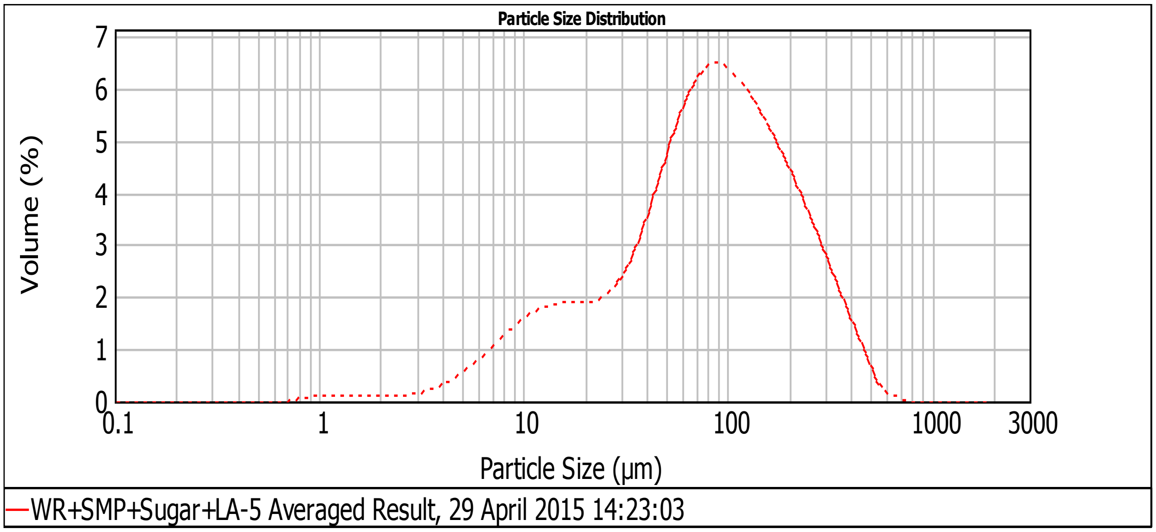
Table 21: Physico-chemical properties and microbiological quality of white ragi based honey blended probiotic complementary health food

Attribute	White Ragi+SMP+Honey	White Ragi+SMP+Honey BB-12	White Ragi+SMP+Honey LA-5
Physical attributes			
Colour	84.76* 2.08* 13.28*	83.46* 2.26* 13.99*	83.54* 2.28* 13.97*
pH	6.40	6.35	6.38
Water Activity	0.325	0.326	0.322
Chemical Composition			
Moisture (%)	6.79	6.96	7.44
Fat (%)	2.02	2.01	2.04
Protein (%)	11.73	12.93	16.52
Carbohydrates (%)	74.69	73.28	69.18
Crude fibre (%)	2.81	2.83	2.84
Ash (%)	1.96	1.99	1.98
Energy density (K.cal/100g)	363.86	362.93	361.16
Microbiological quality counts in log cfu/gm			
Probiotic count	-	9.37	9.69
Coliforms	NIL	NIL	NIL
Yeast and moulds	NIL	NIL	NIL

All values are average of three trials



a) White ragi based formulation with honey and *Bifidobacterium bifidum*



b) White ragi based formulation with honey and *Lactobacillus acidophilus*

Fig. 21: Particle size distribution of the optimized formulations of white ragi based honey blended probiotic complementary health food

bacteria (BB-12) and complementary food with LA-5 respectively, indicating lighter colour. The respective pH complementary foods were 6.40, 6.35 and 6.38 for white ragi based complementary food with honey, complementary food with probiotic bacteria (BB-12) and complementary food with LA-5. The water activity of the optimized honey blended malted white ragi based complementary foods was 0.325, 0.326 and 0.322 for the malted white ragi based honey blended product, malted white ragi based honey blended probiotic complementary food with *B.bifidum* and probiotic complementary food with *L.acidophilus*, respectively.

The results of the chemical composition of the optimized formulations of white ragi based complementary food are depicted in Table-21. The moisture content of the malted white ragi based honey blended product, malted white ragi based honey blended probiotic complementary food with *B.bifidum* and probiotic complementary food with *L.acidophilus* were 6.79, 6.96, and 7.44 per cent, respectively.. This increase in moisture attributed to the blending of the honey. The fat content of the optimized formulations of were 2.02, 2.01 and 2.04 per cent; protein content of complementary food was 11.73, 12.93 and 16.52 per cent; Carbohydrate content of malted white ragi based honey blended product, malted white ragi based honey blended probiotic complementary food with *B.bifidum* and probiotic complementary food with *L.acidophilus* 74.69, 73.28 and 69.18 per cent, respectively. In the above three products, the crude fibre content was 2.81, 2.83 and 2.84 percent respectively. The energy density of malted white ragi based honey blended product, malted white ragi based honey blended probiotic complementary food with *B.bifidum* and probiotic complementary food with *L.acidophilus* were 363.86, 362.93 and 361.16 respectively. The probiotic counts were 9.37 log cfu/g for BB-12 and

9.69 for LA-5. Coliforms and yeast and moulds were absent in all the three samples of white ragi based probiotic complementary health foods. The study revealed that the probiotic organisms by dry blending could be successfully incorporated into the porridge after cooking and cooling of the porridge along with the honey and could contain sufficient number of the probiotic organisms in the prepared porridge to provide the health benefits of the probiotic health foods.

4.3 Processing of complementary health food to produce ready to use (RTU) product

Formulated complementary food prepared by the admixture of best adjudged malted millets and SMP were adjusted to various levels of Total Solids (TS) and heated to various temperatures in order to select a best combination of TS and cooking temperature. The effect of TS content and cooking temperature on the sensory attributes of complementary food is presented in Table-22.

4.3.1 Optimization of total solids in porridge and temperature of cooking on the acceptability of millet based complementary foods.

As could be seen from the result presented in Table-22, overall acceptability scores of the resultant prepared porridge were 7.89, 7.94, 7.72 and 8.06 respectively, for the porridge water ratio of 1:5. However, further increase in the total solids in the porridge to 25, 30 and 35 percent respectively, significantly reduced the acceptability of the prepared porridge to 7.63, 7.34 and 6.83 for malted foxtail millet based product; 7.71, 7.43 and 6.92 for malted little millet based product; 7.72, 7.54 and 7.12 for malted sorghum based product; 7.76, 7.54, and 7.01 for malted white ragi based product. The

Table 22: Optimization of total solids and cooking temperature for spray drying of millet based complementary food

Parameter	**Sensory Scores**			
Total solids in porridge (%) / Proportion of Complementary Food: Water	**Type of millet malted complementary food**			
	Foxtail millet	**Little millet**	**Sorghum**	**White ragi**
	Overall acceptability			
1 : 5	7.89	7.94	7.72	8.06
25	7.63	7.71	7.54	7.76
30	7.34	7.43	7.12	7.54
35	6.83	6.92	6.68	7.01
CD	**0.162**	**0.189**	**0.221**	**0.18**
Cooking Temperature (^{o}C) for 5min	**Overall Acceptability**			
75	7.86	7.96	7.69	7.98
80	7.83	7.93	7.62	8.05
85	7.81	7.89	7.59	8.03
CD	**0.126**	**0.152**	**0.122**	**0.10**

All values are average of three trials

results revealed that the TS content of 25 per cent and above led to have decreased the acceptability and acceptability was highest at 1:5 proportions for all type of millets. The cooking temperature of 75, 80 and 85°C for 5min did not affect the acceptability of the prepared porridge much and the scores awarded were 7.86, 7.83 and 7.8 for malted foxtail millet based product; 7.96, 7.93 and 6.89 for malted little millet based product; 7.69, 7.62 and 7.59 for malted sorghum based product; 7.98, 8.05 and 8.03 for malted white ragi based product respectively. The results revealed that cooking temperature did not influence the resultant porridge much and the effect of cooking temperature was insignificant in all the types of millets which also supports the concept of gelatinization which inferred that no single time temperature combination are suitable for cooking of the porridge and the cooking conditions could be stated as bring to boil and wait till the development of viscosity.

4.3.2 Process optimization for spray drying, fluid bed drying and vacuum drying of formulated complementary food

The millet based complementary foods of malted foxtail millet, malted little millet, malted sorghum and malted white ragi were diluted in the ratio of 1:5 and cooked till boiling and become viscous was further subjected to spray drying at various combinations of outlet air temperature and feed inlet temperature to optimize the conditions of spray drying. Further, the process of fluid bed drying with respect to the temperature of fluid bed drying was standardized. Finally, vacuum drying process was optimized with respect to the total solids of the porridge and vacuum drying temperature.

4.3.2.1 Optimization of outlet air temperature and feed inlet temperature for spray drying and temperature of fluid bed drying

Spray drying and fluid bed drying of the formulated ready to cook (RTC) products was done after preparing porridge and cooking it to make the resultant products ready to reconstitute (RTR). The effects of outlet air temperature and feed inlet air temperature on moisture content of the powder is presented in Table-23. The feed temperature of 50 and 55^{o}C were too found to be too viscous to pump to the spray dryer for all type of millets RTC foods. The feed temperature of 60^{o}C was found optimum for all the millet RTC foods. With the increase in out let air temperature there was decrease in moisture content of product irrespective of the feed inlet temperature. The moisture content of the powder at 75 and 80^{o}C out let air temperatures was more than 5 per cent and the optimum temperature for drying of the in all type of millet based complementary foods was 85-90^{o}C to get the moisture of the powder below 5 per cent in the resultant powder. In case of fluid bed drying the temperature of 50^{o}C was required to get the moisture below 5 per cent in the dried product of all types of millet based complementary foods. Thus, from the above study it was confirmed that the best conditions of spray drying to prepare RTU spray dried millet based complementary food could be done by feeding the porridge at 60^{o}C and maintaining inlet temperature at 160^{o}C inlet temperature and 90^{o}C outlet temperature. Fluid bed drying could be done at the optimized temperature of 50^{o}C.

4.3.2.2 Optimization of processing parameters for vacuum drying of millet based complementary foods

The formulated ready to cook (RTC) product porridge was prepared at various total solids level / proportion of complementary food: water in the porridge such as 1;2,

Table 23: Optimization of feed temperature and outlet air temperature for spray drying and fluid bed drying temperature of millet based complementary food

Drying parameter	**Process Response**			
Feed temperature (^{o}C)	**Possibility of feeding**			
	Type of malted millet complementary food			
	Foxtail millet	**Little millet**	**Sorghum**	**White ragi**
50	Too Viscous to pump			
55	Too Viscous to pump			
60	Optimum			
Outlet air temperature (^{o}C)	**Type of malted millet complementary food**			
	Foxtail millet	**Little millet**	**Sorghum**	**White ragi**
	Moisture Content			
75	6.81	6.49	6.52	6.58
80	5.91	5.76	7.59	5.72
85	4.98	4.92	4.95	4.89
90	4.56	4.48	4.36	4.15
CD	**0.681**	**0.678**	**0.724**	**0.783**
Drying temperature of fluid bed drying (^{o}C)	**Type of malted millet complementary food**			
	Foxtail millet	**Little millet**	**Sorghum**	**White ragi**
	Moisture Content			
40	6.63	6.52	6.36	6.23
45	5.46	5.38	5.32	5.25
50	4.85	4.72	4.68	4.65
CD	**0.584**	**0.592**	**0.562**	**0.546**

All values are average of three trials

Table 24: Optimization of processing parameters for vacuum drying of millet based complementary food

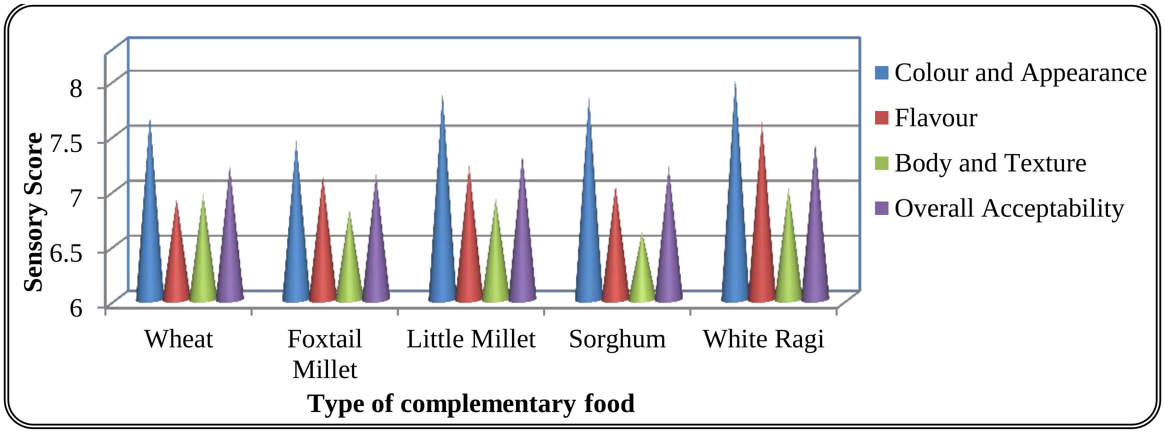
Parameter	Sensory Scores			
Total solids in porridge (%) / Proportion of Complementary Food: Water	**Type of millet malted complementary food**			
	Foxtail millet	**Little millet**	**Sorghum**	**White ragi**
	Overall acceptability			
1:2	7.62	7.86	7.68	7.92
1:3	7.21	7.45	7.34	7.85
50	6.52	6.81	6.62	7.01
60	6.01	6.32	6.12	6.13
CD	**0.284**	**0.291**	**0.314**	**0.261**
Drying temperature (^oC)	**Moisture content**			
40	7.12	6.72	6.32	6.57
45	6.52	6.12	5.48	5.36
50	5.46	5.08	4.62	4.25
55	4.78	4.32	4.01	3.95
CD	**0.371**	**0.342**	**0.425**	**0.293**

All values are average of three trials

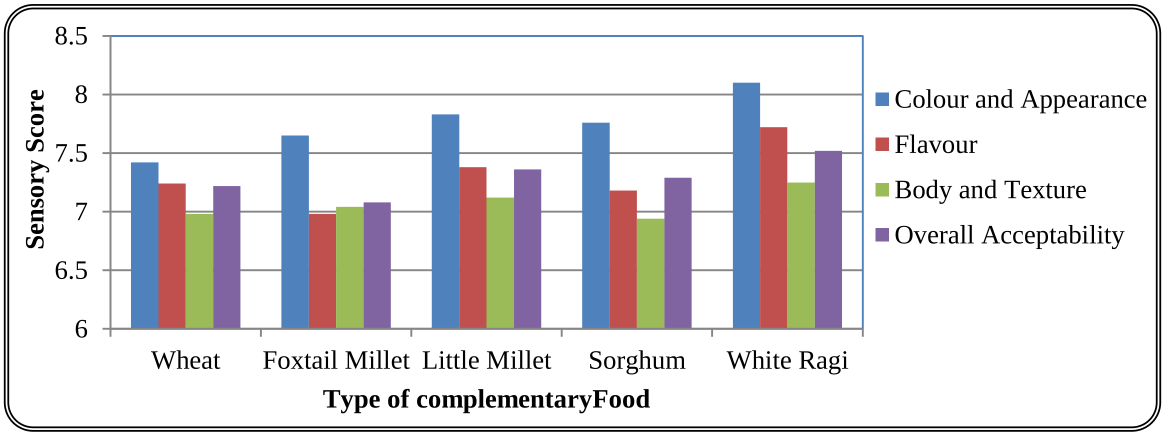
1:3, proportions as well as 50 and 60 per cent total solids level. The prepared porridges were vacuum dried at 50°C to make the resultant products ready to reconstitute (RTR) and subjected for the overall acceptability of the resultant powders. As could be seen from the result presented in Table-24, overall acceptability affected by TS content of porridge for vacuum drying the overall acceptability was highest at 1:2 followed by 1:3 proportion for all millet based products. The total solids level of 50 per cent and 60 per cent resulted in decreased overall acceptability of the resultant powder significantly in all the millet based RTU products. From among the various vacuum drying temperatures tried, the moisture content of the resultant powder were 7.12, 6.52, 5.46 and 4.78 per cent respectively, at 40, 45, 50 and 55°C for foxtail millet based RTU product, 6.72, 6.12, 5.08 and 4.32 per cent respectively, at 40, 45, 50 and 55°C for little millet based RTU product, 6.32, 5.48, 4.62 and 4.01 per cent respectively, at 40, 45, 50 and 55°C for sorghum based RTU product and the moisture content was 6.57, 5.36, 4.25 and 3.95 per cent respectively, at 40, 45, 50 and 55°C for white ragi based RTU product. Thus, the temperature of 50°C was found to be optimum to get the desired moisture content of below 5 per cent in the resultant RTR vacuum dried malted millet based complementary food and even 55°C could reduce the moisture content further.

4.3.2.3 Sensory characteristics of the RTU millet based complementary health foods

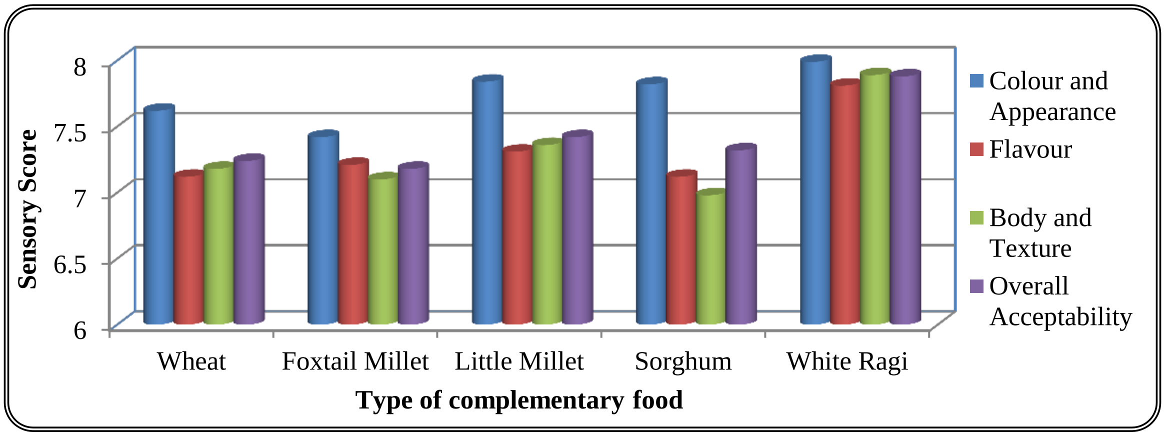
The best adjudged RTU complementary food prepared from foxtail millet, little millet, sorghum and white ragi were subjected to the sensory acceptability keeping wheat based complementary food product as control. The effect of type of malted millet based complementary food on sensory characteristics was evaluated. The results are presented in Figure-22. From among the millets based complementary food formulated, malted white ragi based complementary food was adjudged as best followed by the



a) Sensory acceptability of spray dried malted millet based complementary food



b) Sensory acceptability of fluid bed dried malted millet based complementary food



c) Sensory acceptability of vacuum dried malted millet based complementary food

Fig. 22: Sensory acceptability of spray dried, fluid bed dried and vacuum dried malted millet based complementary food

complementary food with wheat, little millet, sorghum and foxtail millet in respect of all the sensory attributes. Thus, malted white ragi was the best adjudged RTU complementary food even though the complementary foods with malted foxtail millet, malted little millet and malted sorghum could also prepared. In this study, best adjudged malted white ragi based RTU complementary food was selected for the future studies.

4.3.2.4 Sensory and rheological characteristics of the RTU white ragi based complementary health foods

The RTU spray dried, fluid bed dried and vacuum dried white ragi based formulations were subjected to the sensory acceptability keeping the RTC complementary food as control. The results are depicted in Table-25. The colour and appearance scores awarded were 8.08, 8.05, 8.04 and 8.01 respectively, for RTC, spray dried, fluid bed dried and vacuum dried white ragi formulations. Type of drying did not affect the sensory acceptability with respect to colour and appearance. The flavour score for the RTC sample was 8.18 whereas it was 8.01, 8.02 and 8.08 respectively, for RTC, spray dried, fluid bed dried and vacuum dried white ragi formulations. It was evident from the result that, body and texture did not significantly wary with the type of drying. The respective body and texture scores for RTC, spray dried, fluid bed dried and vacuum dried white ragi formulations were 8.28, 8.10, 8.04 and 8.09 respectively. The scores awarded for overall acceptability attributes for RTC, spray dried, fluid bed dried and vacuum dried white ragi formulations were 8.12, 8.02, 8.04 and 8.09 respectively. The results revealed that RTU white ragi based complementary foods prepared with all the types of drying are acceptable even though highest score awarded for the RTC product followed by vacuum dried, fluid bed dried and spray dried RTU product.

Table 25: Sensory characteristics of honey blended RTU white ragi based complementary health food

Type of complementary health food	Sensory scores on the 9 point Hedonic Scale			
	Colour and Appearance	Flavour	Body and Texture	Overall Acceptability
Ready To Cook food as control	8.08	8.18	8.28	8.12
Ready to Use Spray dried complementary food	8.05	8.01	8.10	8.02
Ready to Use Spray dried and fluid bed dried food	8.04	8.02	8.14	8.04
Ready to Use Vacuum dried food	8.01	8.08	8.18	8.09
CD	0.124	0.122	0.248	0.140

All values are average of three trials

The best adjudged vacuum dried malted white ragi RTU food with SMP was studied for rheological characteristics using Anton paar rheometer .The results are depicted in the Figure 23. The viscosity of the porridge of RTU white ragi based product with SMP was 3059mPa.s. The viscosity decreased upon increase in the shear rate over a period of time. This decrease in the viscosity has the relation to the viscosity reduction of the porridge slurry after keeping it for few minutes. This resulted in body and texture scores difference especially whenever the product was not consumed completely. Thus, for preparing honey blended probiotic product, vacuum dried product was selected.

4.3.2.5 Physico-chemical attributes and microbial quality of ready to use best adjudged white ragi based formulations of complementary health food

The physico-chemical attributes and microbial quality of the spray dried, fluid bed dried and vacuum dried white ragi based complementary food products are depicted in the Table -26. The colour (L*, a* and b*) values were 87.02*, 1.25* and 9.73* for spray dried product; 86.02*, 1.76* and 9.62* for fluid bed dried product; 76.9*, 4.37* and 19.28* for vacuum dried RTU complementary food. Decreased a* value for vacuum dried products revealed darker colour of the vacuum dried food compared to other two products. The particle size of spray dried white ragi formulation with SMP and spray dried white ragi formulation with SMP and sugar is depicted in Figure-24. The particle size distribution was observed to be ranging from 0.39µ to 709µ for spray dried white ragi formulation with SMP with maximum per cent (89 volume %) particles were below 200µ. The particle size distribution for the spray dried white ragi formulation with SMP and sugar was ranging from 0.31µ to 632µ with maximum per cent (86 volume %) of the particles in the product were below 239µ. The respective pH of the Spray dried, fluid bed

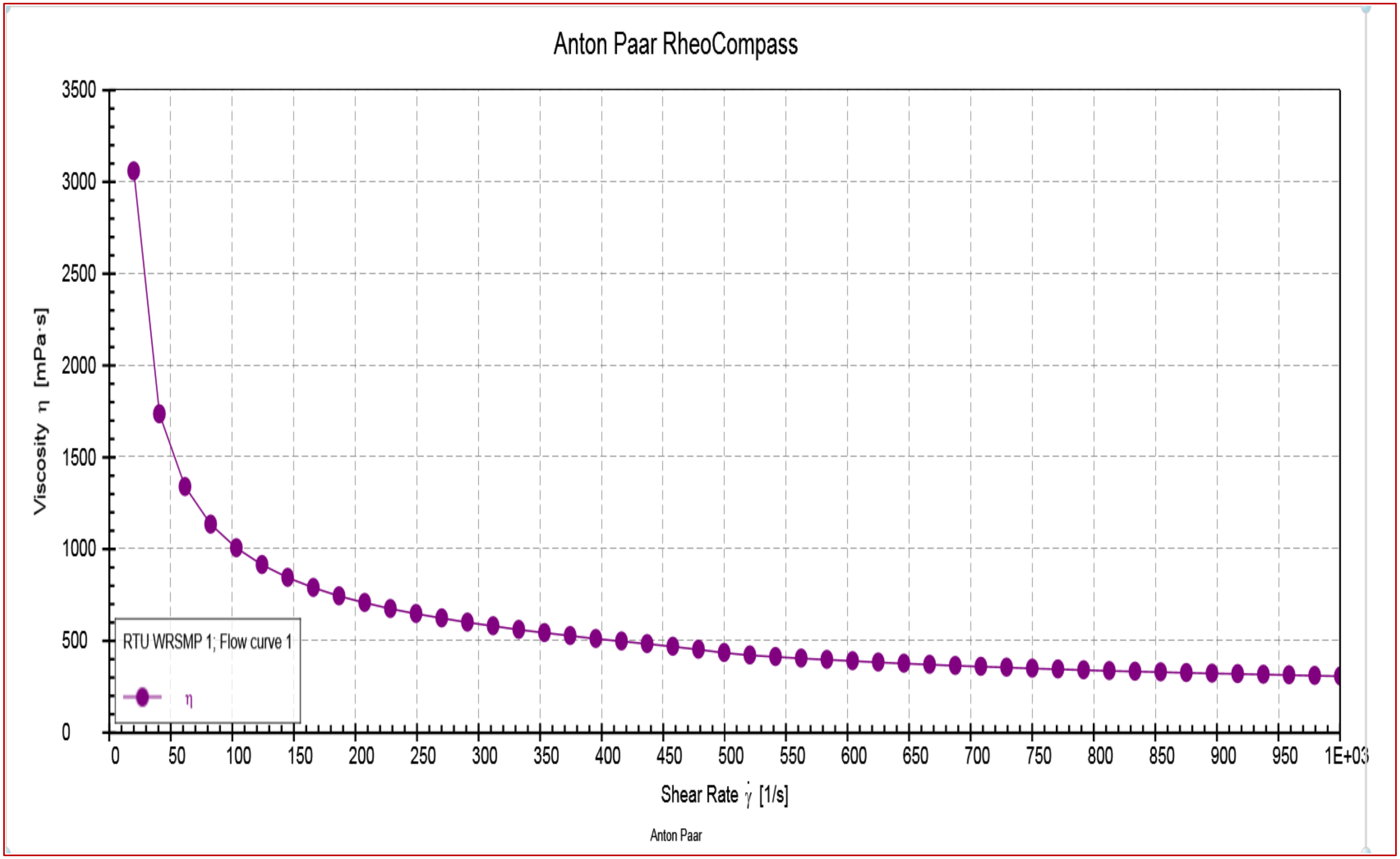
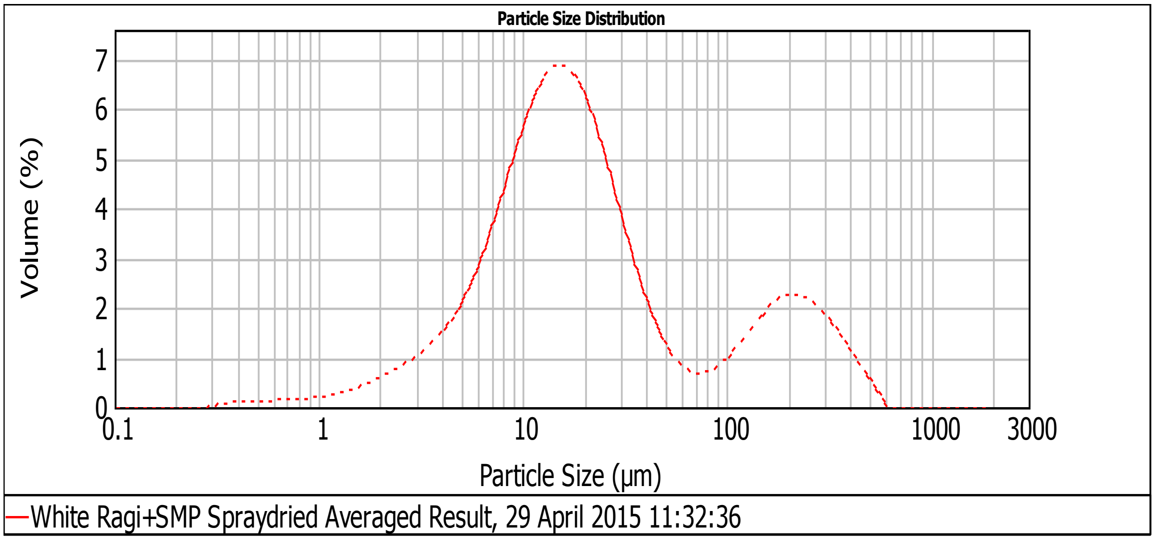


Fig. 23: Rheological characteristics of ready to use white ragi based complementary health food

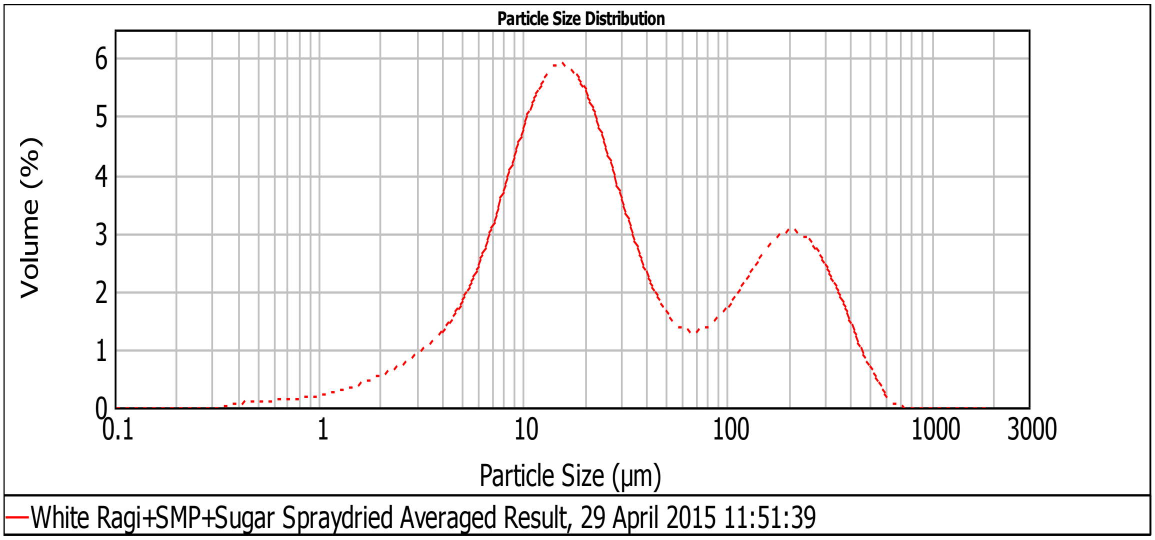
Table 26: Physico-chemical attributes of ready to use best adjudged white ragi based formulations of complementary health food.

Type of Attribute	**Type of complementary health food formulation**		
	Spray Dried RTU complementary health food	**Spray Dried and fluid bed dried RTU complementary health food**	**Vacuum Dried RTU complementary health food**
Physical attributes			
Colour	87.02* 1.25* 9.73*	86.02* 1.76* 9.62*	76.91* 4.37* 19.28*
pH	6.45	6.42	6.41
Water Activity	0.281	0.268	0.244
Chemical Composition			
Moisture (%)	4.60	4.20	3.60
Fat (%)	2.05	2.04	2.00
Protein (%)	13.11	13.1	13.1
Carbohydrates (%)	75.24	75.73	76.37
Crude fibre (%)	2.80	2.75	2.72
Ash (%)	2.20	2.18	2.21
Energy density (K.cal/100g)	371.85	373.68	375.88
Microbiological quality counts in log cfu/gm			
Total count	2.8	2.4	3.8
Coliforms	NIL	NIL	NIL
Yeast and moulds	NIL	NIL	NIL

All values are average of three trials



a) White ragi based spray dried formulation with SMP



b) White ragi based spray dried formulation with SMP and Sugar

Fig. 24: Particle size distribution of the optimized formulations of white ragi based complementary health food

dried and vacuum dried white ragi based complementary food product with SMP were 6.45, 6.42 and 6.41. The water activity of the RTU complementary foods was 0.281, 0.268 and 0.244 for the Spray dried, fluid bed dried and vacuum dried white ragi based complementary food product with SMP. The results of the chemical composition of the RTU formulations of white ragi based complementary food are depicted in Table-26. The moisture content of spray dried, fluid bed dried and vacuum dried white ragi based complementary food products were 4.60, 4.20 and 3.60 per cent respectively. The fat content of the optimized formulations of the spray dried, fluid bed dried and vacuum dried white ragi based complementary food product with SMP were 2.05, 2.04 and 2.0 per cent respectively . The respective protein content of complementary food was 13.11, 13.10 and 13.10 per cent for spray dried, fluid bed dried and vacuum dried white ragi based complementary food product with SMP. The carbohydrate content was 75.24, 75.73 and 76.37 respectively, for the spray dried, fluid bed dried and vacuum dried white ragi based complementary food product with SMP. The crude fibre content was 2.8, 2.75 and 2.72 percent respectively, for the spray dried, fluid bed dried and vacuum dried white ragi based complementary food product with SMP. The ash content of the spray dried, fluid bed dried and vacuum dried white ragi based complementary food product with SMP was found to be 2.20, 2.18 and 2.21 per cent respectively. The energy density of the spray dried, fluid bed dried and vacuum dried white ragi based complementary food product with SMP was 371.85, 373.68 and 375.88 respectively. Microbiological analysis results revealed that the total bacterial count was 2.8, 2.4 and 3.8 log cfu/gm for the spray dried, fluid bed dried and vacuum dried white ragi based complementary food product with SMP. Both coliforms and yeast and moulds were absent in all the RTU formulations.

4.3.2.6 Sensory characteristics of RTU vacuum dried, honey blended malted white ragi based probiotic complementary health foods

The RTU vacuum dried malted white ragi based formulation was added with honey, probiotic organisms were subjected to the sensory acceptability keeping vacuum dried RTU with sugar as control. The results are depicted in Table-27. The colour and appearance scores awarded for RTU malted white ragi complementary food with sugar, honey blended complementary food, probiotic complementary food with *B.bifidum* and probiotic complementary food with *L.acidophilus* were 8.10, 8.12, 8.14 and 8.16 respectively, depicting no difference between the different formulations of complementary foods. The respective flavor scores were 8.20, 8.28, 8.24 and 8.23 for malted white ragi complementary food with sugar, honey blended complementary food, probiotic complementary food with *B.bifidum* and probiotic complementary food with *L.acidophilus*. The body and texture and overall acceptability scores were 8.07 and 8.10; 8.20 and 8.18; 8.11 and 8.12; 8.18 and 8.16 for malted white ragi complementary food with sugar, honey blended complementary food, probiotic complementary food with *B.bifidum* and probiotic complementary food with *L.acidophilus*. From the above results, it was inferred that sensory scores in respect of all the characteristics for all the tried complementary foods were almost similar and the scores did not differ much even after blending of the probiotic organisms. The statistical analysis revealed that all the samples are as good as the control and are highly acceptable.

4.3.3 Optimization of production of RTU extruded complementary health foods

Variety of complementary foods can be prepared using extrusion process. A study was undertaken to produce extruded complementary food from millets. The results of the study are here under.

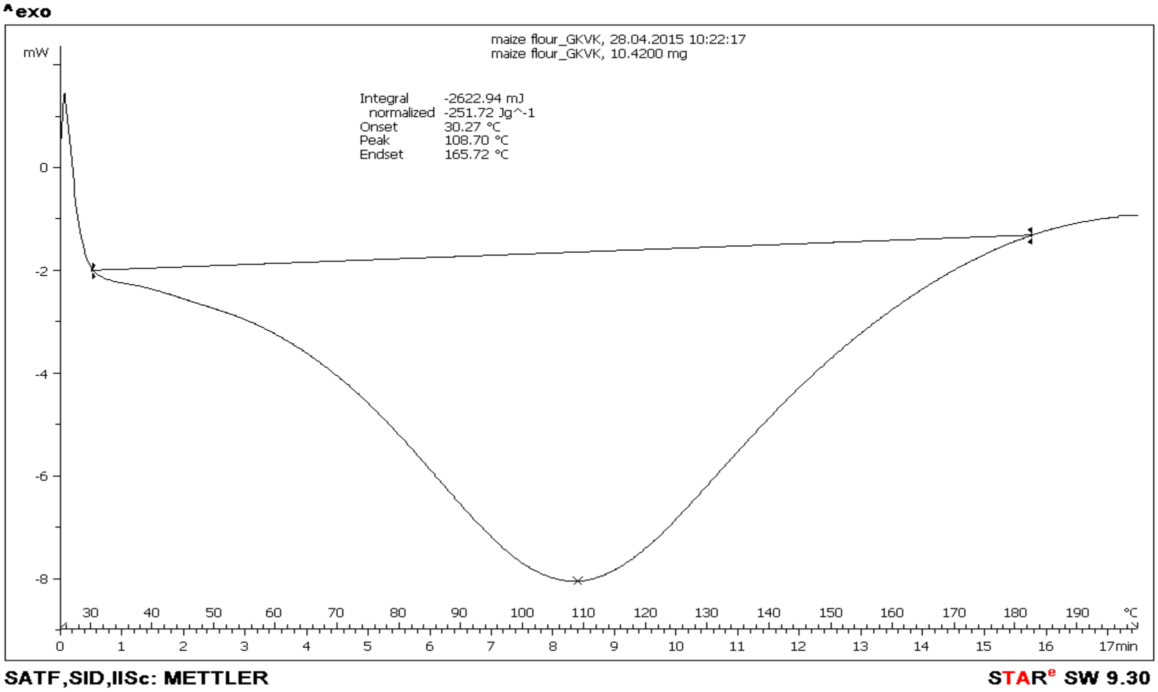
Table 27: Sensory characteristics of honey blended RTU vacuum dried white ragi based complementary health food

Type of complementary health food	Sensory scores on the 9 point Hedonic Scale			
	Colour and Appearance	Flavour	Body and Texture	Overall Acceptability
Ready To Use food with sugar as control	8.12	8.28	8.20	8.18
Ready to Use vacuum dried honey blended complementary food	8.10	8.20	8.07	8.10
Ready to Use vacuum dried food with SMP, Sugar, Honey and *Bifidobacterium bifidum*	8.14	8.24	8.11	8.12
Ready to Use vacuum dried food with SMP, Sugar, Honey and *Lactobacillus acidophilus*	8.16	8.23	8.18	8.16
CD	0.152	0.124	0.185	0.164

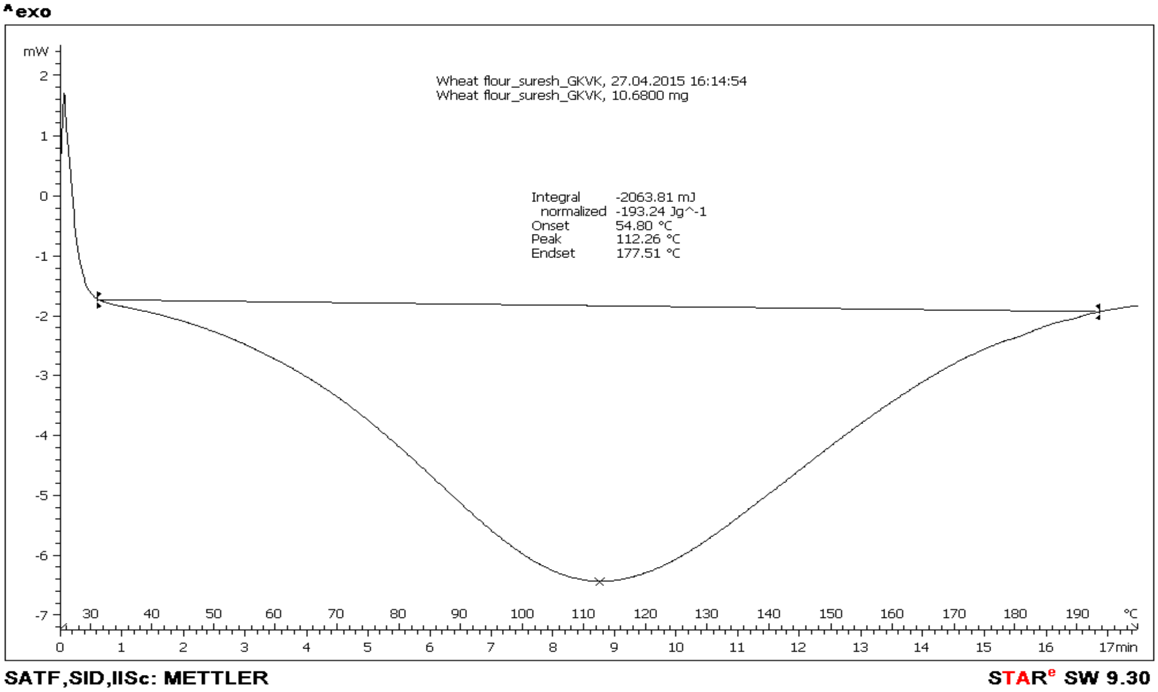
All values are average of three trials

4.3.3.1 Identification of gelatinization temperature for the raw flours to use them in preparation of extruded flours

Ascertaining gelatinization temperature of the raw flours plays a vital role in getting the proper extrusion of the material. Gelatinization temperature and the range of gelatinization of the raw flours of maize, wheat, foxtail millet, little millet, white ragi and sorghum were estimated using Differential Scanning Colorimeter (DSC), Spectroscopy laboratory, SID, at the Indian Institute of Science, Bangalore, to ascertain proper extrusion of the raw flours, identification of gelatinization temperature was done using DSC. The results of the study are depicted in Figure-25, 26 and 27. The onset of gelatinization temperatures of maize flour was at 30.27°C and peaked at 108.70°C and end set at 165.2°C (Figure 25a), onset of gelatinization for wheat flour was at 54.8°C, it peaked at 112.51°C and its end set was at 177.51°C (Figure 25b). The onset of gelatinization temperature for raw foxtail millet flour was at 49.84°C, peaks at 98.89°C and end set temperature is at 156.57°C (Figure. 26a), raw little millet flour has onset temperature of 29.01°C and peaks at 91.17°C and end set was at 148.76°C (Figure.26b). The raw sorghum flour had onset temperature of 30.29°C, peaked at 99.86°C and end set was at 165.43°C (Figure 27a), white ragi had onset temperature of 30.30°C, peaked at 110.21°C and end set was at 172.95°C (Figure 27b). These temperatures are very crucial to get good quality extruded flours and flakes. The trend of gelatinization temperatures obtained for the raw flours of maize, wheat, white ragi and sorghum depicted that the onset, peak and end set temperatures was having similarity. Thus, it was decided to use the same process conditions (120±5°C for extrusion,100±2°C for drying and 150°C for roasting) employed during the production of the extruded flours and corn flour for the

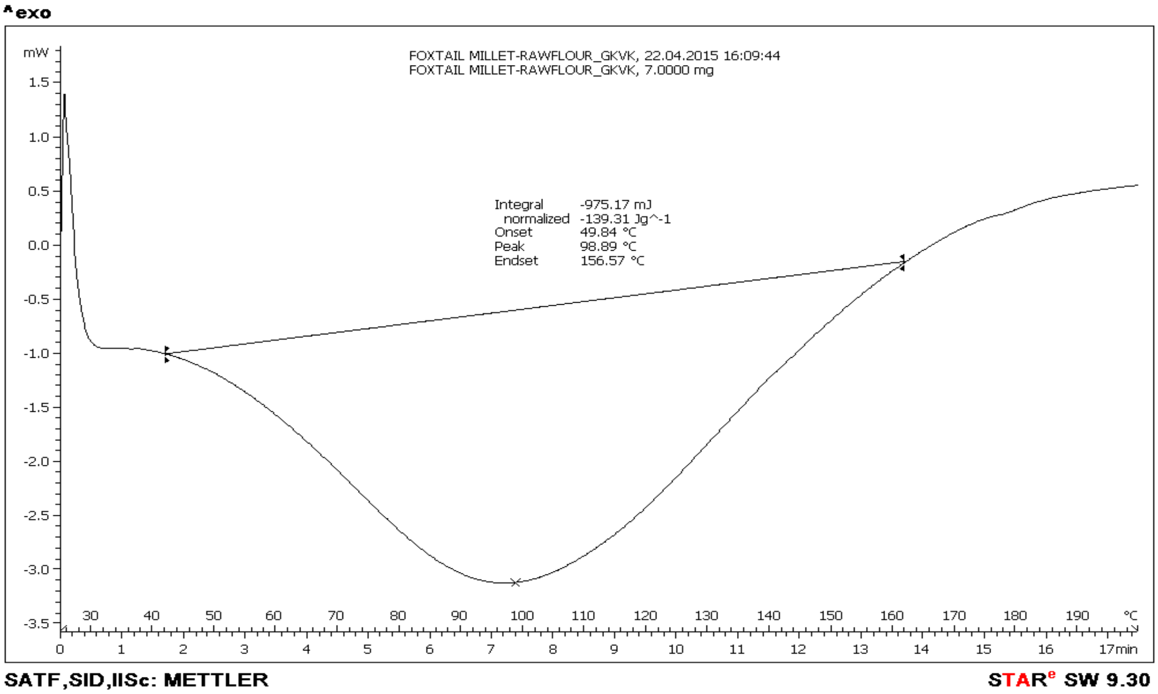


a) Maize/Corn flour

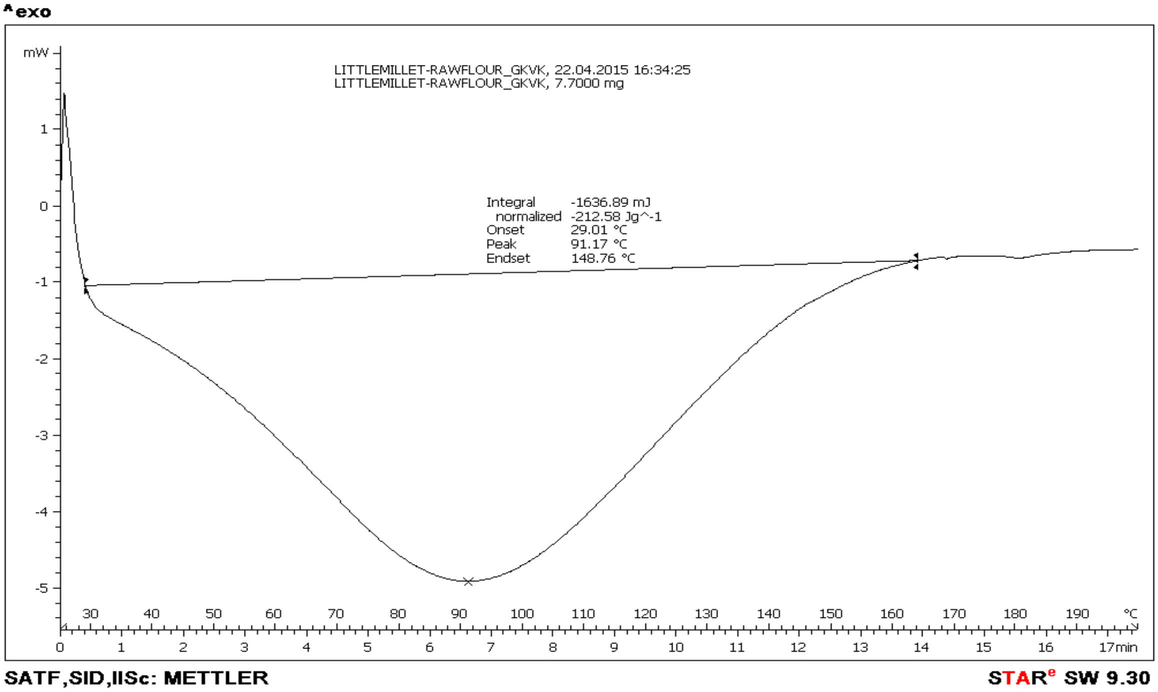


b) Wheat flour

Fig. 25: Identification of gelatinization temperature of raw maize and wheat flours using differential scaning colorimetry (DSC)

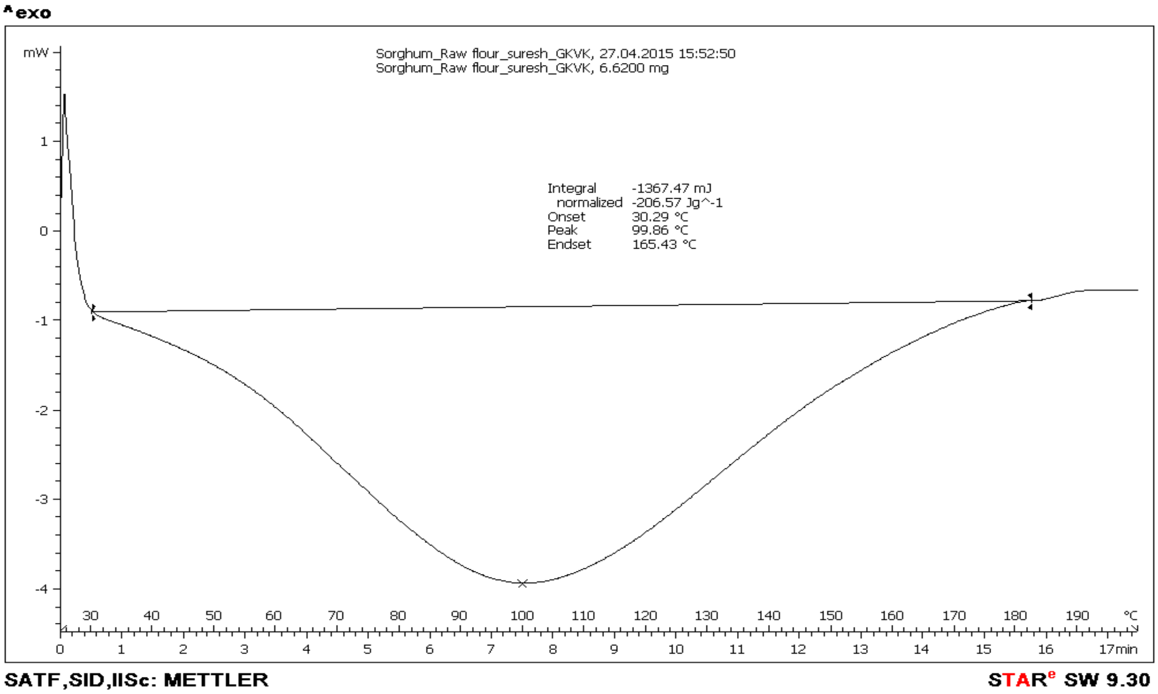


a) Raw foxtail millet flour

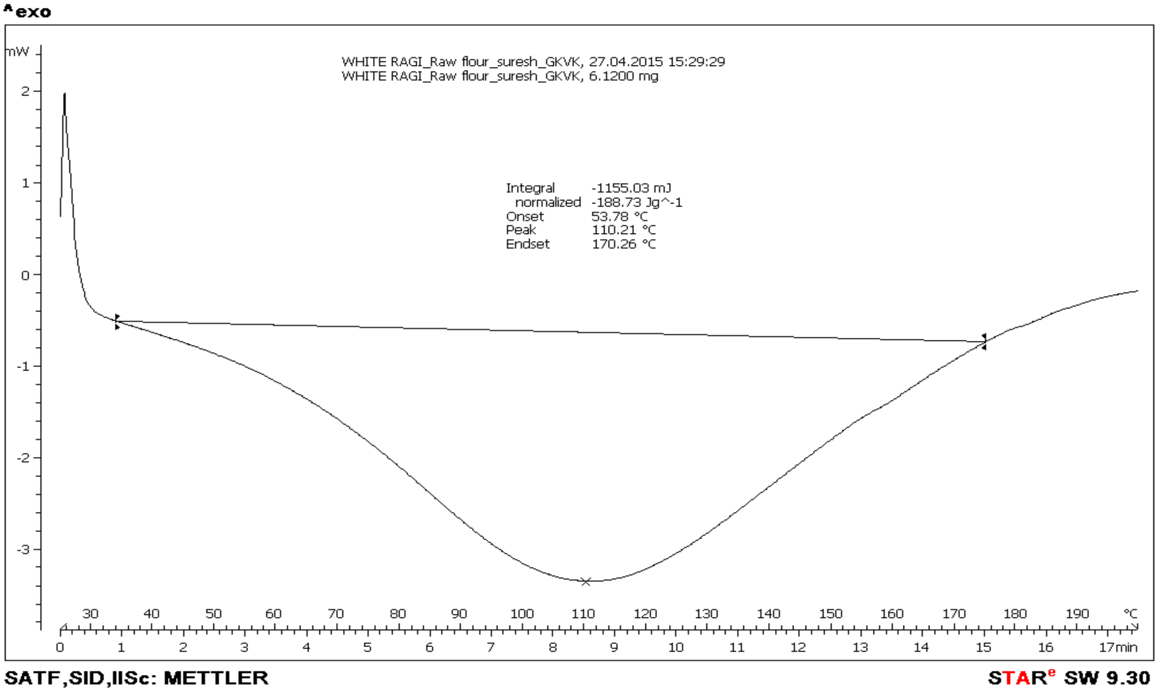


b) Raw little millet flour

Fig. 26: Identification of gelatinization temperature of raw foxtail and little millet flours using differential scanning colorimeter (DSC)



a) Raw sorghum flour



b) Raw white ragi flour

Fig. 27: Identification of gelatinization temperature of raw sorghum and white ragi flours using differential scanning colorimeter (DSC)

production of the extruded flours and flakes from wheat, foxtail millet, little millet, sorghum and white ragi.

4.3.3.2 Sensory acceptability of RTU extruded millet based complementary health foods

The sensory acceptability study of RTU extruded millet based complementary health food added SMP was conducted. The results of the study are depicted in Table-28. The RTU extruded complementary foods containing SMP prepared from extruded foxtail millet, little millet, sorghum and white ragi flours were subjected to the sensory acceptability keeping RTU extruded wheat based complementary food product as control. The effect of type of the complementary food on sensory characteristics was evaluated. The results are presented in Table-28. From among the millets based RTU extruded complementary food formulated, little millet based product was adjudged best followed by the RTU extruded complementary food with foxtail millet, white ragi, sorghum and wheat. The colour and appearance scores were 7.54, 7.84, 8.04, 7.01 and 7.31 for the formulation containing extruded wheat, extruded foxtail millet, extruded little millet, extruded sorghum and extruded white ragi respectively. Colour and appearance scores significantly increased for extruded little millet in comparison with control. The flavor scores were 7.14, 7.56, 7.74, 7.23 and 7.48 respectively, for the complementary food product containing extruded wheat, extruded foxtail millet, extruded little millet, extruded sorghum and extruded white ragi. The increase in the flavor scores for extruded little millet was highest and was significantly higher compared to the formulation of extruded wheat. The body and texture scores were 7.25, 7.88, 8.24, 6.94 and 7.28 respectively, for the formulation with extruded wheat, extruded foxtail millet, extruded

Table 28: Sensory acceptability of RTU extruded millet based complementary health food

Type of complementary health food formulation	Sensory scores on the 9 point Hedonic Scale			
	Colour and Appearance	Flavour	Body and Texture	Overall Acceptability
Extruded wheat based food with SMP	7.54	7.14	7.25	7.21
Extruded Foxtail millet based food with SMP	8.24	7.56	7.88	7.96
Extruded little millet based food with SMP	8.04	7.74	8.24	8.10
Extruded sorghum millet based food with SMP	7.01	7.23	6.94	7.29
Extruded white ragi millet based food with SMP	7.31	7.48	7.28	7.45
CD	0.356	0.362	0.372	0.254

All values are average of three trials

little millet, extruded sorghum and extruded white ragi. The body and texture scores were highest for white ragi and were significantly higher than that of all other formulations including extruded wheat formulation. Sensory scores awarded for overall acceptability attribute were 7.21, 7.76, 8.10, 7.29 and 7.45 for the complementary food product containing extruded wheat, extruded foxtail millet, extruded little millet, extruded sorghum and extruded white ragi. The rheological study of the little millet extruded RTU complementary health food containing SMP revealed that the viscosity of the porridge was 11600mPa.s initially was decreased slowly as the shear rate is increased (Fig. 28). The viscosity of the porridge was 14700mPa.s for WPH containing product (Fig. 29). This parameter decides the body and texture of the developed product. The study revealed that using extruded little millet was the best to prepare the extruded little millet based RTU complementary food compared to other extruded millets.

4.3.3.3 Sensory and rheological characteristics of honey blended extruded little millet based probiotic complementary health food

The RTU blend of best adjudged honey blended extruded little millet based complementary health food was added with the probiotic organisms. Honey and probiotic organisms were dry blended into the complementary food. The prepared products were subjected to sensory evaluation. The sensory acceptability of the products is depicted in Table-29. The colour and appearance scores awarded extruded little millet complementary food with sugar, honey blended complementary food, probiotic complementary food with *B.bifidum* and probiotic complementary food with *L.acidophilus* were 8.04, 8.13, 8.12 and 8.11 respectively, depicting no difference between the different formulations of RTU complementary foods. The respective flavor

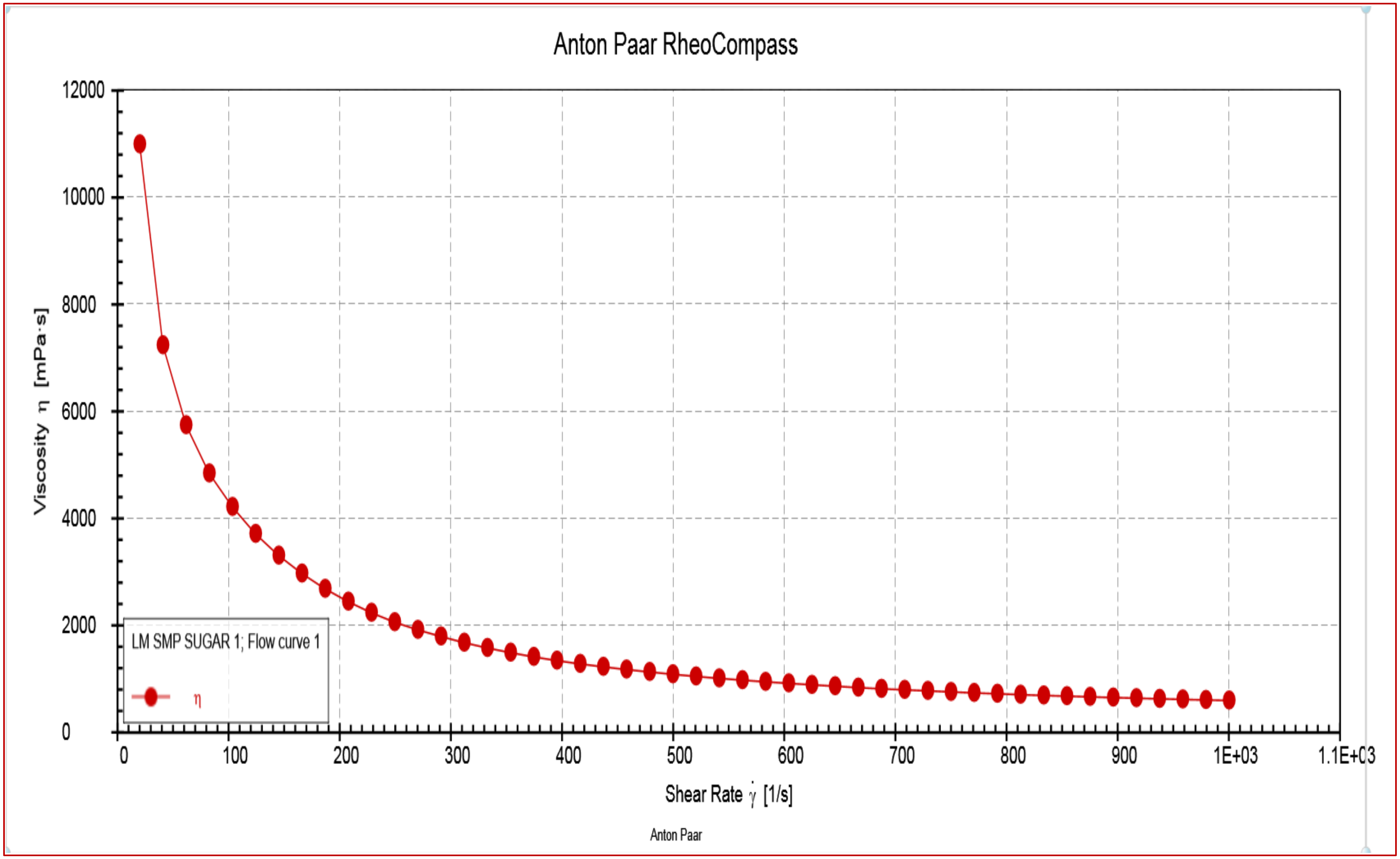


Fig 28: Rheological characteristics of ready to use extruded little millet based complementary health food with SMP

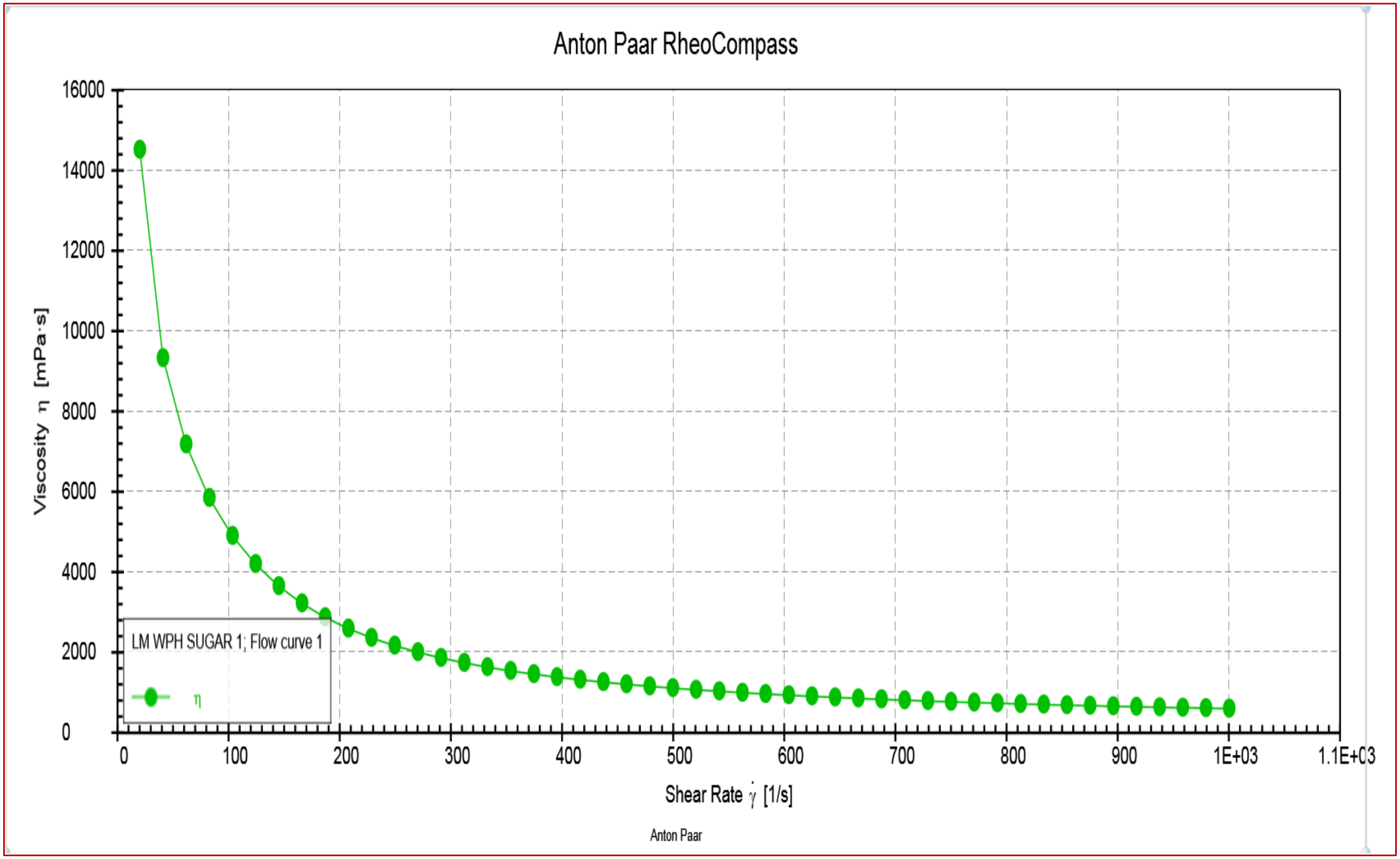


Fig 29: Rheological characteristics of ready to use extruded little millet based complementary health food with WPH

Table 29: Sensory acceptability of RTU extruded little millet based probiotic complementary health food

Type of complementary health food formulation	**Sensory scores on the 9 point Hedonic Scale**			
	Colour and Appearance	**Flavour**	**Body and Texture**	**Overall Acceptability**
Extruded little millet based food with SMP and Sugar	8.04	8.01	8.24	8.10
Extruded little millet based food with SMP, sugar and Honey	8.13	8.18	8.17	8.17
Extruded little millet based food with SMP, Sugar, Honey and *Bifidobacterium bifidum*	8.12	8.16	8.15	8.14
Extruded little millet based food with SMP, Sugar, Honey and *Lactobacillus acidophilus*	8.11	8.17	8.16	8.15
CD	0.154	0.192	0.180	0.154

All values are average of three trials

scores were 8.01, 8.18, 8.16 and 8.17 for extruded little millet complementary food with sugar, honey blended complementary food, probiotic complementary food with *B.bifidum* and probiotic complementary food with *L.acidophilus*. The body and texture and overall acceptability scores were 8.24 and 8.10; 8.17 and 8.17; 8.15 and 8.14; 8.16 and 8.15 for extruded little millet complementary food with sugar, honey blended complementary food, probiotic complementary food with *B.bifidum* and probiotic complementary food with *L.acidophilus*. From the above results, it was inferred that sensory scores in respect of all the characteristics for all the extruded little millet complementary foods were almost similar and the scores did not differ much even after blending of the probiotic organisms.

The Rheological characteristics of the RTU extruded little millet based honey blended probiotic complementary food with SMP and WPH were analyzed using Anton paar rheometer are the results are depicted in the Figure 30 and 31. The viscosity of the porridge of extruded little millet based product with SMP was 8665mPa.s. The viscosity of the porridge of extruded little millet based product with WPH was 10829mPa.s. In both the cases the viscosity decreased upon increase in the shear rate over a period of time. This decrease in the viscosity has the relation to the viscosity reduction of the porridge slurry resulted in body and texture scores difference especially whenever the product was not consumed completely and the developed products are given in plate-5.

4.3.3.4 Physico-chemical and microbiological quality of RTU extruded little millet based honey blended probiotic complementary health foods

The honey blended extruded little millet based complementary health foods were analyzed for various physical, chemical and microbiological parameters along with the

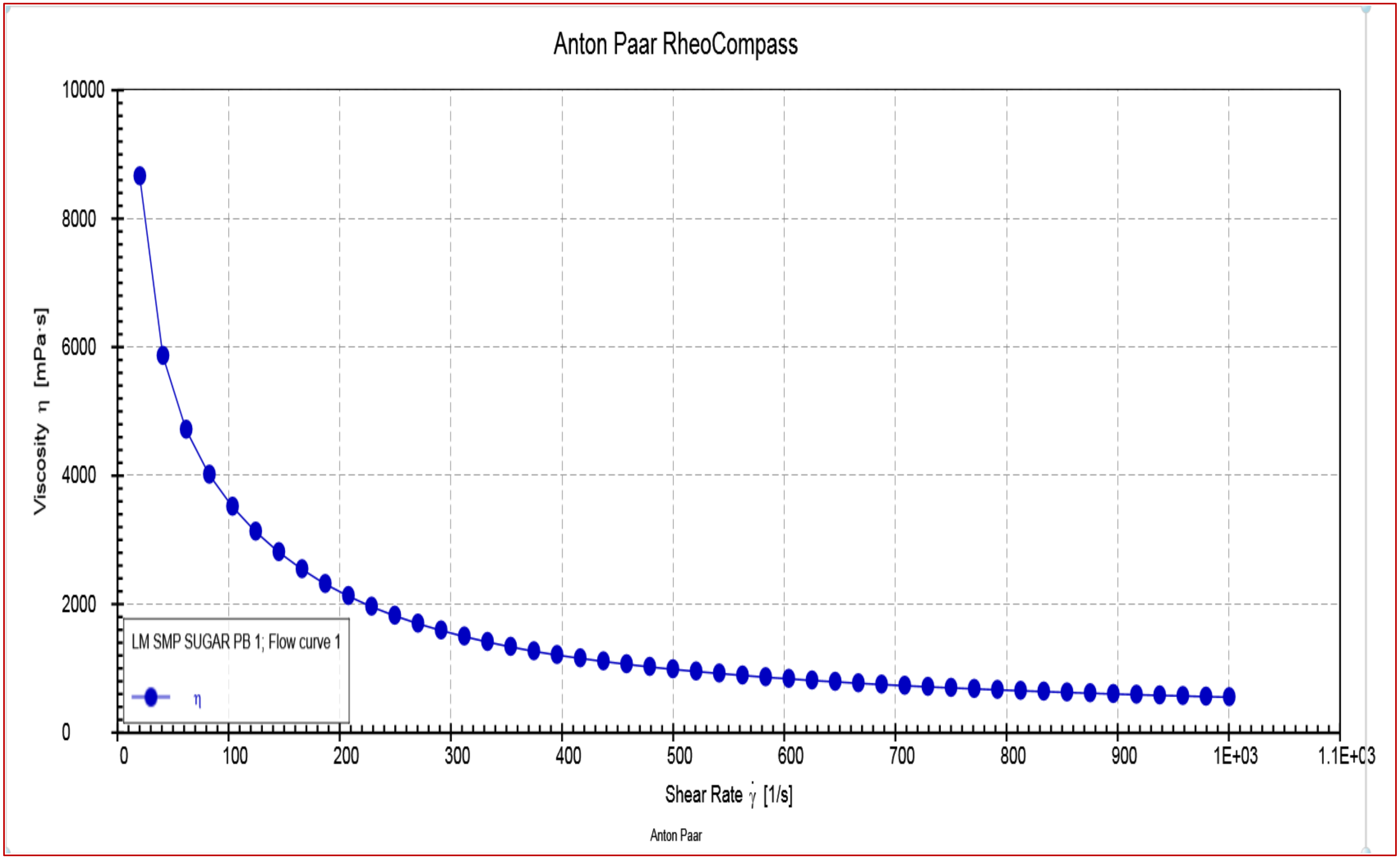


Fig. 30: Rheological characteristics of ready to use extruded little millet based probiotic complementary health food

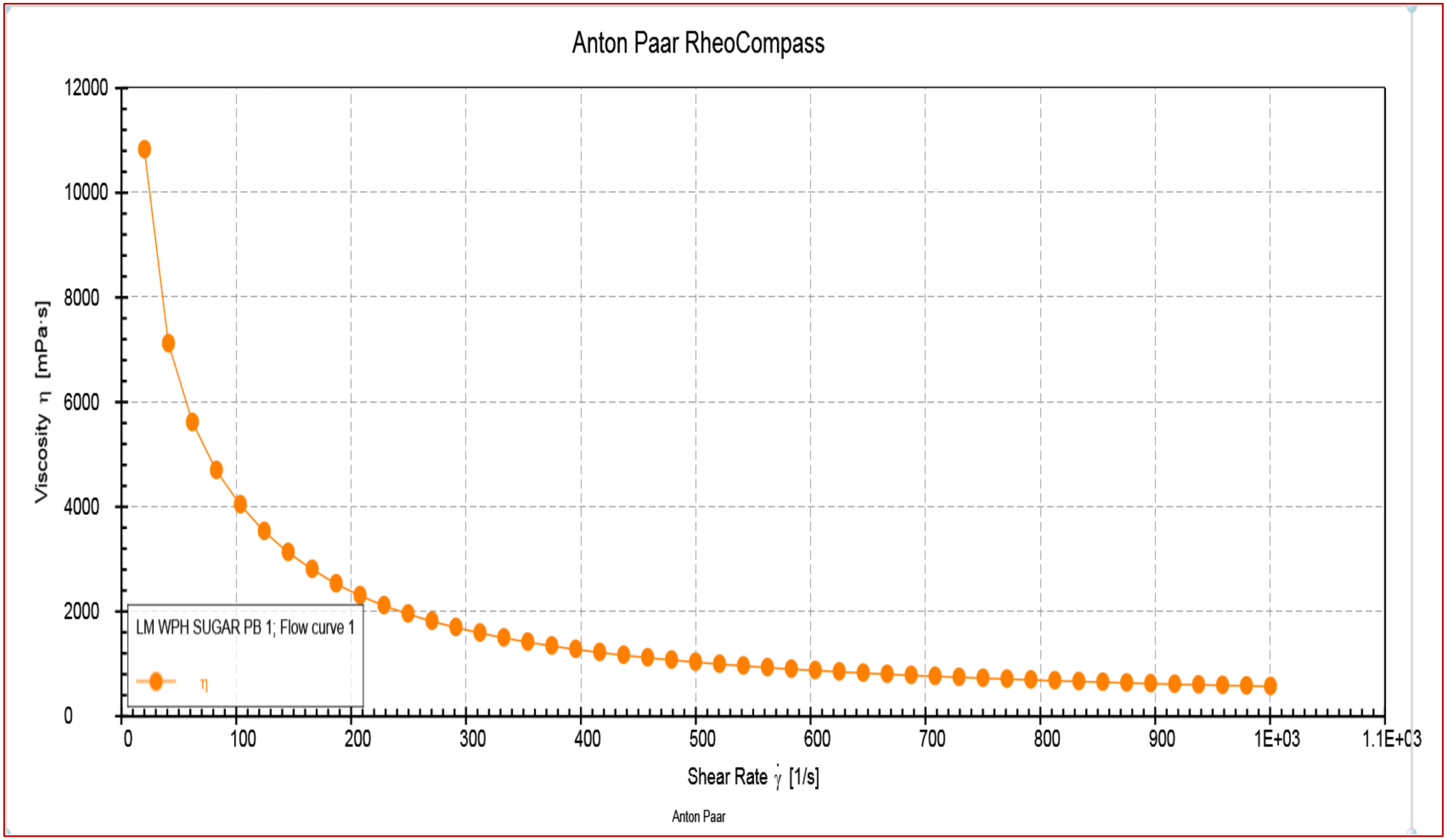
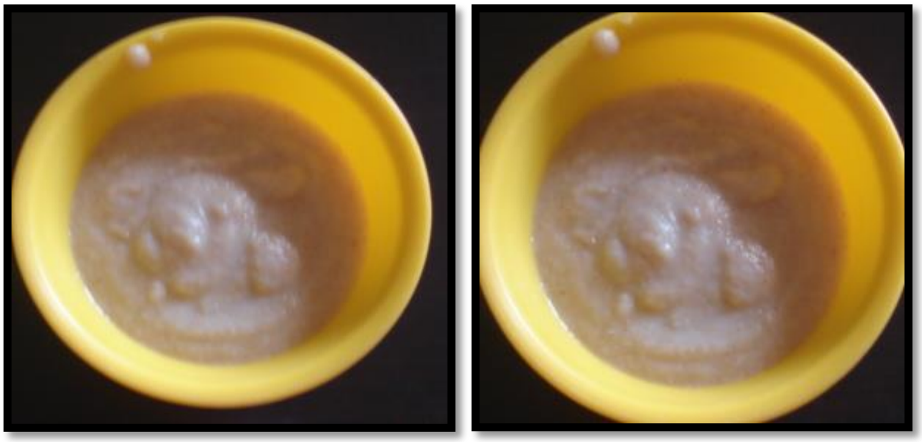


Fig. 31: **Rheological characteristics of ready to use extruded little millet based probiotic complementary health food with WPH and honey**

Ready to cook (RTC) and Ready to Use (RTU) white ragi based complementary health food



Ready to Use (RTU) extruded little millet based complementary health food

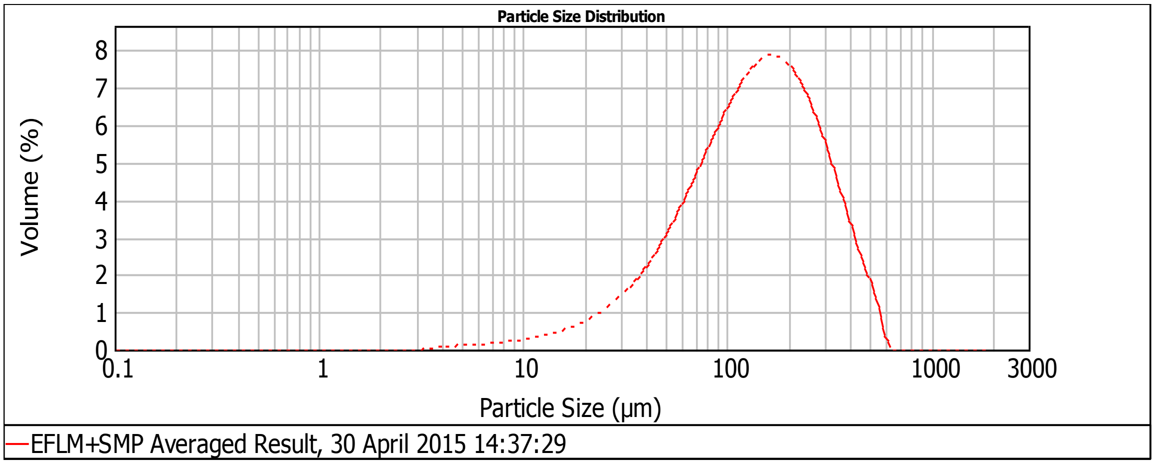
Plate 5: RTC and RTU Porridges of complementary foods developed in the study

sugar containing complementary food. The results of the study are depicted in Table-30 and Fig. 32. It could be seen from the Fig.32a, 32b and 32c, the particle size distribution was observed to be ranging from 3.99µ to 632µ, 2.82µ to 1782µ and 3.17µ to 2000µ respectively, for extruded little millet based complementary health food with sugar, extruded little millet based probiotic complementary food with *L.acidophilus* and probiotic complementary food with *B.bifidum* respectively. However, the maximum per cent (68 volume %) of the particles were below 200µ in extruded little millet based product with sugar, where as in extruded little millet based probiotic complementary food the maximum per cent (60.86 volume %) of the particles were below 200µ with *L.acidophilus* and the maximum per cent (60.52 volume %) of the particles were below 200µ for extruded little millet based probiotic complementary food with *B.bifidum* honey blended probiotic complementary health food. The colour (L* a* b*) values were 79.54*, 3.48* and 18.52*; 78.47*, 3.63* and 18.74*; 78.82*, 3.55* and 18.61* for extruded little millet based complementary health food with sugar, extruded little millet based probiotic complementary food with *L.acidophilus* and probiotic complementary food with *B.bifidum* respectively indicating darker colour which could be due to exposure to higher temperature during preparation of extruded flour. The respective pH complementary foods were 6.34, 6.33 and 6.34 for extruded little millet based complementary health food with sugar, extruded little millet based probiotic complementary food with *L.acidophilus* and probiotic complementary food with *B.bifidum*. The water activity of the optimized honey blended extruded little millet based complementary foods was 0.179, 0.256 and 0.247 extruded little millet based complementary health food with sugar, extruded little millet based probiotic complementary food with *L.acidophilus* and probiotic complementary food with *B.bifidum* respectively.

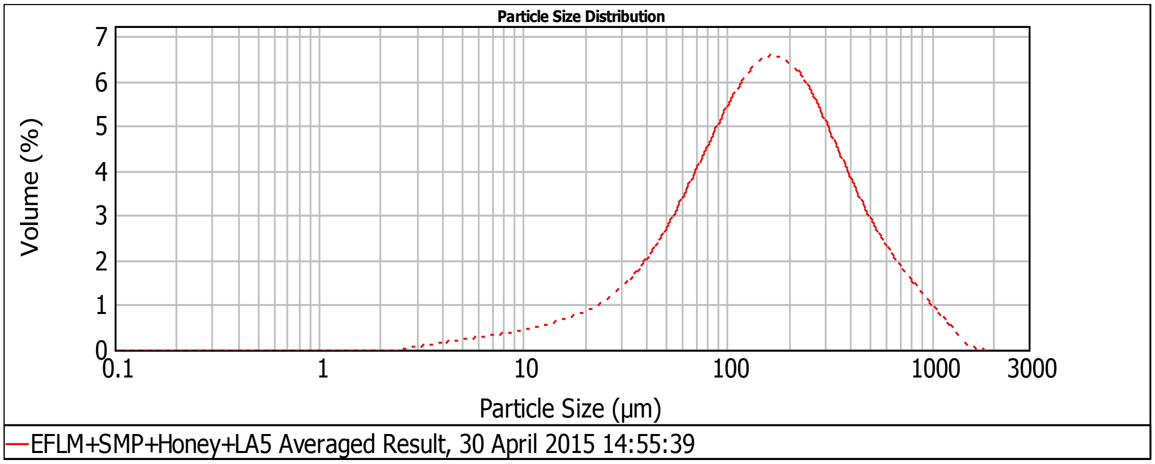
Table 30: Physico-chemical properties and microbiological quality of extruded little millet based complementary health food

Attribute	**Extruded little millet+SMP+sugar**	**White Ragi+SMP+Honey BB-12**	**White Ragi+SMP+Honey LA-5**
Physical attributes			
Colour	79.54* 3.48* 18.52*	78.47* 3.63* 18.74*	78.82* 3.55* 18.61*
pH	6.34	6.33	6.34
Water Activity	0.179	0.256	0.247
Chemical Composition			
Moisture (%)	3.43	4.45	4.13
Fat (%)	1.38	1.36	1.35
Protein (%)	12.52	11.92	11.98
Carbohydrates (%)	75.48	75.09	75.33
Crude fibre (%)	1.87	1.91	1.93
Ash (%)	5.32	5.27	5.28
Energy density (K.cal/100g)	364.42	360.28	361.39
Microbiological quality counts in log cfu/gm			
Total count	1.32	-	-
Probiotic count	-	9.81	9.69
Coliforms	NIL	NIL	NIL
Yeast and moulds	NIL	NIL	NIL

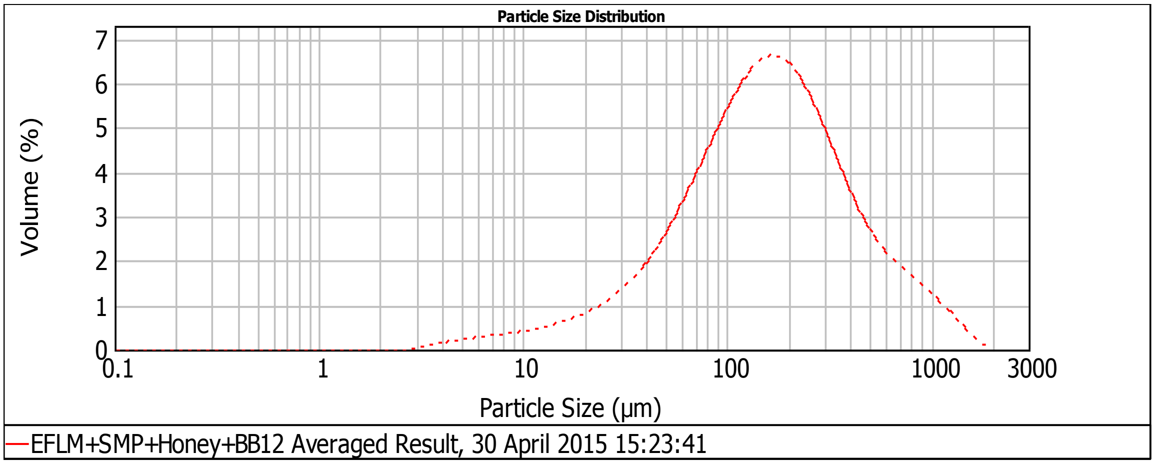
All values are average of three trials



a) Extruded little millet based formulation with SMP



b) Extruded little millet based formulation with honey and *Lactobacillus acidophilus*



c) Extruded little millet based formulation with honey and *Bifidobacterium bifidum*

Fig. 32: Particle size of best adjudged extruded little millet flour based complementary health food

The results of the chemical composition of the optimized formulations of extrude little millet based complementary food are depicted in Table-30. The moisture content of the extruded little millet based complementary health food with sugar, extruded little millet based probiotic complementary food with *L.acidophilus* and probiotic complementary food with *B.bifidum* were 3.43, 4.45 and 4.13 per cent, respectively. This increase in moisture attributed to the blending of the honey. The fat content of the optimized formulations were 1.38, 1.36 and 1.35 respectively for extruded little millet based complementary health food with sugar, extruded little millet based probiotic complementary food with *L.acidophilus* and probiotic complementary food with *B.bifidum*. The protein content was 12.52, 11.92 and 11.98 for extruded little millet based complementary health food with sugar, extruded little millet based probiotic complementary food with *L.acidophilus* and probiotic complementary food with *B.bifidum*. The carbohydrate content of extruded little millet based complementary health food with sugar, extruded little millet based probiotic complementary food with *L.acidophilus* and probiotic complementary food with *B.bifidum* were 75.48, 75.09 and 75.33 per cent, respectively. The crude fibre content was 2.81, 2.83 and 2.84 percent respectively, for extruded little millet based complementary health food with sugar, extruded little millet based probiotic complementary food with *L.acidophilus* and probiotic complementary food with *B.bifidum*. The energy density of extruded little millet based complementary health food with sugar, extruded little millet based probiotic complementary food with *L.acidophilus* and probiotic complementary food with *B.bifidum* was 364.42, 360.28 and 361.39 respectively. The total count for the extruded little millet based complementary health food with sugar was 1.32 log cfu/g and the probiotic counts were 9.81 log cfu/g for extruded little millet based probiotic complementary food with *B.bifidum* and 9.69 log cfu/gm for probiotic complementary food with *L.acidophilus*. Coliforms and yeast and moulds were absent in all the three samples of white ragi based probiotic complementary health foods. The study revealed that the probiotic organisms by dry blending could be successfully incorporated into the extruded formulation along with the honey and could contain sufficient number of the probiotic organisms in the prepared porridge to provide the health benefits of the probiotic health foods.

4.3.4 Preparation of RTU millet flakes

The present study was focused to work on production of ready-to-eat breakfast cereals in the form of flakes mainly to provide varieties of complementing foods to be given to the children of the age group of 2-5years instead of only malted food. Millet based flakes were developed by completely replacing the corn flour in the formulation. The flakes were prepared with foxtail millet, little millet, sorghum and white ragi keeping wheat flakes as control.

4.3.4.1 Sensory characteristics of the various millet flakes as a breakfast cereal with milk

Millet based flakes were developed by completely replacing the corn flour in the formulation. The flakes were prepared with foxtail millet, little millet, sorghum and white ragi keeping wheat flakes as control. Sensory evaluation of the developed millet flakes as a breakfast cereal was conducted keeping wheat flakes as control. The results of the study are depicted in Table-31. From among the millet flakes prepared, sorghum flakes were

Table 31: Sensory characteristics various millet flakes as a breakfast cereal with milk

Type of complementary health food formulation	Sensory scores on the 9 point Hedonic Scale			
	Colour and Appearance	Flavour	Body and Texture	Overall Acceptability
Wheat	7.80	7.94	8.21	7.91
Sorghum	7.70	7.81	7.68	7.72
Little millet	7.21	7.12	7.41	7.31
Foxtail millet	7.01	7.03	7.12	7.04
White ragi	7.51	7.65	7.69	7.62
CD	0.324	0.445	0.386	0.355

All values are average of three trials

adjudged best and comparable with that of the wheat flakes followed by the white ragi flakes, little millet flakes and foxtail millet flakes. The colour and appearance scores were 7.80, 7.70, 7.21, 7.01 and 7.51 for wheat flakes, sorghum flakes, little millet flakes, foxtail millet flakes and white ragi flakes, respectively. The flavor scores were 7.94, 7.81, 7.12, 7.03 and 7.65 respectively, for wheat flakes, sorghum flakes, little millet flakes, foxtail millet flakes and white ragi flakes. The body and texture scores were 8.21, 7.68, 7.41, 7.12 and 7.69 respectively, for wheat flakes, sorghum flakes, little millet flakes, foxtail millet flakes and white ragi flakes. Sensory scores awarded for overall acceptability attribute were 7.91, 7.72, 7.31, 7.04 and 7.62 for wheat flakes, sorghum flakes, little millet flakes, foxtail millet flakes and white ragi flakes respectively. The scores awarded to the sorghum flakes were the best among the millets followed by white ragi flakes, little millet flakes and foxtail millet flakes.

4.3.4.2 Sensory acceptability of millet flakes as breakfast cereal with hot milk, cold milk and as a masala snack

The millet flakes were served in different media and form such as millet flakes in hot milk, millet flakes in cold milk and millet flakes as masala snacks keeping wheat flakes as control. The results are shown in Table-32. The colour an appearance, flavour, body and texture and overall acceptability scores of wheat flakes in hot milk were 8.00, 8.00, 7.80 and 8.10 in hot milk; 7.80, 7.70, 8.20 and 7.70 in cold milk; 8.00, 8.20, 7.82 and 7.95 as masala snacks respectively. The respective sensory scores for foxtail millet flakes for colour an appearance, flavour, body and texture and overall acceptability in hot milk were 6.81, 7.12, 7.01 and 6.96 in hot milk; 7.22, 7.26, 7.21 and 7.23 in cold milk; 8.0, 7.90, 7.71 and 7.88 as masala snacks. The colour an appearance, flavour, body and

Table 32: Sensory acceptability of millet flakes as a breakfast cereal with hot milk, cold milk and as a masala snack

Type of complementary health food	Flakes with hot milk				Flakes with cold milk				Flakes as snack food			
	C & A	Flavour	B & T	O A	C & A	Flavour	B & T	O A	C & A	Flavour	B & T	O A
Wheat flakes	8.00	8.00	7.80	8.10	7.80	7.70	8.20	7.90	7.80	7.80	7.87	7.99
Foxtail millet flakes	6.81	7.12	7.01	6.96	7.22	7.26	7.21	7.23	8.00	7.90	7.71	7.88
Little millet flakes	6.90	7.30	7.10	7.10	7.38	7.35	7.39	7.36	8.13	8.05	7.87	7.90
Sorghum flakes	8.20	7.90	7.80	8.00	7.70	7.60	7.60	7.70	80.00	8.20	7.82	7.95
White ragi flakes	7.35	7.33	7.42	7.40	7.50	7.20	7.40	7.40	8.13	8.05	7.87	7.93
CD	0.210	0.345	0.451	0.423	0.231	0.362	0.472	0.342	0.231	0.210	0.32	0.23

* All values are average of three trials

texture and overall acceptability scores of little millet flakes in hot milk were 6.90, 7.30, 7.10 and 7.10 in hot milk; 7.38, 7.35, 7.39 and 7.36 in cold milk; 8.10, 8.05, 7.86 and 7.90 as masala snacks respectively. The colour an appearance, flavour, body and texture and overall acceptability scores of sorghum flakes in hot milk were 8.20, 7.90, 7.80 and 8.00 in hot milk; 7.70, 7.60, 7.60 and 7.70 in cold milk; 8.00, 8.20, 7.82 and 7.95 as masala snacks respectively. The respective sensory scores for white ragi flakes for colour an appearance, flavour, body and texture and overall acceptability in hot milk were 7.35, 7.33, 7.42 and 7.40 in hot milk; 7.50, 7.20, 7.40 and 7.40 in cold milk; 8.13, 8.05, 7.87 and 7.93 as masala snacks. The sensory acceptability of flakes revealed that the in all the three forms the sorghum flakes were the best among the millet blends which was awarded scores near to that of the control wheat flakes followed by white ragi flakes, little millet flakes and foxtail millet flakes. The developed products are given in plate-6.

4.3.4.3 Physico-chemical attributes and microbial quality of millet flakes

The physico-chemical attributes and microbial quality of the flakes prepared with foxtail millet, little millet, sorghum and white ragi were analyzed keeping wheat flakes as control. The results of the analysis are depicted in the Table -33. The water activity was 0.392, 0.299, 0.285, 0.339 and 0.367 for wheat flakes, foxtail millet flakes, little millet flakes, sorghum flakes and white ragi flakes, respectively. The results of the chemical composition of the RTU formulations of white ragi based complementary food are depicted in Table-33. The moisture content of wheat flakes, foxtail millet flakes, little millet flakes, sorghum flakes and white ragi flakes were 1.69, 1.52, 1.72, 1.69 and 2.73 per cent respectively. The fat content of the wheat flakes, foxtail millet flakes, little millet flakes, sorghum flakes and white ragi flakes were 0.30, 0.85, 0.95, 0.47 and 0.39 per cent

Sorghum flakes

White ragi flakes

Masala flakes

Plate 6: Ready-to-use sorghum, white ragi and masala flakes developed in the study

Table 33: Physico-chemical properties and microbiological quality of wheat and millet flakes

Attribute	Wheat Flakes	Foxtail millet flakes	Little millet flakes	Sorghum flakes	White ragi flakes
Physico-chemical properties					
Water Activity	0.392	0.299	0.285	0.339	0.367
Moisture (%)	1.69	1.52	1.72	1.69	2.73
Fat (%)	0.30	0.85	0.95	0.47	0.39
Protein (%)	12.13	11.32	10.81	11.32	12.64
Carbohydrates (%)	82.90	75.65	77.84	82.78	76.67
Crude fibre (%)	1.72	7.21	6.84	1.87	4.64
Ash (%)	1.26	3.45	1.84	1.87	2.93
Energy density (K.cal/100g)	382.82	355.53	363.15	380.63	360.75
Microbiological quality counts in log cfu/gm					
Total count	1.23	1.56	1.34	1.45	1.28
Coliforms	NIL	NIL	NIL	NIL	NIL
Yeast and moulds	NIL	NIL	NIL	NIL	NIL

All values are average of three trials

respectively. The respective protein content of flakes was 12.13, 11.32, 10.81, 11.32 and 12.64 per cent respectively, for wheat flakes, foxtail millet flakes, little millet flakes, sorghum flakes and white ragi flakes. The carbohydrate content was 82.90, 75.65, 77.84, 82.78 and 76.67 respectively, for wheat flakes, foxtail millet flakes, little millet flakes, sorghum flakes and white ragi flakes. The crude fibre content was 1.72, 7.21, 6.84, 1.87, and 4.64 per cent respectively, for wheat flakes, foxtail millet flakes, little millet flakes, sorghum flakes and white ragi flakes. The ash content of wheat flakes, foxtail millet flakes, little millet flakes, sorghum flakes and white ragi flakes was found to be 1.26, 3.45, 1.84, 1.82 and 2.93 per cent respectively. The energy density of wheat flakes, foxtail millet flakes, little millet flakes, sorghum flakes and white ragi flakes was 382.82, 355.53, 363.15, 380.63 and 360.75 respectively. Microbiological analysis results revealed that the total bacterial count was 1.23, 1.56, 1.34, 1.45 and 1.28 log cfu/gm respectively for wheat flakes, foxtail millet flakes, little millet flakes, sorghum flakes and white ragi flakes. Coliforms and yeast and moulds were absent in all the RTU flakes.

4.4 Bioassay studies

In order to evaluate the nutritional quality of developed complementary foods, bioassay study was conducted on albino rats (Wister strain). The results generated from bioassay studies are presented in Table 34, 35 and 36.

4.4.1 Effect of type of formulated complementary food on body weight gain of rats

The initial average weight of different groups of rats ranged between 32.2 and 34.50 g. Though initial weight of all groups of rats were almost similar but in the period of acclimatization of 5days the body weights have changed and the same are noted as the initial weights (Table-34). In the next subsequent weeks there was significant variation in average weight gained depending on the diet fed. The amount of weight increase in the control rats was from 60g to 125gm during the feeding period. However, In all the samples of complementary food fed rats the weight gain was found to be much higher than the control sample. The initial weight of the malted complementary group was 56.33-72.67g and weight gain in rats during the study for the malted food group ranged from 140.8g to 159.3g depending on the type of feed. The complementary food with white ragi and SMP resulted in highest weight gain compared to other malted foods. In the extruded complementary food group, the amount of weight gain was higher in little millet extruded product fed rat gained weight to 159g. Among extruded flakes the highest weight gain was observed in sorghum flake group. The activity of rats at the different stages of bioassay study is given in plate-7.

4.4.2 Effect of complementary food on FER, PER, NPU and blood glucose levels

All the foods given as feed to the rats were having almost similar FER (Table-35). The FER was highest (0.49) for white ragi with WPH containing product among malted complementary foods. Among extruded foods, FER of wheat food was 0.46 and 0.44 for little millet extruded complementary food. Among flakes, sorghum flakes FER was highest (0.50). The PER of control food was 1.46. However, the malted complementary food prepared with WPH was having highest PER (2.05) not only among malted foods but also compared to all other groups of foods used in the study. In extruded food group, little milled food PER was better than wheat food. Among flakes, the PER was ranging from 1.31 to 1.45 with highest being observed for little millet flakes. The NPU of the WPH containing food was highest at 82.5 per cent. For SMP containing products, NPU ranged from 71.2 to 76.5 per cent in malted complementary food group, 71.6-72.1 for

Table 34: Effect of feeding complementary foods on the body weight gain of rats

Complementary food GROUP	Initial Weight (g)	Final Weight (g)
Malted complementary food		
Control	60.83±2.77	125±1.82
MALTED WHEAT FLOUR WITH SMP and SUGAR	64±3.425	156.3±3.04
MALTED WHITE RAGI with Green gram and SUGAR	61.67±4.40	140.8±4.86
MALTED WHITE RAGI SMP and SUGAR	72.67±3.518	156.2±3.21
MALTED WHITE RAGI with WPH, SMP and SUGAR	69.67±2.728	158.3±5.11
MALTED WHITE RAGI (RTU) SMP with SUGAR	64.67±5.554	159.3±7.91
MALTED WHITE RAGI with SMP, SUGAR, Honey and *Bifidobacterium bifidum*	56.33±2.741	149±4.17
MALTED WHITE RAGI with SMP, SUGAR, Honey and *Lactobacillus acidophilus*	59.5±3.622	151.5±3.85
Extruded complementary food		
WHEAT EXTRUDED WITH SMP and SUGAR	68.5±4.53	152.3±3.68
LITTLE MILLET EXTRUDED FLOUR WITH SMP and SUGAR	66±2.338	159±5.12
Extruded flakes		
WHEAT FLAKES	68.33±5.408	154.3±7.32
FOX TAIL MILLET FLAKES	59.67±3.537	155±3.89
SORGHUM FLAKES	73.17±2.197	164.7±7.80
WHITE RAGI FLAKES	63.67±1.476	147.3±3.98
LITTLE MILLET FLAKES	63.5±2.473	153±5.32

Values expressed as Mean± SEM

Plate 7: Activity photos of rats at different stages during bioassay studies

Table 35: Feed Efficiency Ratio (FER), Protein Efficiency Ratio (FER) and Net Protein Utilization (NPU) of complementary foods

Type of Feed	FER	PER	NPU
Control	0.50	1.46	63.9
MALTED WHEAT FLOUR WITH SMP and SUGAR	0.45	1.65	75.2
MALTED WHITE RAGI with Green gram and SUGAR	0.44	1.42	62.1
MALTED WHITE RAGI SMP and SUGAR	0.47	1.72	76.5
MALTED WHITE RAGI with WPH, SMP and SUGAR	0.49	2.05	82.4
MALTED WHITE RAGI (RTU) SMP with SUGAR	0.45	1.76	72.1
MALTED WHITE RAGI with SMP, SUGAR, Honey and *Bifidobacterium bifidum*	0.47	1.73	73.1
MALTED WHITE RAGI with SMP, SUGAR, Honey and *Lactobacillus acidophilus*	0.44	1.69	73.5
Extruded complementary food			
WHEAT EXTRUDED WITH SMP and SUGAR	0.46	1.64	72.1
LITTLE MILLET EXTRUDED FLOUR WITH SMP and SUGAR	0.44	1.72	71.6
Extruded flakes			
WHEAT FLAKES	0.44	1.38	62.5
FOX TAIL MILLET FLAKES	0.46	1.30	60.4
SORGHUM FLAKES	0.49	1.31	62.3
WHITE RAGI FLAKES	0.50	142	65.1
LITTLE MILLET FLAKES	0.48	1.45	64.1

extruded complementary food group and 60.4 to 65.1 for extruded flakes group (Table-35). The blood glucose levels of the rats fed with control diet was 90.49mg/dl and the blood glucose levels of the rats fed with the treatment diet were 82.96 to 93.35mg/dl for malted food group, 73.50 to 100.30 for extruded food group and 76.22 to 88.32 for flakes group (Table-36). All the blood glucose levels were well within the acceptable range.

4.5 Storage studies

4.5.1 Storage stability of best adjudged RTU white ragi based complementary health food with SMP

Ready to use malted white ragi based vacuum dried complementary food developed in the study was packed in and Poly Ethylene Terephthalate (PET) sachets and Metalyzed polyester (MPE) subjected to Modified Atmospheric Packaging (MAP) by using admixture of CO_2 and N_2 at various proportions and stored at 30^{o}C. The effect of type of packaging material and the ratio of admixture on storage stability as measured in terms of Hydroxyl Methyl Furfural (HMF), Free Fatty Acid (FFA) and Peroxide Value (PV) is presented in the Tables 37, 38 and 39.

4.5.1.1 Effect of MAP on Hydroxyl Methyl Furfural (HMF) content of best adjudged RTU white ragi based complementary health food with SMP during storage

The effect of MAP and type of packaging material on Hydroxy Methyl Furfural (HMF) is presented in Table 37. With increase in the storage period from 0 to 180 days, there was significant increase in HMF values under both MAP and normal packaging system. The values increased from 1.81 to 6.82 in PET and 1.81 to 4.94 mg/kg in MPE

Table: 36: Effect of feeding complementary foods on the blood glucose levels of the rats

Type of Feed	Blood glucose (mg/dL)
Control	90.49±5.13
MALTED WHEAT FLOUR WITH SMP and SUGAR	93.35±1.16
MALTED WHITE RAGI with Green gram and SUGAR	88.6±4.07
MALTED WHITE RAGI SMP and SUGAR	82.96±5.38
MALTED WHITE RAGI with WPH, SMP and SUGAR	88.92±8.06
MALTED WHITE RAGI (RTU) SMP with SUGAR	86.52±5.63
MALTED WHITE RAGI with SMP, SUGAR, Honey and *Bifidobacterium bifidum*	90.58±7.85
MALTED WHITE RAGI with SMP, SUGAR, Honey and *Lactobacillus acidophilus*	85.6±6.92
WHEAT EXTRUDED WITH SMP and SUGAR	73.5±9.61
LITTLE MILLET EXTRUDED FLOUR WITH SMP and SUGAR	100.3±6.80
WHEAT FLAKES	88.32±7.01
FOX TAIL MILLET FLAKES	86.89±6.93
SORGHUM FLAKES	87.35±3.98
WHITE RAGI FLAKES	76.22±3.28
LITTLE MILLET FLAKES	79.46±3.15

Table 37: HMF (mg/kg) content of RTU vacuum dried white ragi based complementary health food during storage at 30±1°C

Packaging material	CO_2:N_2 ratio	Storage (days)							CD
		0	30	60	90	120	150	180	
MPE	C	1.81	2.13	2.24	2.81	3.24	4.01	4.94	0.96
	20:80		1.89	1.97	2.13	2.28	2.45	2.68	
	40:60		1.91	2.14	2.32	2.46	2.62	2.92	
	60:40		1.94	2.25	2.41	2.54	2.78	3.19	
	80:20		1.95	2.29	2.45	2.68	3.01	3.48	
CD		0.35							
PET	C	1.81	2.81	3.68	4.53	5.42	5.62	6.82	0.32
	20:80		2.11	2.24	2.47	2.70	3.21	3.67	
	40:60		2.58	3.01	3.41	4.01	4.92	5.68	
	60:40		2.71	3.15	3.7	4.10	5.20	6.12	
	80:20		3.02	3.32	3.82	4.31	5.62	6.42	
CD		0.49							

after 180 days under normal atmosphere packaging. The HMF content of product stored under MAP at 20:80 CO_2 and N_2 ratio was found to be lesser as compared to other levels of MAP. The best adjudged RTU white ragi based complementary health food with SMP stored in MPE pouches contained lesser HMF as compared to product stored in PET pouches at all duration of storage as well as at levels of CO_2 and N_2 admixtures. The HMF content after 180 days of storage was 3.67 with respect to PET and 2.92mg/kg with respect to MPE at 20:80 admixtures of CO_2 and N_2 ratio.

4.5.1.2 Effect of packaging material and MAP on Free Fatty Acids (FFA) of best adjudged RTU white ragi based complementary health food with SMP during storage

The effect of MAP and type of package material on Free Fatty Acids (FFA) of functional weaning food is presented in Table 38. The FFA values of best adjudged RTU white ragi based complementary health food with SMP stored at ambient condition increased from 0.68 to 2.48 in PET and 0.68 to 1.98 per cent oleic acid in MPE packaging after 180 days in case of normal atmosphere packaging. However, in the products stored under admixture of 20:80 CO_2 to N_2 ratio, the FFA content after 180 days of storage was 1.34 per cent oleic acid for PET packages and 1.19 per cent oleic acid for MPE. The powders packed in PET and MPE pouches under MAP (20:80) were significantly better as compared to control. However, increased level of CO_2 to N_2 ratio above 20:80, there was significant increase in FFA of the product in case of both PET and MPE. Irrespective of packaging material used, the product stored under 20:80 CO_2 to N_2 ratio was found to be better for storage of best adjudged RTU white ragi based complementary health food with SMP.

Table 38: FFA (per cent oleic acid) content of RTU vacuum dried white ragi based complementary health food during storage at 30±1°C

Packaging material	CO_2:N_2 ratio	Storage (days)							CD
		0	**30**	**60**	**90**	**120**	**150**	**180**	
MPE	**C**	0.61	0.93.	1.24	1.44	1.62	1.83	1.98	0.13
	20:80		0.73	0.82	0.94	1.01	1.14	1.19	
	40:60		0.88	1.01	1.17	1.26	1.32	1.42	
	60:40		0.92	1.12	1.23	1.34	1.42	1.48	
	80:20		0.99	1.17	1.28	1.42	1.68	1.83	
CD		0.115							
PET	**C**	0.61	0.98	1.32	1.54	1.84	2.15	2.48	0.23
	20:80		0.83	1.01	1.12	1.19	1.26	1.34	
	40:60		0.92	1.12	1.23	1.31	1.39	1.48	
	60:40		0.98	1.18	1.29	1.41	1.48	1.54	
	80:20		1.05	1.24	1.48	1.56	1.73	1.92	
CD		0.092							

4.5.1.3 Effect of packaging material and Modified Atmosphere Packaging (MAP) on peroxide value of best adjudged RTU white ragi based complementary health food with SMP during storage

The effect of MAP and type of packaging material on PV of best adjudged RTU white ragi based complementary health food with SMP during storage is presented in Table 39. The extent of increase in PV during storage was found to be significant with respect to both PET and MPE in case of atmosphere packaging. However, in case of MAP the extent of increase in PV was significantly lesser as compared to control packaging. The powders packed in PET and MPE pouches under MAP (20:80) were found to be significantly better compared to control and other levels of CO_2 and N_2 ratio. The product packed with CO_2 and $N_{2,}$ ratio of 20:80 MAP was found to be better for storage of complementary food irrespective of the packaging material. Complementary food stored in MPE pouches has shown lesser PV compared to the product stored in PET pouches at all duration of storage as well as at all the levels of CO_2 and N_2 admixtures. The PV after 180 days of storage was 0.32 with respect to PET, where as it was only 0.15 m.eq/kg of oxygen with respect to PET at 20:80 admixtures of CO_2 and N_2.

4.5.2 Storage stability of the ready to cook malted millet based complementary health foods

The best adjudged RTC malted millet based complementary health foods with SMP were packed into the MPE pouches and stored at 30±1^{o}C. The overall acceptability and microbial quality of ready-to-cook (RTC) millet based complementary health foods during storage at 30±1^{o}C are depicted in Table-40. The overall acceptability scores were consistently decreased during storage from 7.93 to 6.01 after 60 days of storage period

Table 39: Peroxide value (m.eq/kg) of RTU vacuum dried white ragi based complementary health food during storage at 30±1°C

Packaging material	CO_2:N_2 ratio	Storage (days)							CD
		0	30	60	90	120	150	180	
MPE	**C**	NIL	0.13	0.21	0.32	0.46	0.59	0.78	0.18
	20:80		0.01	0.03	0.06	0.09	0.12	0.15	
	40:60		0.04	0.09	0.13	0.21	0.31	0.38	
	60:40		0.07	0.11	0.18	0.27	0.39	0.51	
	80:20		0.09	0.17	0.26	0.39	0.52	0.64	
CD		0.028							
PET	**C**	NIL	0.18	0.27	0.42	0.68	0.82	0.92	0.12
	20:80		0.03	0.06	0.13	0.21	0.27	0.32	
	40:60		0.08	0.12	0.19	0.29	0.43	0.56	
	60:40		0.12	0.19	0.28	0.37	0.52	0.65	
	80:20		0.15	0.23	0.34	0.51	0.68	0.86	
CD		0.036							

Table 40: Overall acceptability and microbial quality of ready-to-cook (RTC) millet based complementary health foods during storage at 30±1°C

Type of Complementary food	No of days of storage					
	0	15	30	45	60	75
	Overall acceptability scores					
Foxtail millet based complementary food	7.93	7.62	7.23	6.78	6.01	-
Little millet based complementary food	8.02	7.61	7.24	6.91	6.24	-
Sorghum based complementary food	7.97	7.43	7.11	6.83	6.32	-
White Ragi based complementary food	8.17	8.01	7.45	7.01	6.28	-
Microbial Quality						
Type of Complementary food	**No of days of storage**					
	0	**15**	**30**	**45**	**60**	**75**
	Total Count in log cfu/g					
Foxtail millet based complementary food	4.36	4.39	4.71	4.92	5.62	-
Little millet based complementary food	3.96	4.24	4.58	4.69	4.92	-
Sorghum based complementary food	3.25	3.93	4.34	4.58	4.81	-
White Ragi based complementary food	3.05	3.62	4.23	4.45	4.73	-

for malted foxtail millet based complementary food. The microbial load at the 0th day was 4.36 log cfu/g was consistently increased as the storage period increased. The RTC malted foxtail millet based complementary food was acceptable only up to 45 days. The overall acceptability scores were 8.05 initially were decreased to 6.24 after 60 days of storage period for malted little millet based complementary food. The microbial load at the 0th day was 3.96 log cfu/g was increased as the storage period increased to 4.92 log cfu/g after 60days of storage period. The RTC malted little millet based complementary food was acceptable up to 60 days. The overall acceptability scores were 7.97 at 0th day were decreased to 6.32 after 60 days of storage period for malted sorghum based complementary food. The microbial load at the 0th day was 3.25 log cfu/g was increased as the storage period increased to 4.81 log cfu/g after 60 days of storage period. The RTC malted sorghum based complementary food was acceptable up to 60 days. The overall acceptability scores were 8.17 initially were decreased to 6.28 after 60 days of storage period for malted white ragi based complementary food. The microbial load at the 0th day was 3.05 log cfu/g was increased as the storage period increased to 4.73 log cfu/g after 60days of storage period. The RTC malted white ragi based complementary food was acceptable up to 60 days.

4.5.3 Storage stability of the ready to use millet based complementary health foods

The best adjudged RTU malted white ragi based vacuum dried complementary health food with SMP, RTU little millet based extruded complementary health food with SMP, RTU sorghum flakes and RTU white ragi flakes were packed into the MPE pouches and stored at 30±1°C. The overall acceptability and microbial quality of ready-to-use (RTU) millet based complementary health foods during storage at 30±1°C are depicted in Table-41. The overall acceptability scores were consistently decreased during storage from 8.06 to 7.10 after 180 days of storage period for RTU malted white ragi based vacuum dried complementary health food with SMP. The microbial load at the 0th day was 2.91 log cfu/g was consistently increased as the storage period increased to 4.98 log cfu/g at the end of storage period of 180days. The RTU malted white ragi based vacuum dried complementary health food with SMP was acceptable up to 180days. The overall acceptability scores were 8.12 initially were decreased to 7.24 after 180 days of storage period for RTU little millet based extruded complementary health food with SMP. The microbial load at the 0th day was 1.32 log cfu/g was increased as the storage period increased to 2.92 log cfu/g after 180days of storage period. The RTU little millet based extruded complementary health food with SMP was acceptable up to 180 days. The overall acceptability scores of sorghum flakes were 8.00 at 0th day were decreased to 7.21 after 180 days of storage period. The microbial load of sorghum flakes at the 0th day was 1.45log cfu/g, was increased as the storage period increased to 3.54 log cfu/g after 180 days of storage period. The sorghum flakes were acceptable up to 180 days. The overall acceptability scores were 7.40 initially for white ragi flakes were decreased to 7.06 after 180 days of storage period. The microbial load at the 0th day was 1.36 log cfu/g was increased as the storage period increased to 3.72 log cfu/g after 180 days of storage period. The white ragi flakes were acceptable up to 180 days. In all the samples coliforms and yeast and moulds were absent. From the study, it was inferred that the RTU white ragi based complementary health food, RTU little millet based extruded complementary food and RTU sorghum flakes and RTU white ragi flakes were acceptable up to 180days at 30±1°C when packed in MPE pouches.

Table 41: Overall acceptability and Microbial quality of ready-to-use (RTU) millet based complementary health foods during storage at 30±1°C

Type of Complementary food	No of days of storage						
	0	30	60	90	120	150	180
	Overall acceptability scores						
RTU white ragi based vacuum dried complementary food	8.06	8.01	7.84	7.65	7.42	7.24	7.10
RTU little millet based extruded complementary food	8.12	8.05	7.92	7.82	7.66	7.43	7.24
RTU sorghum flakes	8.00	7.92	7.87	7.65	7.42	7.28	7.21
RTU white ragi flakes	7.40	7.31	7.23	7.20	7.14	7.10	7.06

Microbial Quality

Type of Complementary food	No of days of storage						
	0	30	60	90	120	150	180
	Total Count in log cfu/g						
RTU white ragi based vacuum dried complementary food	2.91	3.14	3.45	3.78	4.24	4.60	4.98
RTU Little millet based extruded complementary food	1.32	1.40	1.52	1.76	1.99	2.38	2.92
RTU sorghum flakes	1.45	1.72	1.91	2.53	2.92	3.26	3.72
RTU white ragi flakes	1.36	1.67	1.93	2.56	2.97	3.36	3.72

Viability of probiotic organisms

Type of Complementary food	No of days of storage						
	0	30	60	90	120	150	180
	Viable Count in log cfu/g						
RTU white ragi based vacuum dried complementary food with *B.bifidum*	9.31	8.12	7.24	6.39	5.61	4.32	3.56
RTU little millet based extruded complementary food with *B.bifidum*	9.81	8.93	7.81	6.83	5.74	4.73	3.62
RTU white ragi based vacuum dried complementary food with *L.acidophilus*	9.66	8.42	7.62	6.73	5.24	4.30	3.21
RTU little millet based extruded complementary food with *L.acidophilus*	9.69	8.39	7.53	6.42	5.03	4.12	3.04

The viability of probiotic organisms during storage of the best adjudged RTU malted white ragi based vacuum dried honey blended probiotic complementary health food with SMP, RTU little millet based extruded honey blended probiotic complementary health food with SMP were packed into the MPE pouches and stored at 30±1^{o}C. The overall acceptability and microbial quality of ready-to-use (RTU) millet based complementary health foods during storage at 30±1^{o}C are depicted in Table-41. A progressive decrease in viable count of both *B.bifidum* and *L.acidophilus* was observed from 9.31 log cfu/g to 3.56 log cfu/g in RTU malted white ragi based vacuum dried honey blended probiotic complementary health food with SMP with the progress of storage period from 0 to 180 days. The viable counts of *B.bifidum* and *L.acidophilus* were 3.56 and 3.21 log cfu/g at the end of 180 days of storage. The viability beyond 6.0 log cfu/g could be maintained only up to 90 days of storage for both the probiotic organisms. Similarly, the decrease in viable count of both *B.bifidum* and *L.acidophilus* was observed in RTU little millet based extruded honey blended probiotic complementary health food with SMP with the progress of storage period from 0 to 180 days. The viable counts of *B.bifidum* and *L.acidophilus* were 3.62 and 3.04 log cfu/g at the end of 180 days of storage. The viability beyond 6.0 log cfu/g could be maintained only up to 90 days of storage for both the probiotic organisms. In all the samples coliforms and yeast and moulds were absent. Thus, the RTU malted white ragi based vacuum dried honey blended probiotic complementary health food with SMP and RTU little millet based extruded honey blended probiotic complementary health food with SMP could be stored for 90days to harness the benefit of the probiotic products.

DISCUSSION

V. DISCUSSION

Complementary feeding typically covers the period from 6 - 24 months of age. This is a critical period of growth during which nutrient deficiencies and illnesses contribute globally to higher rates of under nutrition among children less than five years of age. A number of successful strategies have been developed to improve complementary feeding practices in low and middle-income countries. But there is an urgent need for developing a suitable complementary food for the 2-5year age group, keeping in view of above need in mind, this investigation was undertaken to explore the possibilities of utilization of millets in formulating complementary food. The results obtained in the present investigation are discussed here under.

5.1 Composition of ingredients used in formulation of complementary health food

The chemical compositions of the ingredients play vital role in deciding of the formulations to be prepared and the resultant composition of the developed product. The chemical composition of the raw flours used for the preparation of extruded flours and also in preparation of flakes. The chemical composition of the raw flours is depicted in Table-1. The moisture, fat, protein, carbohydrate, crude fibre, and ash content of the raw wheat flour, green gram, foxtail millet flour, little millet flour, sorghum flour and white ragi flour were in accordance with the results of the composition of the foods reported by Gopalan *et al.*, 1991; FAO, 1995; and FAO, 1998. The compositional values in raw white ragi flour for moisture, fat, protein, carbohydrate, crude fibre, and ash content were 9.67, 1.90, 12.77, 68.06, 4.70 and 2.90 per cent. The energy density of the raw white ragi flour was 340.42 kcal/100g.The results were in agreement wih the results of Ravishankar *et al.*, 2015.

The composition of the malted flours of small millets, green gram and sorghum were used for the preparation of complementary food is depicted in Table-1. The moisture, fat, protein, carbohydrate, crude fibre, and ash content of the malted wheat flour and malted green gram flour were comparable with the reports of the earlier workers Gokavi, 2001; swamy, 2003 and Rani, 2006. The composition of malted foxtail millet flour, malted little millet flour were in accordance with the results of Chandru, 2010 and Ranganna, 2011. The malted sorghum flour had 5.92, 2.65, 10.86, 76.97, 2.00, and 1.60 per cent of moisture, fat, protein, carbohydrate, crude fibre, and ash content respectively with the energy density of 375.17 kcal/100g. SMP used for the preparation of complementary food in the present investigation had the moisture, fat, protein, carbohydrate, crude fibre, and ash content of 4.1, 0.0, 36.2, 54.5, 0 and 5.20 per cent respectively with the energy density of 362.80kcal/100g confirming to the present FSSAI standards. The respective compositional values in WPH for moisture, fat, protein, carbohydrate, crude fibre, and ash content were 5.3, 6.8, 79.0, 6.60, 0.0, and 2.30 per cent with the energy density of the WPH was 403.60 kcal/100g were confirming to the certificate of analysis provided by the ingredient supplier company.

The extruded flours were used in the study for the formulation of RTU extruded complementary health food and the chemical composition of the extruded flours is depicted in Table-1. The moisture, fat, protein, carbohydrate, crude fibre, and ash content of the extruded wheat flour was found to be 5.69, 1.89, 13.47, 75.63, 2.12 and 1.20 per cent respectively with the energy density of 373.41kcal/100g. Extruded foxtail millet flour had 4.36, 1.81, 12.24, 71.84, 2.65 and 7.10 per cent of moisture, fat, protein, carbohydrate, crude fibre, and ash content respectively with the energy density of 352.61 kcal/100g. The moisture, fat, protein, carbohydrate, crude fibre, and ash content of the extruded little millet flour was observed to be 4.20, 1.95, 9.68, 71.85, 4.80 and 7.52 per cent with the energy density of 343.67 kcal/100g. The respective compositional values in extruded white ragi flour for moisture, fat, protein, carbohydrate, crude fibre, and ash content were 3.80, 1.43, 11.15, 78.44, 2.20 and 2.98 per cent. The energy density of the extruded white ragi flour was 371.23 kcal/100g. Extruded sorghum flour had 3.60, 2.91, 10.20, 79.41, 2.12 and 1.76 per cent of moisture, fat, protein, carbohydrate, crude fibre, and ash content respectively with the energy density of 384.69 kcal/100g. However, literature available is scanty on the compositional aspects of the extruded flours but the literature concentrated on the extruded products development.

5.2 Formulation of millet based complementary health food

The millet based complementary foods were prepared using foxtail millet, little millet, sorghum and white ragi. The results of the formulation of the complementary foods, their gelatinization characteristics in the form of porridge, amino acid profiles, physico-chemical, rheological attributes and microbial quality of the developed complementary foods are discussed here under.

5.2.1 Formulation of foxtail millet based complementary health food

The foxtail millet complementary food was formulated by blending various levels of malted millet flours. With the increase in the level of foxtail millet malt from 0 to 100 per cent there was decrease in the scores pertaining to color and appearance, However, the statistically there was no significant difference among the blends in terms of colour and appearance (CD=0.677). With increase in the level of foxtail millet malt replacement there was slight decrease in the scores pertaining to flavour attributes. But the decrease in the flavour scores was insignificant. Body and texture of the complementary food were also showed decreasing trend upon replacement of wheat with foxtail millet malt. The scores pertaining to body and texture/consistency attributes and overall acceptability attributes decreased with increase in the level of foxtail millet malt in the complementary food. However, the decreased score with respect to consistency and overall acceptability attributes upon increased level of replacement was insignificant. The complementary food was formulated by replacing malted green gram flour with SMP at 25, 50, 75 and 100 per cent keeping malted green gram blended complementary food as control. The effects of replacement of green gram protein with SMP on sensory characteristics were evaluated. Upon increase in the incorporation level of SMP in the complementary food there was a consistent increase in the scores with respect to the colour and appearance were observed. Similarly, the flavour scores were also increased upon replacement of green gram with SMP. The score upon 100 percent replacement with SMP was significant (CD=0.33) in comparison with the control. The body and texture scores increased upon SMP incorporation in the complementary food and the increase in score with 100 per cent SMP was statistically significant compared to the green gram based complementary food.

As the SMP level in the complementary food increased, sensory scores of overall acceptability attribute were also significantly increased. Milk proteins are superior quality proteins. They possess good functional properties primarily because of their unique amino acids composition as; they provide essential amino acids required for infant and adult nutrition and also due to desirable physico-chemical attribute (Harwalky, 1993). Milk powders are extremely useful products and as this realization grows, so does the demand for a high quality product. Consumers can benefit from the durability, convenience, and stability to microbial spoilage of these products (Schwambach and Peterson, 2006). In the present investigation, the SMP incorporation increased the sensory acceptability of the resultant product.

Increasing in the level of WPH there was improvement in color and appearance, flavor, body and texture/consistency and overall acceptability of the product was there up to a level of 50 per cent replacement (Table-4). Further increase to 75 per cent level decreased the score with respect all the sensory attributes. The increase in flavour scores was slightly higher as compared to control. However, above 50 per cent level, there was significant decrease in the scores awarded to the flavour attribute was observed. It was evident from the result that, body and texture improved upon substitution of SMP with WPH up to 50 per cent level, thereafter the scores for body and texture attribute decreased. The scores awarded for overall acceptability attributes followed similar pattern as that of other sensory attributes. Substitution of SMP with WPH had increased the overall acceptability attribute up to 50 per cent. However, above 50 per cent level scores significantly decreased with respect to overall acceptability attribute in comparison with control. Whey solids could be effectively used and should be exploited in novel food formulations to overcome the nutritional deficiencies in grains and legumes. Because of their high quality proteins, particularly the sulphur containing amino acids and acts as a balancing ingredient in weaning food formulation (Makhal *et al.,* 2003). Whey proteins contain certain inherent bioactivity which can be further nurtured and enhanced by enzymatic hydrolysis (Jayaprakasha *et al.*, 2005). The results reveal that the whey protein hydrolysate could be an important ingredient in formulation of complementary foods with health benefits.

The Gelatinization of the starch present in the product influences the body and texture of the product and the consistency in porridge. The results of the study are depicted in Figure-1. From the results, it was inferred that no single time temperature combination can be fixed for cooking time to prepare porridge and the cooking conditions could be stated as bring down to boil and wait till the development of viscosity. The amino acid profile in the form of amino acid sequences obtained in MALDY-MS is shown in Figure 3a, 3b and 3c. The complementary food containing green gram has very few amino acids in the formulated product. However, the product with WPH had almost all the essential amino acids in the product.

The optimized blends of foxtail millet based complementary health foods with green gram; SMP and WPH were analyzed for various physical, chemical and microbiological parameters. The particle size distribution was observed to be ranging from 2µ to 632µ. However, the maximum per cent (80 volume %) of the particles are below 200µ in all the three types of foxtail millet based complementary health foods. Physical characteristics including particle size, swelling power, solubility and dispersibility are the supplementary factors which determine and influence sensory qualities and thus the intake. Particle size of the flour varies depending upon the mill, grinding pressure, grain sample and also endosperm texture of the grains Finer the flour, greater is the tendency to form lumps on the other hand coarser the particles grittier is the porridge (Kulkarni *et al* 1991), hence particles of <250μ are preferred for better consistency of the porridge. The results of the present study are in agreement with those reported by Itagi (2003) and Shaila (2010) for complementary food indicating the milling perfection. The tri-stimulus colour values (L* a* b*) of green gram, SMP and WPH added foxtail millet based complementary food is presented in Table-5 and the slight higher L* upon SMP suggesting brighter colour of the product. The respective pH of the green gram, SMP and WPH complementary foods were 6.43, 6.58 and 6.84. The water activity of the optimized complementary foods was 0.417 for green gram blended, 0.418 for the product with SMP and 0.423 for the product with WPH which bring about enzymatic changes during storage. The results of the chemical composition of the optimized formulations of foxtail millet based complementary food are depicted in Table-5. The increased protein content of complementary food with SMP and WPH was depicting increased level of substitution of SMP and WPH has increasing effect on the protein content of complementary food which is due to the higher protein content of the SMP and WPC than green gram. Carbohydrate content in the green gram, SMP and WPH added complementary foods were decreasing with increased level of WPH in the blend. The complementary food crude fibre content decreased with increased level of SMP and WPH. Increased level of substitution of SMP and WPH led to increased ash content of the complementary food. The energy density of foxtail millet based complementary health food was 368.66, 377.7 and 378.83 for green gram, SMP and WPH containing complementary food respectively were according to the BIS specification (IS: 1656, 1969) of 300-400kcal for composite mixes. Microbial analysis results revealed that TBC were in the acceptable level of FSSAI standards for malted foods, Coliforms were absent in all the three samples of foxtail millet based complementary health foods. The flow chart for preparation of foxtail millet based complementary health food is given in Fig. 33.

5.2.2 Formulation of little millet based complementary health food

The malted wheat flour used in the standard formulation was replaced with malted little millet flour at 25, 50, 75 and 100 per cent levels. The effect of replacement of malted wheat flour with malted little millet flour on sensory acceptability of little millet based complementary food is depicted in Table-6. Increase in the level of malted little millet flour from 0 to 100 per cent increased scores pertaining to color and appearance. There was significant difference between the 100 per cent little millet flour blend in terms of colour and appearance with that of the control. With increase in the level of malted little millet flour in the product significantly increased the flavor attribute scores. The body and texture scores of the complementary food showed decreasing trend initially however the extent of decrease was insignificant. But further increase in the flour in the blend to higher levels resulted in increasing of the body and texture scores reflecting the improvement in the consistency of the porridge with the incorporation of malted little millet flour in the product. The improvement in the overall acceptability was significant (0.354) upon complete replacement of the wheat flour with little millet flour in the complementary food. The complementary food was formulated by adding SMP in place of malted green gram flour at 25, 50, 75 and 100 per cent keeping malted green gram blended complementary food as control.

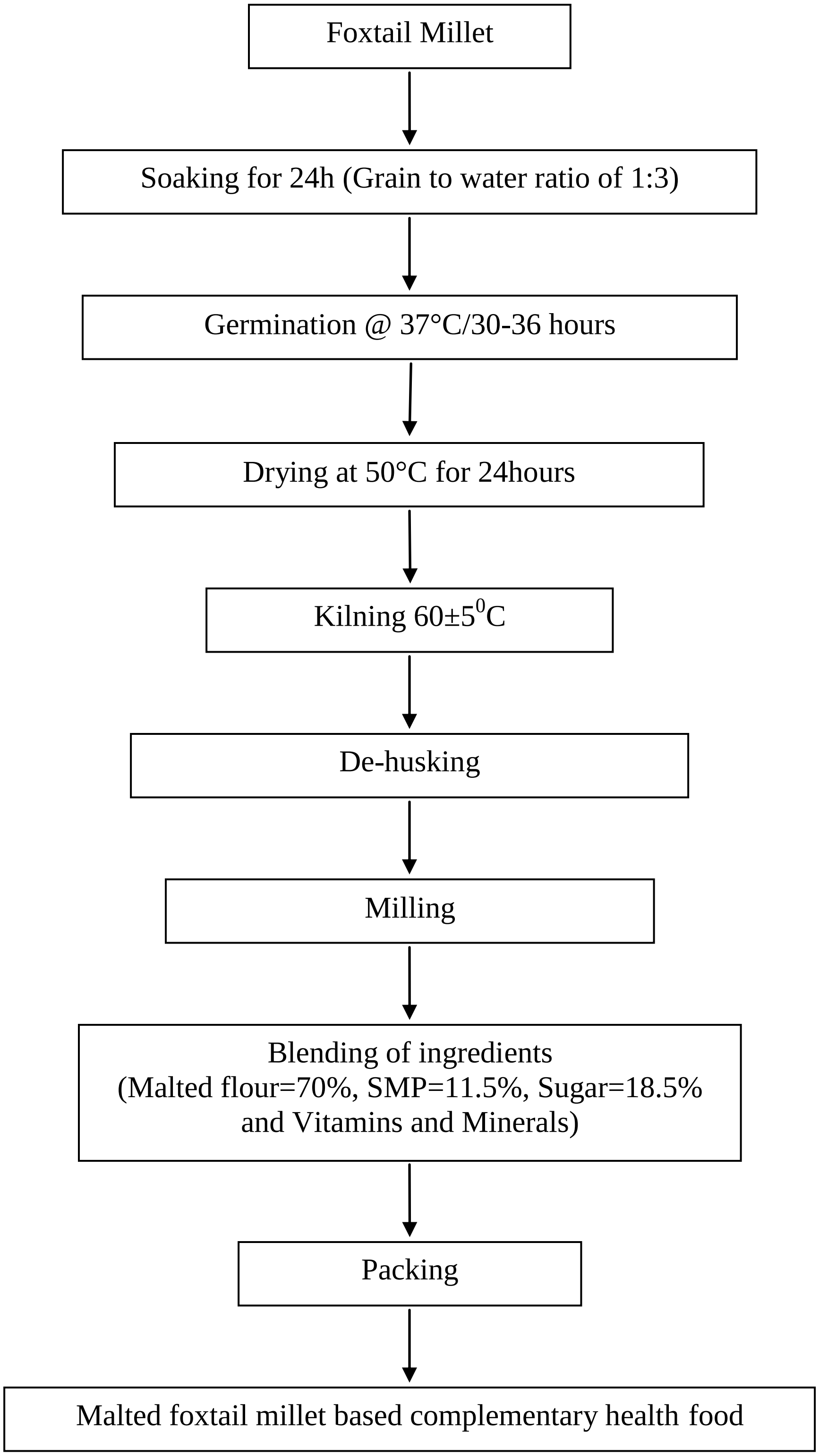


Fig. 33: Flow diagram for the development of malted foxtail millet based Ready-to-Cook (RTC) complementary health food

The effects of replacement of green gram protein with SMP on sensory characteristics were evaluated. The results are presented in Table-7. As the incorporation level of SMP in the complementary food increased, there was a consistent increase in the scores with respect all the sensory characteristics of the resultant product. The flavour scores awarded for SMP containing little millet malt based complementary food showed significant increase in the flavor scores at all the levels of incorporation (CD=0.213). The body and texture scores were also significantly increased (0.414) upon addition of SMP. As the SMP level in the complementary food increased, sensory scores of overall acceptability attribute were also significantly increased. The results of the study inferred that best product could be obtained by incorporating SMP completely in place of green gram. Milk proteins are superior quality proteins. They possess good functional properties primarily because of their unique amino acids composition as; they provide essential amino acids required for infant and adult nutrition and also due to desirable physico-chemical attribute (Harwalky, 1993). Milk powders are extremely useful products and as this realization grows, so does the demand for a high quality product. Consumers can benefit from the durability, convenience, and stability to microbial spoilage of these products (Schwambach and Peterson, 2006). In the present investigation, the SMP incorporation increased the sensory acceptability of the resultant product.

The effect of replacement of SMP with WPH on sensory attributes of complementary food is presented in Table-8. Increase in the level of WPH in the blend slight decrease in the colour and appearance scores was observed. However, the extent of reduction was insignificant suggesting no difference among the different blends. It is observed that increase in the level of substitution did not have the significant influence on the flavour of the resultant product. It was evident from the result that, body and texture did not significantly wary upon substitution of SMP with WPH. The scores awarded for overall acceptability attributes followed similar pattern as that of other sensory attributes. Complete replacement of SMP with WPH had no effect on the overall acceptability attribute in comparison with control. From the study, it was opined that SMP could be completely replaced with WPH to have the benefit of the protein enhancement. Whey solids could be effectively used and should be exploited in novel food formulations to overcome the nutritional deficiencies in grains and legumes. Because of their high quality proteins, particularly the sulphur containing amino acids and acts as a balancing ingredient in weaning food formulation (Makhal *et al.*, 2003). Whey proteins contain certain inherent bioactivity which can be further nurtured and enhanced by enzymatic hydrolysis (Jayaprakasha *et al.*, 2005). The results reveal that the whey protein hydrolyzate could be an important ingredient in formulation of complementary foods with health benefits. In the present investigation, SMP could be completely replaced with WPH to have the benefit of the protein enhancement in the little millet based complementary food. The Gelatinization of the starch present in the product influences the body and texture of the product and the consistency in porridge. The results of the study are depicted in Figure-4. From the results, it was inferred that no single time temperature combination can be fixed for cooking time to prepare porridge and the cooking conditions could be stated as bring down to boil and wait till the development of viscosity. The Rheological characteristics of the best adjudged little millet based complementary food containing SMP using Anton paar rheometer are depicted in the

Figure 5. The viscosity of the porridge could have influenced the body and texture scores difference (Table-8) upon increasing the level of replacement of type of protein as general and incorporation of SMP in particular. The amino acid profile in the form of amino acid sequences obtained in MALDY-MS is shown in Figure 7a, 7b and 7c. The complementary food containing green gram has very few amino acids in the formulated product. The same was true with the SMP containing complementary food but more essential amino acids. However, the product with WPH had almost all the essential amino acids in the product.

The optimized blends of little millet based complementary health foods with green gram; SMP and WPH were analyzed for various physical, chemical and microbiological parameters. The results of the study are depicted in Table-9 and Figure-6. The particle size distribution revealed that maximum per cent of the particles were below 288µ in little millet based complementary health foods. Finer the flour, greater is the tendency to form lumps on the other hand coarser the particles grittier is the porridge (Kulkarni *et al* 1991), hence particles of <250µ are preferred for better consistency of the porridge.

The tri-stimulus colour values (L* a* b*) of green gram, SMP and WPH added little millet based complementary food revealed higher L* in all types of blends which is due to whiter colour of the little millet. Upon blending SMP, the product becomes brighter. The respective pH of the green gram, SMP and WPH complementary foods were 6.27, 6.37 and 6.75. The water activity of the optimized complementary foods was 0.392 for green gram blended, 0.410 for the product with SMP and 0.425 for the product with WPH. The results of the chemical composition of the optimized formulations of little millet based complementary food are depicted in Table-9. The protein content of complementary food with green gram, SMP and WPH depicted increased level of substitution of SMP and WPH has enhancement effect on the protein content and decreased carbohydrate content of complementary food. The crude fibre content decreased with increased level of SMP and WPH. Increased level of substitution of SMP and WPH led to increased ash content of the complementary food. The energy density of little millet based complementary health food were according to the BIS specification (IS: 1656, 1969) of 300-400kcal for composite mixes. Microbial analysis results revealed that TBC were in the acceptable level of FSSAI standards for malted foods, Coliforms were absent in all the three samples of little millet based complementary health foods. The flow chart for preparation of little millet based complementary health food is given in Fig. 34.

5.2.3 Formulation of sorghum based complementary health food

The malted wheat flour used in the standard formulation was replaced with malted sorghum flour. The effect of replacement of malted wheat flour with malted sorghum flour on sensory acceptability of sorghum based complementary food is depicted in Table-10. Increase in the level of malted sorghum flour from 0 to 100 per cent increased scores pertaining to color and appearance however the extent of increase was insignificant. The flavour scores were increased initially up to 50 per cent with increase in the level of malted sorghum flour and started decreasing when the sorghum flour level. The change in the score was insignificant (CD=0.646) between the levels even though the best score was at 50 per cent levels. Body and texture of the complementary food were

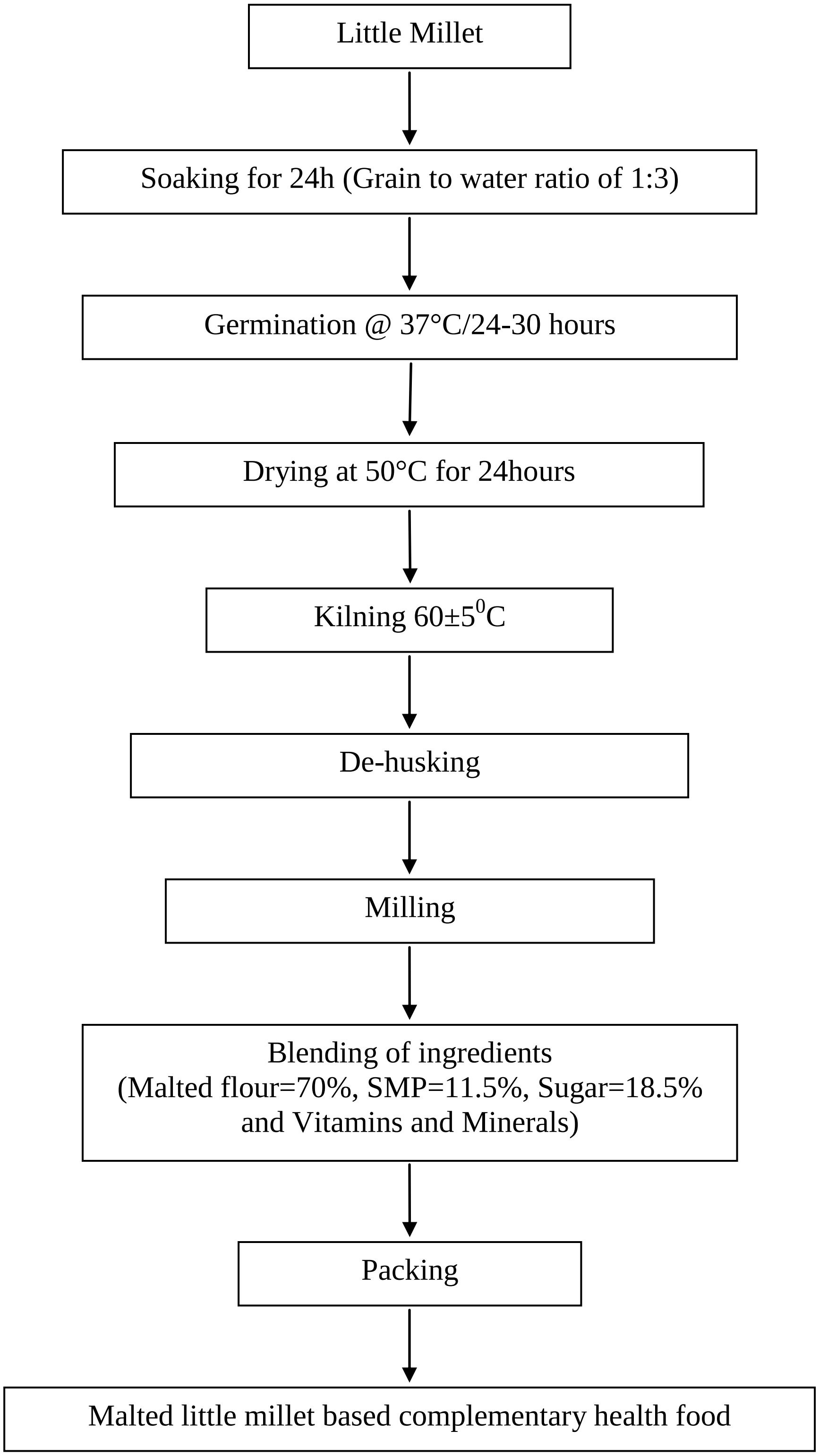


Fig. 34: Flow diagram for the development of malted little millet based Ready-to-Cook (RTC) complementary health food

also showed increasing trend upon replacement of wheat with sorghum malted flour however the extent of increase was insignificant reflecting the consistency of the porridge were increased with the incorporation up to 50 per cent level of malted sorghum flour and decreased slightly beyond 50 per cent. The slight decrease in the overall acceptability scores beyond 50 per cent level was observed. The results of the study showed that best acceptable sorghum based complementary food could be prepared from incorporation of sorghum only up to 50 percent in place of wheat.

The malted sorghum based complementary food was formulated by replacing malted green gram flour with SMP keeping malted green gram blended complementary food as control. The effects of replacement of green gram protein with SMP on sensory characteristics are presented in Table-11. As the incorporation level of SMP in the complementary food increased, there was a consistent increase in the scores with respect all the sensory characteristics of the resultant product. The flavour scores were increased upon replacing green gram with SMP. The score awarded for flavor of malted sorghum based complementary food upon 100 percent replacement with SMP (7.89) was significant in comparison with the control (7.06). The body and texture scores were improved upon addition of SMP. Sensory scores of overall acceptability attribute were also significantly increased upon increased SMP incorporation in the sorghum based complementary food containing SMP. The study confirmed that the acceptability of the malted sorghum based complementary food could be significantly improved by incorporating SMP in place of green gram. Milk proteins are superior quality proteins and possess good functional properties and provide desirable physico-chemical characteristics (Harwalky, 1993). Milk powders are extremely useful products and one can benefit from these products (Schwambach and Peterson, 2006). In the present investigation, the SMP incorporation increased the sensory acceptability of the resultant product.

The effect of replacing SMP by incorporating WPH on sensory attributes of sorghum based complementary food is presented in Table-12. Increase in the level of WPH in the blend did not significantly affect the colour and appearance scores of the product. However, the scores did decrease when the WPH level in the blend increased beyond 50 per cent. It was observed that increase in the level of substitution did have the significant influence on the flavour of the resultant product. The body and texture did not significantly wary upon substitution of SMP with WPH up to 75 per cent. Further increase in the substitution significantly decreased the body and texture scores. Replacement of SMP with WPH had no effect on the overall acceptability attribute in comparison with control at 50 per cent level. However, 75 per cent has resulted in decrease in overall acceptability scores and upon blending 100 per cent WPH resulted in significant decrease in the scores awarded for overall acceptability. Whey solids could be effectively used and should be exploited in novel food formulations to overcome the nutritional deficiencies in grains and legumes. Because of their high quality proteins, particularly the sulphur containing amino acids and acts as a balancing ingredient in weaning food formulation (Makhal *et al.,* 2003). Whey proteins contain certain inherent bioactivity which can be further nurtured and enhanced by enzymatic hydrolysis (Jayaprakasha *et al.,* 2005). The results reveal that the whey protein hydrolyzate could be an important ingredient in formulation of complementary foods with health benefits. The 50 per cent WPH containing blend had the sensory scores near to that of the control and was taken as the best among the blends.

The Gelatinization of the starch influences the body and texture of the complementary food and the consistency in porridge. The results of the gelatinization study are depicted in Figure-8. From the results, it was opined that no single time temperature combination can be fixed for cooking time to prepare porridge and the cooking conditions could be stated as bring down to boil and wait till the development of viscosity. The Rheological characteristics using Anton paar rheometer are depicted in the Fig. 9. The viscosity of the porridge was 28000mPa.s. This viscosity resulted in decreasing scores for body and texture and scores difference upon increasing the level of replacement of type of protein. The complete replacement of green gram by incorporating SMP did significantly improve the body and texture of the complementary food. The amino acid profile in the form of amino acid sequences obtained in MALDY-MS is shown in Figure 11a, 11b and 11c. The complementary food containing green gram has very few amino acids in the formulated product. The same was true with the SMP containing complementary food but more essential amino acids. However, the product with WPH had almost all the essential amino acids in the product.

The optimized blends of sorghum based complementary health foods with green gram; SMP and WPH were analyzed for various physical, chemical and microbiological parameters. The results of the study are depicted in Table-13 and Figure.10. Finer the flour, greater is the tendency to form lumps on the other hand coarser the particles grittier is the porridge (Kulkarni *et al* 1991), hence particles of <250µ are preferred for better consistency of the porridge. In the sorghum product, the maximum per cent (90 volume %) of the particles are below 260µ in all the three sorghum based complementary health food. The colour (L*, a* and b*) values sorghum based complementary food contained higher L* values indicating the developed products are lighter and brighter in colour. The pH sorghum complementary foods were 6.03, 6.19 and 6.56 and the water activity of the optimized complementary foods was 0.224 for green gram blended, 0.237 for the product with SMP and 0.251 for the product with WPH. The results of the chemical composition of the optimized formulations of sorghum based complementary food are depicted in Table-13. The increased level of substitution of SMP and WPH has increasing effect on the protein content and decreased carbohydrate content of complementary food. The crude fibre content decreased with increased level of SMP and WPH. Increased level of substitution of SMP and WPH led to increased ash content of the complementary food. The energy density of sorghum based complementary health food was 373.75, 378.33 and 383.94 respectively for green gram, SMP and WPH containing complementary food were according to the BIS specification (IS: 1656, 1969) of 300-400kcal for composite mixes. Microbial analysis results revealed TBC of the developed products were as per FSSAI standards and were free from coliforms and yeast and moulds. The composition of the sorghum based complementary foods was similar to that of the composition of the sorghum supplementary food developed by Banakar (2005). The flow chart for preparation of sorghum based complementary health food is given in Fig. 35.

5.2.4 Formulation of white ragi based complementary health food

The malted wheat flour used in the standard formulation was replaced with malted white ragi flour at 25, 50, 75 and 100 per cent levels. The effect of replacement of malted wheat flour with malted white ragi flour on sensory acceptability of white ragi based complementary food is depicted in Table-14. Increase in the level of malted white ragi flour from 0 to 100 per cent increased scores pertaining to color and appearance. There

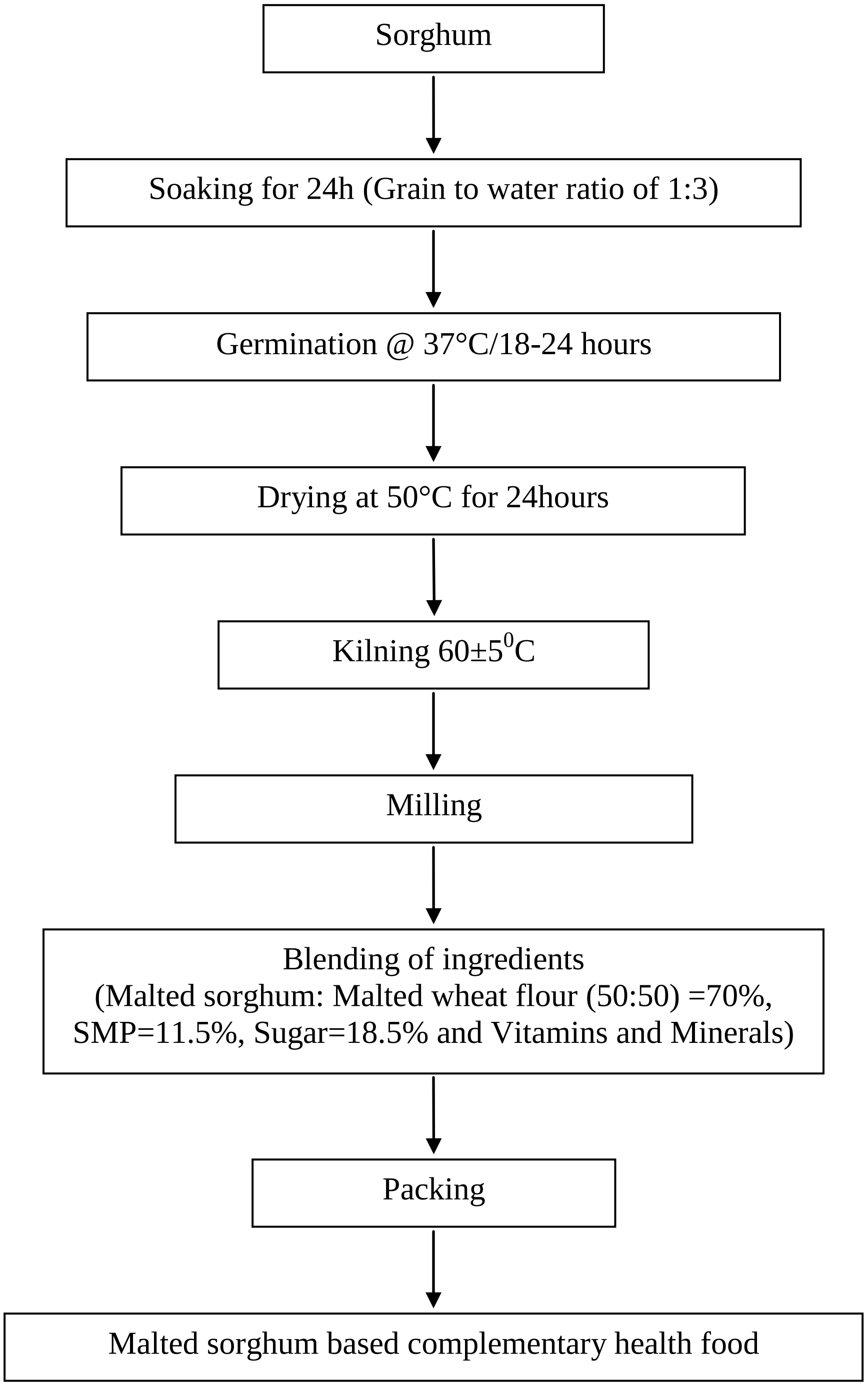


Fig. 35: Flow diagram for the development of malted sorghum based Ready-to-Cook (RTC) complementary health food

was significant difference between the 100 per cent white ragi flour blend in terms of colour and appearance with that of the control. With increase in the level of malted white ragi flour significantly improved the flavor attribute scores. Increase in flavour scores at 75 and 100 per cent level of malted white ragi flour incorporation were statistically significant (CD=0.253). Body and texture of the complementary food were also showed increasing trend upon replacement of wheat with white ragi malted flour and the extent of rise in the scores was significant. Upon increase in the flour blend level, the body and texture showed increasing trend. The increase in the overall acceptability scores at 100 per cent level was significant (CD=0.244).

The complementary food was formulated by replacing malted green gram flour blending SMP at 25, 50, 75 and 100 per cent keeping malted green gram blended complementary food as control. The effects of replacement of green gram protein with SMP on sensory characteristics were evaluated (Table-15). As the incorporation level of SMP in the complementary food increased, there was a consistent increase in the scores with respect all the sensory characteristics of the resultant product. Colour and appearance scores significantly increased to 8.18 from the 7.60 in green gram based complementary food. The flavour score (8.27) upon 100 percent replacement with SMP was significant in comparison with the control (7.33). The body and texture scores significantly increased upon addition of SMP. As the SMP level in the complementary food increased, sensory scores of overall acceptability attribute were also significantly increased. Milk proteins are superior quality proteins and possess good functional properties and provide desirable physico-chemical characteristics (Harwalky, 1993). Dairy powders are extremely useful products and as this realization grows, so does the demand for a high quality product (UPADHYAY, 1999.). SMP is a highly nutritious, versatile, and multi-functional food ingredient finds its application in bakery, confectionery, dairy, sports and nutrition products, infant formulas, and other consumer products. The foaming and whipping properties of SMP allows this product to work well in ice creams, cakes, dry mixes, mousses, and aerated confections such as malted milk and nougat centered candy (Schwambach and Peterson, 2006.). In the present investigation, the SMP incorporation increased the sensory acceptability of the resultant product. The study revealed that by incorporating SMP replacing green gram completely could improve the acceptability of the resultant product to a greater extent and is the best way to prepare the malted white ragi based complementary food.

The complementary food was formulated by replacing SMP with WPH at 0, 50, 75 and 100 per cent levels. The results of the study are shown in Table-16. Increase in the level of WPH in the blend did not affect the sensory acceptability with respect to colour and appearance; increase in the level of substitution did not have the significant influence on the flavour of the resultant product up to 75 per cent incorporation of WPH and decreased thereafter. It was evident from the result that, body and texture did not significantly wary upon substitution of SMP with WPH up to 75 per cent level. Further incorporation significantly decreased the body and texture scores. Complete replacement of SMP with WPH had significantly decreasing effect on the overall acceptability attribute in comparison with control. Whey solids could be effectively used and should be exploited in novel food formulations to overcome the nutritional deficiencies in grains and legumes. Because of their high quality proteins, particularly the sulphur containing amino acids and acts as a balancing ingredient in weaning food formulation (Makhal *et* *al.,* 2003). Whey proteins contain certain inherent bioactivity which can be further nurtured and enhanced by enzymatic hydrolysis (Jayaprakasha *et al.,* 2005). The results reveal that the whey protein hydrolyzate could be an important ingredient in formulation of complementary foods with health benefits. However, the present study results revealed that WPH could be incorporated up to the level of 75 percent replacing the SMP in the formulated product to harness the benefit of higher protein content.

The Gelatinization of the starch influences the body and texture of the complementary food and the consistency in porridge. The results of the study are depicted in Figure-12. From the results, it was confirmed that no single time temperature combination can be fixed for cooking time to prepare porridge and the cooking conditions could be stated as bring down to boil and wait till the development of viscosity. The Rheological characteristics of formulated malted white ragi based complementary foods studied using Anton paar rheometer are depicted in the Figure.13 and 14. The Rheological study revealed that the viscosity was 6700 mPa.s in the SMP containing and 3000mPa.s for WPH containing malted white ragi based complementary food This steady decrease was mainly attributed to the nature of white ragi based formulations where in the viscosity decreased after preparation of porridge and the formulations were becoming thin after some time resulting in decreased sensory acceptability. This could be the reason for the slightly reduced scores for body and texture scores and also the difference (Table-16) upon increasing the level of replacement of type of protein in white ragi based food. The amino acid profile in the form of amino acid sequences obtained in MALDY-MS is shown in Figure 16a, 16b and 16c. The complementary food containing green gram has very few amino acids in the formulated product. The same was true with the SMP containing complementary food but more essential amino acids. However, the product with WPH had almost all the essential amino acids in the product. The optimized blends of white ragi based complementary health foods with green gram, SMP and WPH were analyzed for various physical, chemical and microbiological parameters. The results of the study are depicted in Table-17 and Figure.15.

The particle size distribution was observed to be ranging from 0.80µ to 709µ, for the product with green gram, 2.8µ to 502µ for product containing SMP and 3µ to 563µ for product with WPH. However, the maximum per cent (74 volume %) of the particles were below 150µ in the first two types and below 200µ for the product with WPH containing white ragi based complementary health food. Physical characteristics including particle size, swelling power, solubility and dispersibility are the supplementary factors which determine and influence sensory qualities and thus the intake. Particle size of the flour varies depending upon the mill, grinding pressure, grain sample and also endosperm texture of the grains. Finer the flour, greater is the tendency to form lumps on the other hand coarser the particles grittier is the porridge (Kulkarni *et al* 1991), hence particles of <250µ are preferred for better consistency of the porridge. The results of the present study are in agreement with those reported by Itagi (2003) and Shaila (2010) for complementary food indicating the milling perfection.

The colour (L*, a* and b*) values were slightly higher for SMP and WPH added white ragi based complementary food indicating lighter colour of the SMP and WPH containing product than the product with green gram. The respective pH of the green gram, SMP and WPH complementary foods were 6.15, 6.44 and 6.69. The water activity of the optimized complementary foods was 0.269 for green gram blended, 0.263 for the product with SMP and 0.258 for the product with WPH. The results of the chemical composition of the optimized formulations of white ragi based complementary food are depicted in Table-17. The moisture content of green gram, SMP and WPH based products were 6.22, 6.18 and 6.15 per cent respectively for the complementary food with green gram, SMP and WPH. Increased level of incorporation of SMP and WPH has increasing effect on the protein content of complementary food. Carbohydrate content in the green gram, SMP and WPH added complementary foods were observed to be 74.51, 73.11 and 69.32 per cent, respectively. The energy density of white ragi based complementary health food was 366.40, 364.88 and 368.42 respectively, for green gram, SMP and WPH containing complementary food according to the BIS specification (IS: 1656, 1969) of 300-400kcal for composite mixes. Microbial analysis results revealed that TBC were in the acceptable level of FSSAI standards for malted foods, Coliforms were absent in all the three samples of white ragi based complementary health foods. The flow chart for preparation of white ragi based complementary health food is given in Fig. 36.

5.2.5 Comparison of sensory and rheological characteristics of the best adjudged millet based complementary health foods

The best adjudged complementary food prepared from foxtail millet, little millet, sorghum and white ragi were subjected to the sensory acceptability keeping wheat based complementary food product as control. The effect of type of the complementary food on sensory characteristics was evaluated. The results are presented in Table-18 and Figure-17. From among the millets based complementary food formulated, malted white ragi

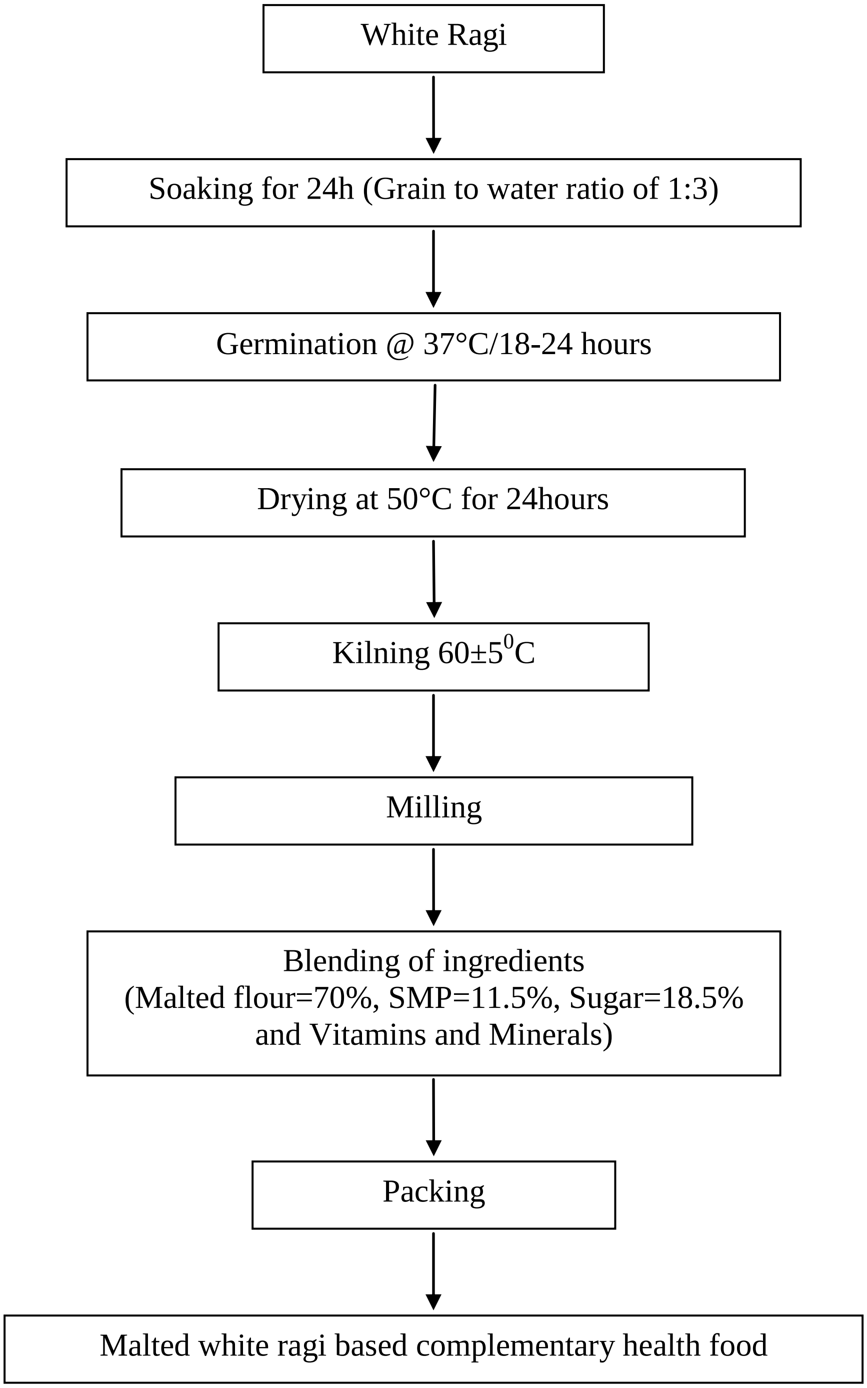


Fig. 36: Flow diagram for the development of malted white ragi based Ready-to-Cook (RTC) complementary health food

based complementary food was adjudged as best followed by the complementary food with wheat, little millet, sorghum and foxtail millet. Colour and appearance scores significantly increased for malted white ragi in comparison with control and the colour and appearance scores were decreased significantly for complementary food containing malted foxtail millet. The increase in the flavor scores for white ragi was highest and was significantly higher compared to all the other formulations including wheat. The body and texture scores were highest for white ragi and were at par with that of the malted wheat formulation. The study revealed that using malted white ragi was the best to prepare the malt based complementary food even though the complementary foods with malted foxtail millet, malted little millet and malted sorghum could also be prepared. The Rheological characteristics using Anton paar rheometer are depicted in the Figure-18. The viscosity reduction was observed when the porridge slurry was prepared and after kept for few minutes. This resulted in body and texture scores difference (Table-17) upon increasing the level of replacement of type of protein in white ragi based food. Among the millets used for formulating complementary food, white ragi based product was adjudged as best and the same was used for further studies to develop honey and probiotic complementary foods.

5.3 Formulation of honey blended malted white ragi based probiotic complementary health food

At a fixed level of honey of 5 per cent, as the sugar level decreased the scores did not affect the sensory scores significantly up to the level of sugar at 16.5. The sensory evaluation study revealed that the sugar level to be added to the honey blended malted white ragi based complementary health food was 16.5 per cent that adjudged as best and was comparable to the control. The RTC blend of best adjudged honey blended malted white ragi based complementary health food was added with the probiotic organisms. Honey was added to the porridge and probiotic organisms were dry blended into the complementary food porridge after preparation, cooking and cooling. The prepared products were subjected to sensory evaluation. The sensory acceptability of the products is depicted in Table-20. The scores awarded for malted white ragi complementary food with sugar, honey blended complementary food, probiotic complementary food with *B.bifidum* and probiotic complementary food with *L.acidophilus* were almost similar and the scores did not differ much even after blending of the probiotic organisms. All the blends were highly acceptable.

The Rheological characteristics of the RTC white ragi based honey blended probiotic complementary food with SMP and WPH were analyzed using Anton paar rheometer and the results are depicted in the Figure 19 and 20. The viscosity of the porridge of white ragi based product with SMP was 3000mPa.s. The viscosity of the porridge of white ragi based product with WPH was 2100 mPa.s. In both the cases the viscosity decreased upon increase in the shear rate over a period of time. However, the extent of decrease in the viscosity was relatively higher in the WPH containing malted white ragi based honey blended probiotic complementary health food. This resulted in body and texture scores difference especially whenever the product was not consumed completely. The viscosities obtained in the present study are in agreement with the malted, roasted and formulated weaning mixes by Krishisagar *et al.*, 1994.

The honey blended white ragi based complementary health foods were analyzed for various physical, chemical and microbiological parameters. The results of the study are depicted in Table-21 and Figure.21. The maximum per cent (74 volume %) of the particles were below 100µ in both the types of malted white ragi based honey blended probiotic complementary health food. The water activity of the optimized honey blended malted white ragi based complementary foods was 0.325, 0.326 and 0.322 for the malted white ragi based honey blended product, malted white ragi based honey blended probiotic complementary food with *B.bifidum* and probiotic complementary food with *L.acidophilus*, respectively.

The results of the chemical composition of the optimized formulations of white ragi based complementary food are depicted in Table-21. The increase in moisture attributed to the blending of the honey. The energy density of malted white ragi based honey blended product, malted white ragi based honey blended probiotic complementary food with *B.bifidum* and probiotic complementary food with *L.acidophilus* were 363.86, 362.93 and 361.16 respectively. The probiotic counts were 9.37 log cfu/g for BB-12 and 9.69 for LA-5. Coliforms and yeast and moulds were absent in all the three samples of white ragi based probiotic complementary health foods. The study revealed that the probiotic organisms by dry blending could be successfully incorporated into the porridge after cooking and cooling of the porridge along with the honey and could contain sufficient number of the probiotic organisms in the prepared porridge to provide the health benefits of the probiotic health foods. The flow chart for preparation of white ragi based probiotic complementary health food is given in Fig. 37 and the developed products are given in plate-5.

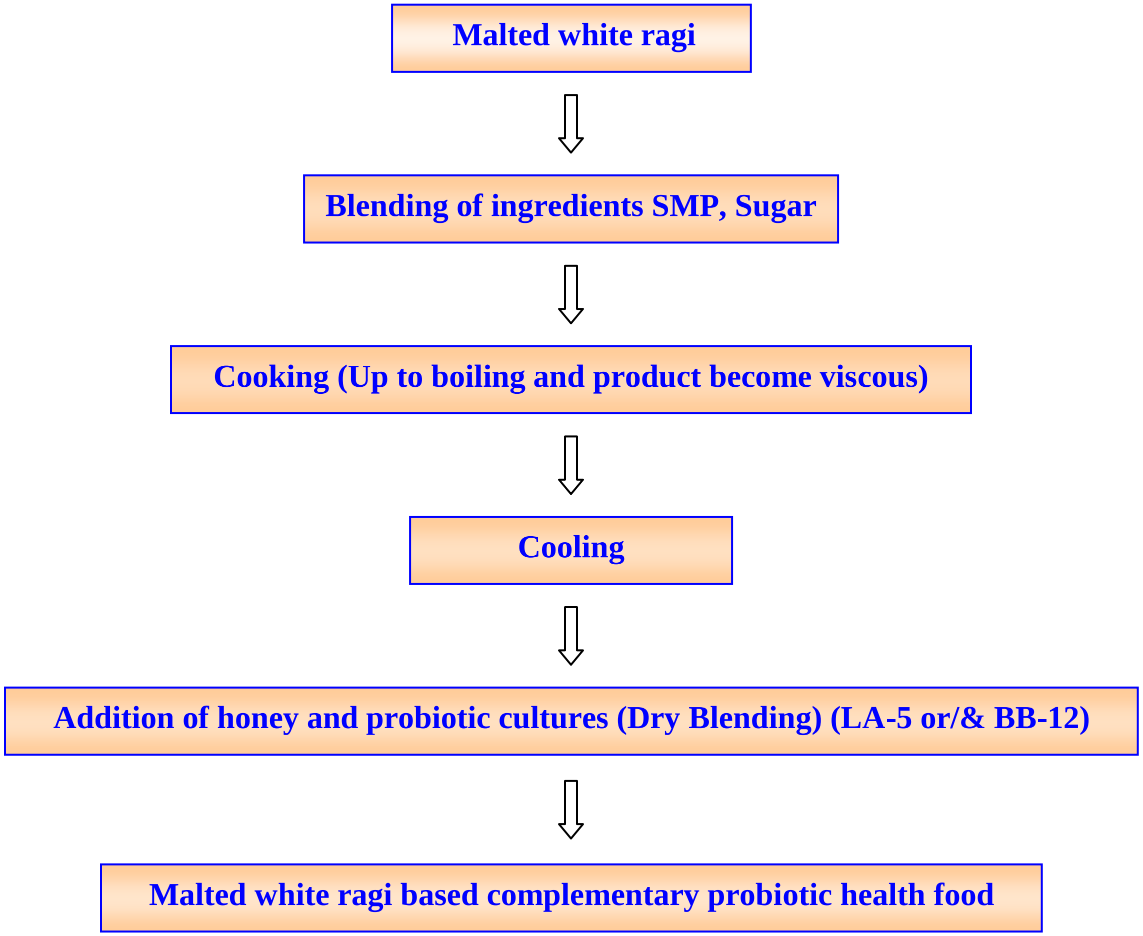


Fig. 37: Flow chart for preparation of Ready-to-Cook White ragi based Probiotic Complementary Health Food

5.4 Processing of complementary health food to produce ready to use (RTU) product

Formulated complementary food prepared by the admixture of best adjudged malted millets and SMP were adjusted to various levels of Total Solids (TS) and heated to various temperatures in order to select a best combination of TS and cooking temperature.

5.4.1 Optimization of total solids in porridge, cooking temperature of porridge, spray drying, fluid bed drying and vacuum drying process

The effect of TS content and cooking temperature on the sensory attributes of complementary food is presented in Table-22. The results revealed that the TS content of 25 per cent and above led to have decreased the acceptability and acceptability was highest at 1:5 proportions for all type of millets. Effect of cooking and TS content on viscosity and speadability of weaning food were studied by Griffith and Perez, 1998. An optimum spreadability and viscosity was obtained at a combination of 25 per cent TS and cooking temperature of 75^{o}C. Viscosity of various cereals based on formulated weaning food of both cold and cooked paste viscosity has been studied by Kshirsagar *et al.*, (1994). Progressive decrease in viscosity with increase in levels of total solids has been reported by Malleshi and Desikachar, (1988). However, in the present study, the acceptability was highest at 1:5 proportions for all type of millets. The cooking temperature of 75, 80 and 85°C for 5min did not affect the acceptability of the prepared porridge much. The results revealed that cooking temperature did not influence the resultant porridge much and the effect of cooking temperature was insignificant in all the types of millets which also supports the concept of gelatinization which inferred that no single time temperature combination are suitable for cooking of the porridge and the cooking conditions could be stated as bring to boil and wait till the development of viscosity.

Spray drying and fluid bed drying of the formulated ready to cook (RTC) products was done after preparing porridge and cooking it to make the resultant products ready to reconstitute (RTR). The effects of outlet air temperature and feed inlet air temperature on moisture content of the powder is presented in Table-23. The feed temperature of 60^{o}C was found optimum for all the millet RTC foods. With the increase in out let air temperature there was decrease in moisture content of product irrespective of the feed inlet temperature and the optimum temperature for drying of the in all type of millet based complementary foods was 85-90^{o}C to get the moisture of the powder below 5 per cent in the resultant powder. In case of fluid bed drying the temperature of 50^{o}C was required to get the moisture below 5 per cent in the dried product of all types of millet based complementary foods. Thus, from the above study it was confirmed that the best conditions of spray drying to prepare RTU spray dried millet based complementary food could be done by feeding the porridge at 60^{o}C and maintaining inlet temperature at 160^{o}C inlet temperature and 90^{o}C outlet temperature. Fluid bed drying could be done at the optimized temperature of 50^{o}C.

The formulated ready to cook (RTC) product porridge was prepared at various total solids level / proportion of complementary food: water in the porridge such as 1;2, 1;3, proportions as well as 50 and 60 per cent total solids level. The prepared porridges were vacuum dried at 50^{o}C to make the resultant products ready to reconstitute (RTR) were subjected for the overall acceptability of the resultant powders. The overall acceptability was highest at 1:2 followed by 1:3 proportions for all millet based products (Table-24). From among the various vacuum drying temperatures tried, the temperature of 50^{o}C was found to be optimum to get the desired moisture content of below 5 per cent in the resultant RTR vacuum dried malted millet based complementary food and even 55^{o}C could reduce the moisture content further.

5.4.2 Sensory characteristics of the RTU millet based complementary health foods

The best adjudged RTU complementary food prepared from foxtail millet, little millet, sorghum and white ragi were subjected to the sensory acceptability keeping wheat based complementary food product as control. From among the millets based complementary food formulated, malted white ragi based complementary food was adjudged as best followed by the complementary food with wheat, little millet, sorghum and foxtail millet in respect of all the sensory attributes. Thus, malted white ragi was the best adjudged RTU complementary food even though the complementary foods with malted foxtail millet, malted little millet and malted sorghum could also prepared. In this study, best adjudged malted white ragi based RTU complementary food was selected for the future studies.

The RTU spray dried, fluid bed dried and vacuum dried white ragi based formulations were subjected to the sensory acceptability keeping the RTC complementary food as control. The results revealed that RTU white ragi based complementary foods prepared with all the types of drying are acceptable even though highest score awarded for the RTC product followed by vacuum dried, fluid bed dried and spray dried RTU product. The viscosity of the porridge the best adjudged vacuum dried malted white ragi RTU food with SMP was 3059mPa.s. The viscosity decreased upon increase in the shear rate over a period of time. This decrease in the viscosity has the relation to the viscosity reduction of the porridge slurry after keeping it for few minutes. This resulted in body and texture scores difference especially whenever the product was not consumed completely.

5.4.3 Physico-chemical characteristics of the RTU millet based complementary health foods

The physico-chemical attributes and microbial quality of the spray dried, fluid bed dried and vacuum dried white ragi based complementary food products are depicted in the Table -26. The colour (L*, a* and b*) values for vacuum dried RTU complementary food had decreased a* value revealed darker colour of the vacuum dried food compared to other two products. The maximum per cent (86 volume%) of the particles in the product were below 239µ Figure-24). The water activity of the RTU complementary foods was 0.281, 0.268 and 0.244 for the Spray dried, fluid bed dried and vacuum dried white ragi based complementary food product with SMP. The RTU vacuum dried malted white ragi based formulation was added with honey, probiotic organisms were subjected to the sensory acceptability keeping vacuum dried RTU with sugar as control. The sensory scores in respect of all the characteristics for all the tried complementary foods were almost similar and the scores did not differ much even after blending of the probiotic organisms. The statistical analysis revealed that all the samples are as good as the control and are highly acceptable. The flow chart for preparation of Ready-to-Use (RTU) Complementary Health Food is given in Fig. 38 and the developed products are given in plate-5.

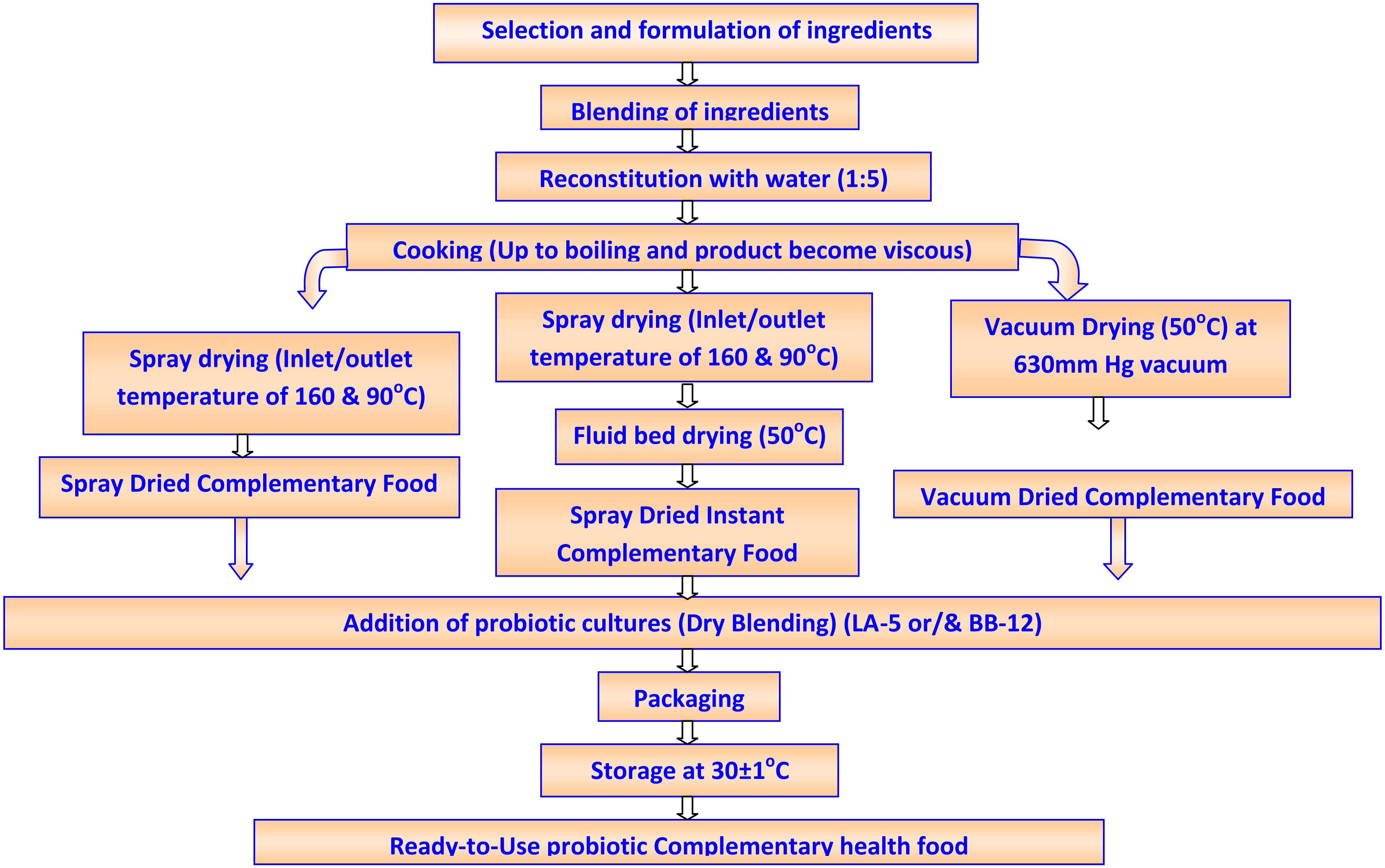


Fig. 38: Flow chart for production of Ready-to-Use (RTU) Complementary Health Food

5.5 Optimization of production of RTU extruded complementary health foods

Variety of complementary foods can be prepared using extrusion process. A study was undertaken to produce extruded complementary food from millets. The results of the study are here under.

5.5.1 Identification of gelatinization temperature for the raw flours to use them in preparation of extruded flours

Gelatinization temperature and the range of gelatinization of the raw flours of maize, wheat, foxtail millet, little millet, white ragi and sorghum were estimated using Differential Scanning Colorimeter (DSC), to ascertain proper extrusion of the raw flours, identification of gelatinization temperature was done using DSC. The results of the study are depicted in Figure-25, 26 and 27. Knowing gelatinization temperature of the raw flours plays a vital role in getting the proper extrusion of the material and these temperatures are very crucial to get good quality extruded flours and flakes. The trend of gelatinization temperatures obtained for the raw flours of maize, wheat, white ragi and sorghum depicted that the onset, peak and end set temperatures was having similarity. Extrusion cooking for the production of breakfast cereals involved high-temperature cooking and forced passage of extrudate through a die (Coponio *et al*., 2007). Thus, it was decided to use the same process conditions (120±5°C for extrusion,100±2°C for drying and 150°C for roasting) employed during the production of the extruded flours and corn flour for the production of the extruded flours and flakes from wheat, foxtail millet, little millet, sorghum and white ragi.

5.5.2 Sensory acceptability and rheological attributes of RTU extruded millet based complementary health foods

The RTU extruded complementary foods containing SMP prepared from extruded foxtail millet, little millet, sorghum and white ragi flours were subjected to the sensory acceptability keeping RTU extruded wheat based complementary food product as control. The effect of type of the complementary food on sensory characteristics was evaluated. The results are presented in Table-28. From among the millets based RTU extruded complementary food formulated, little millet based product was adjudged best followed by the RTU extruded complementary food with foxtail millet, white ragi, sorghum and wheat. Colour and appearance scores significantly increased for extruded little millet in comparison with control. The increase in the flavor scores for extruded little millet was highest and was significantly higher compared to the formulation of extruded wheat. The body and texture scores were highest for white ragi and were significantly higher than that of all other formulations including extruded wheat formulation. The rheological study of the little millet extruded RTU complementary health food containing SMP revealed that the viscosity of the porridge was 11600mPa.s initially was decreased slowly as the shear rate is increased. The viscosity of the porridge was 14700mPa.s for WPH containing product. Vijayakumar and Mohankumar (2009) studied the effect of incorporation of millet flour blend on the improvement of the quality of composite flour in terms of increasing nutrient density, thinner the gruel by lowered viscosity and increase in the level of syneresis which may improve the resistant starch content on storage. The viscosity results are in agreement with the above study. The study revealed that using extruded little millet was the best to prepare the extruded little millet based

RTU complementary food compared to other extruded millets. The RTU blend of best adjudged honey blended extruded little millet based complementary health food was added with the probiotic organisms. Honey has a major role to play as a carrier of foods containing relatively high levels of vitamins and minerals, and has been shown to help the body absorb minerals such as calcium (Ustunol, *2002*) and also helps in growth of lactic acid bacteria and bifidobacteria in a honey medium. From the above results, it was inferred that sensory scores in respect of all the characteristics for all the extruded little millet complementary foods were almost similar and the scores did not differ much even after blending of the probiotic organisms. The Rheological characteristics of the RTU extruded little millet based honey blended probiotic complementary food with SMP and WPH were analyzed using Anton paar rheometer are the results are depicted in the Figure 30 and 31. The viscosity of the porridge of extruded little millet based product with SMP was 8665mPa.s. The viscosity of the porridge of extruded little millet based product with WPH was 10829mPa.s. In both the cases the viscosity decreased upon increase in the shear rate over a period of time. This decrease in the viscosity has the relation to the viscosity reduction of the porridge slurry resulted in body and texture scores difference especially whenever the product was not consumed completely.

5.5.3 Physico-chemical and microbiological quality of RTU extrude little millet based honey blended probiotic complementary health foods

The honey blended extruded little millet based complementary health foods were analyzed for various physical, chemical and microbiological parameters along with the sugar containing complementary food. The results of the study are depicted in Table-30 and Figure.32. The maximum per cent (68 volume %) of the particles were below 200µ in extruded little millet based product with sugar, where as in extruded little millet based probiotic complementary food the maximum per cent (60.86 volume %) of the particles were below 200µ with *L.acidophilus* and the maximum per cent (60.52 volume %) of the particles were below 200µ for extruded little millet based probiotic complementary food with *B.bifidum* honey blended probiotic complementary health food. Particle size of the flour varies depending upon the mill, grinding pressure, grain sample and also endosperm texture of the grains. Finer the flour, greater is the tendency to form lumps on the other hand coarser the particles grittier is the porridge (Kulkarni *et al* 1991), hence particles of <250µ are preferred for better consistency of the porridge. The particles of the present study are in agreement with that of the above findings thus having highest acceptability.

Extrusion cooking for the production of breakfast cereals involved high-temperature cooking and forced passage of extrudate through a die (Coponio *et al*., 2007). The colour (L* a* b*) values inferred the darker colour of the extruded complementary foods which could be due to exposure to higher temperature during preparation of extruded flour. The water activity of the optimized honey blended extruded little millet based complementary foods was 0.179, 0.256 and 0.247 extruded little millet based complementary health food with sugar, extruded little millet based probiotic complementary food with *L.acidophilus* and probiotic complementary food with *B.bifidum* respectively which shows the lower water activity will definitely improve the storage stability of the resultant products.

The results of the chemical composition of the optimized formulations of extrude little millet based complementary food are depicted in Table-30. The increase in moisture attributed to the blending of the honey. The crude fibre content was 2.81, 2.83 and 2.84 percent respectively, for extruded little millet based complementary health food with sugar, extruded little millet based probiotic complementary food with *L.acidophilus* and probiotic complementary food with *B.bifidum*. The energy density of extruded little millet based complementary health food with sugar, extruded little millet based probiotic complementary food with *L.acidophilus* and probiotic complementary food with *B.bifidum* was 364.42, 360.28 and 361.39 respectively. The total count for the extruded little millet based complementary health food with sugar was 1.32 log cfu/g and the probiotic counts were 9.81 log cfu/g for extruded little millet based probiotic complementary food with *B.bifidum* and 9.69 log cfu/gm for probiotic complementary food with *L.acidophilus*. Coliforms and yeast and moulds were absent in all the three samples of white ragi based probiotic complementary health foods. Probiotic products have been reported to improve and maintain intestinal microflora, protect against infection, alleviate lactose intolerance, reduce blood cholesterol levels and also stimulate the immune system (Peter and Williams, 2007). A study was found that viability of 10^9cfu/g in spray dried powder containing probiotic lactobacilli in combination with prebiotics, which may be useful as functional food ingredients for the manufacture of probiotic foods. The study revealed that the probiotic organisms by dry blending could be successfully incorporated into the extruded formulation along with the honey and could contain sufficient number of the probiotic organisms in the prepared porridge to provide the health benefits of the probiotic health foods. The flow chart for preparation of Ready-to-Use (RTU) extruded complementary health food is given in Fig. 39.

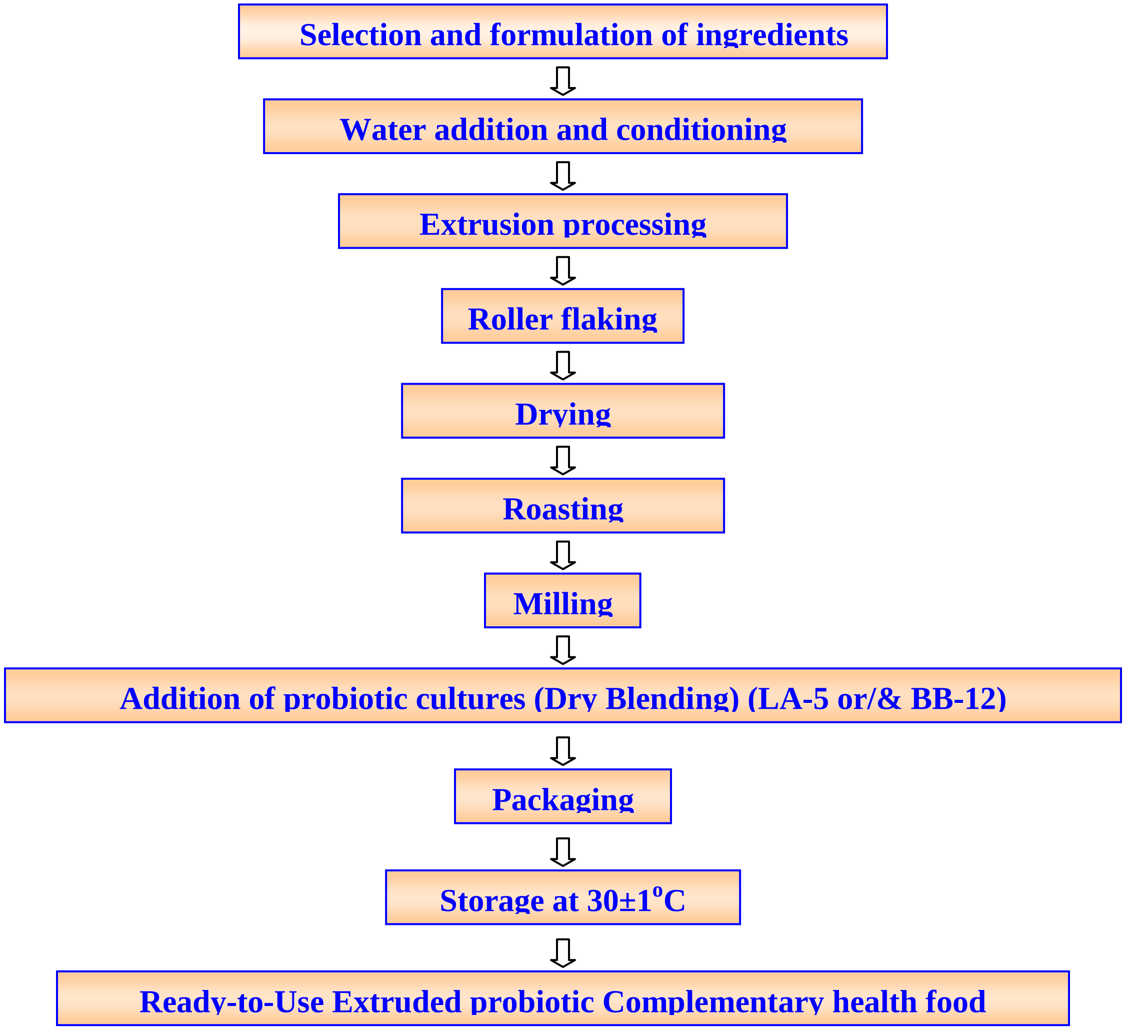


Fig. 39: Flow chart for production of Ready-to-Use Extruded Complementary Health Food

5.6 Preparation of RTU millet flakes, assessment of acceptability, physico-chemical attributes and microbial quality of the millet flakes

Millet based flakes were developed by completely replacing the corn flour in the formulation. The flakes were prepared with foxtail millet, little millet, sorghum and white ragi keeping wheat flakes as control. Millet based flakes were developed by completely replacing the corn flour in the formulation. Sensory evaluation of the developed millet flakes as a breakfast cereal was conducted keeping wheat flakes as control. The results of the study are depicted in Table-31. From among the millet flakes prepared, sorghum flakes were adjudged best and comparable with that of the wheat flakes followed by the white ragi flakes, little millet flakes and foxtail millet flakes. The millet flakes were served in different media and form such as millet flakes in hot milk, millet flakes in cold milk and millet flakes as masala snacks keeping wheat flakes as control. The results are shown in Table-32. The sensory acceptability of flakes revealed that the in all the three forms the sorghum flakes were the best among the millet blends which was awarded scores near to that of the control wheat flakes followed by white ragi flakes, little millet flakes and foxtail millet flakes.

The physico-chemical attributes and microbial quality of the flakes prepared with foxtail millet, little millet, sorghum and white ragi were analyzed keeping wheat flakes as control. The results of the analysis are depicted in the Table -33. The water activity was 0.392, 0.299, 0.285, 0.339 and 0.367 for wheat flakes, foxtail millet flakes, little millet flakes, sorghum flakes and white ragi flakes, respectively. The results of the chemical composition of the RTU formulations of white ragi based complementary food are depicted in Table-33. The moisture content of wheat flakes, foxtail millet flakes, little millet flakes, sorghum flakes and white ragi flakes were 1.69, 1.52, 1.72, 1.69 and 2.73 per cent respectively. The fat content of the extrude flakes decreased drastically. Extrusion cooking for the production of breakfast cereals involved high-temperature cooking and forced passage of extrudate through a die and the sensory properties of these products were greatly influenced by the extent of lipid degradation even if the products have low lipid contents. (Coponio *et al*., 2007). Reduction in the fat might be attributed to the lipid degradation due to high temperatures followed for preparation of flakes. The energy density of wheat flakes, foxtail millet flakes, little millet flakes, sorghum flakes and white ragi flakes was 382.82, 355.53, 363.15, 380.63 and 360.75 respectively. Microbiological analysis results revealed that the low total bacterial count could be again attributed to the high temperatures during manufacture of flakes. The respective flow charts for preparation of Ready-to-Use (RTU sorghum flakes and white ragi flakes is given in Fig. 40 and Fig. 41.

5.7 Bioassay studies

In order to evaluate the nutritional quality of developed complementary foods, bioassay study was conducted on albino rats (Wister strain). The results generated from bioassay studies are presented in Table 34, 35 and 36. The amount of weight increase in the control rats was from 60g to 125gm during the feeding period. However, in all the samples of complementary food fed rats the weight gain was found to be much higher than the control sample. The initial weight of the malted complementary group was 56.33-72.67g and weight gain in rats during the study for the malted food group ranged from 140.8g to 159.3g depending on the type of feed. The complementary food with white ragi and SMP resulted in highest weight gain compared to other malted foods. In

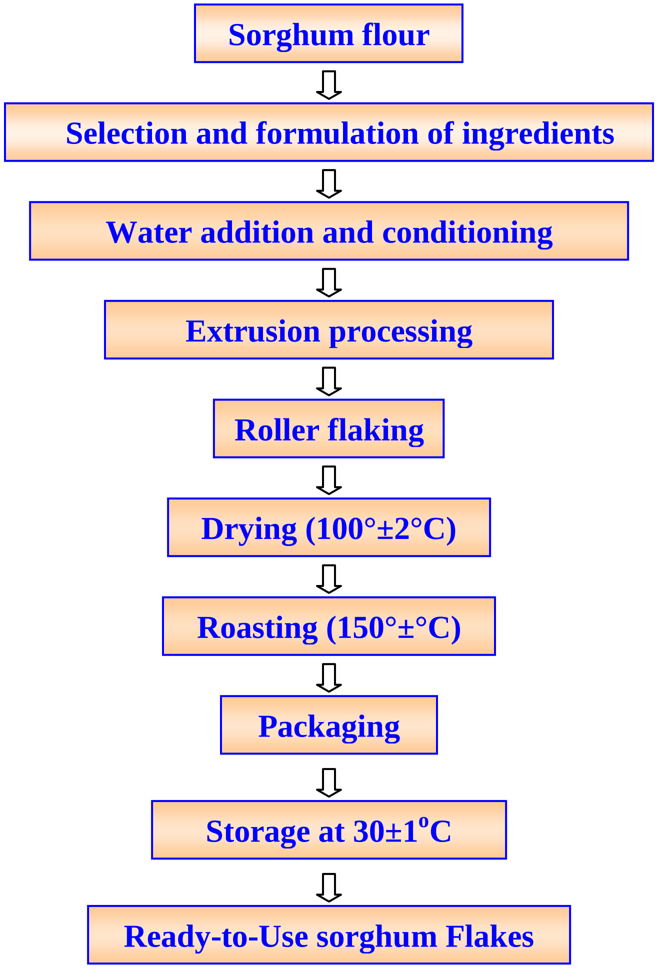


Fig. 40: Flow chart for production of Ready-to-Use Sorghum flakes

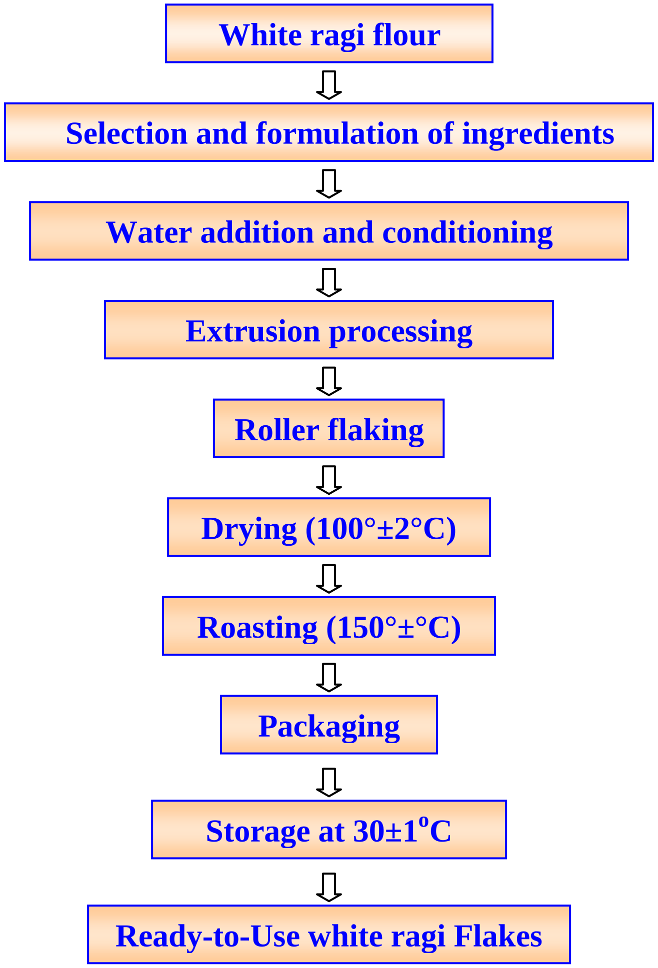


Fig. 41: Flow chart for production of Ready-to-Use white ragi flakes

the extruded complementary food group, the amount of weight gain was higher in little millet extruded product fed rat gained weight to 159g. Among extruded flakes the highest weight gain was observed for sorghum flake group. All the foods given as feed to the rats were having almost similar FER (Table-35). The FER was highest (0.49) for white ragi with WPH containing product among malted complementary foods. The PER of control food was 1.46. However, the malted complementary food prepared with WPH was having highest PER (2.05) not only among malted foods but also compared to all other groups of foods used in the study. Effect of different kinds of feed on Feed Efficiency Ratio (FER) and the resultant PER has been demonstrated by some of the earlier workers (Suhasini and Malleshi, 2003). Several studies have shown that protein hydrolyzates contain mostly di- and tri-peptides which are known to be absorbed more rapidly than intact protein (Manninen, 2004) leading to increase in PER**.** Storage of weaning food did not adversely affect the PER and sensory qualities of the weaning food containing malt (Malleshi and Desikachar, 1988). In the present study, in extruded food group, little milled food PER was better than wheat food. Among flakes, the PER was ranging from 1.31 to 1.45 with highest being observed for little millet flakes. The NPU of the WPH containing food was highest at 82.5 per cent. For SMP containing products, NPU ranged from 71.2 to 76.5 per cent in malted complementary food group, 71.6-72.1 for extruded complementary food group and 60.4 to 65.1 for extruded flakes group (Table-35). Onweluzo and Nwabugwu, (2009) observed NPU of 70.13 to 74.57 in weaning foods. The results of the present study are in agreement with the above study and in fact the NPU of the WPH containing food was highest at 82.5 per cent was better than the NPU of above study. The blood glucose levels of the rats fed with control diet was 90.49mg/dl and the blood glucose levels of the rats fed with the treatment diet were 82.96 to 93.35mg/dl for malted food group, 73.50 to 100.30 for extruded food group and 76.22 to 88.32 for flakes group (Table-36). All the blood glucose levels were well within the acceptable range.

5.8 Storage studies

The developed dried products need to have longer shelf life at room temperature in order to have sustainable marketing and the product needs to be packed and stored safely in order to protect nutrients and prevent damage and deterioration.

5.8.1 Storage stability of best adjudged RTU vacuum dried white ragi based complementary health food with SMP

Ready to use malted white ragi based vacuum dried complementary food developed in the study was packed in and Poly Ethylene Terephthalate (PET) sachets and Metalyzed polyester (MPE) subjected to Modified Atmospheric Packaging (MAP) by using admixture of CO_2 and N_2 at various proportions and stored at 30^oC. The effect of type of packaging material and the ratio of admixture on storage stability as measured in terms of Hydroxyl Methyl Furfural (HMF), Free Fatty Acid (FFA) and Peroxide Value (PV) is presented in the Tables 33, 34 and 35. The extent of browning during storage is measured in terms of Hydroxy Methyl Furfural (HMF). HMF is an intermediately compound during maillard reaction and reflects extent of browning. Browning reaction greatly modifies food properties and is responsible for changes in flavour, aroma, colour, nutritional value stability and shelf life. HMF is an indication of the severity of heat treatment and also length and condition of storage (Hurtado *et al.,* 1998). The effect of MAP and type of packaging material on Hydroxy Methyl Furfural (HMF) is presented in Table 37. With increase in the storage period from 0 to 180 days, there was significant increase in HMF values under both MAP and normal packaging system. The HMF content of product stored under MAP at 20:80 CO_2 and N_2 ratio was found to be lesser as compared to other levels of MAP. The effect of storage condition on HMF content has been studied by several earlier workers and reported that HMF content keeps increasing during storage depending on temperature irrespective of packaging material (Antonio *et al.,* 2003). The best adjudged RTU white ragi based complementary health food with SMP stored in MPE pouches contained lesser HMF as compared to product stored in PET pouches at all duration of storage as well as at levels of CO_2 and N_2 admixtures indicating MPE pouches are more preferred pouches compared to PET for storing RTU white ragi based complementary health food.

The effect of MAP and type of package material on Free Fatty Acids (FFA) of functional weaning food is presented in Table 38. The FFA values of best adjudged RTU white ragi based complementary health food with SMP stored at ambient condition increased from 0.68 to 2.48 in PET and 0.68 to 1.98 per cent oleic acid in MPE packaging after 180 days in case of normal atmosphere packaging. However, in the products stored under admixture of 20:80 CO_2 to N_2 ratio, the FFA content after 180 days of storage was 1.34 per cent oleic acid for PET packages and 1.19 per cent oleic acid for MPE. Hydrolytic rancidity is one of the modes of spoilage of dried mix. Free Fatty Acid (FFA) is a measure of microbial lipolytic activity in food products. Higher FFA content may lead to bitter taste after few days of storage and hence it is necessary to reduce lipolytic activity (Malleshi and Desikachar, 1982). The powders packed in PET and MPE pouches under MAP (20:80) were significantly better as compared to control. However, increased level of CO_2 to N_2 ratio above 20:80, there was significant increase in FFA of the product in case of both PET and MPE. Similar observations were also made by Swamy (2003) Ahmed *et al.* (2008) and Mahadevaiah (2010) who observed no remarkable change in moisture content, PV, FFA during storage of weaning food. Irrespective of packaging material used, the product stored under 20:80 CO_2 to N_2 ratio was found to be better for storage of best adjudged RTU white ragi based complementary health food with SMP.

The effect of MAP and type of packaging material on PV of best adjudged RTU white ragi based complementary health food with SMP during storage is presented in Table 39. The extent of increase in PV during storage was found to be significant with respect to both PET and MPE in case of atmosphere packaging. However, in case of MAP the extent of increase in PV was significantly lesser as compared to control packaging. The powders packed in PET and MPE pouches under MAP (20:80) were found to be significantly better compared to control and other levels of CO_2 and N_2 ratio. Wadud *et al.*, (2004) observed a negligible increase of PV even after 6 months of storage. The product packed with CO_2 and $N_{2,}$ ratio of 20:80 MAP was found to be better for storage of complementary food irrespective of the packaging material. Complementary food stored in MPE pouches has shown lesser PV compared to the product stored in PET pouches at all duration of storage as well as at all the levels of CO_2 and N_2 admixtures. The PV after 180 days of storage was 0.32 with respect to PET, where as it was only 0.15 m.eq/kg of oxygen with respect to PET at 20:80 admixtures of CO_2 and N_2.

5.8.2 Storage stability of the ready to cook malted millet based complementary health foods

The best adjudged RTC malted millet based complementary health foods with SMP were packed into the MPE pouches and stored at 30±1^{o}C. The overall acceptability and microbial quality of ready-to-cook (RTC) millet based complementary health foods during storage at 30±1^{o}C are depicted in Table-40. The RTC malted foxtail millet based complementary food was acceptable only up to 45 days. The RTC malted little millet based complementary food, RTC malted sorghum based complementary food, RTC malted white ragi based complementary food were acceptable up to 60 days. The results were in agreement with the results of Ranganna (2011) and Chandru (2010) for millet malted nutria mixes.

5.8.3 Storage stability of the ready to use millet based complementary health foods

The best adjudged RTU malted white ragi based vacuum dried complementary health food with SMP, RTU little millet based extruded complementary health food with SMP, RTU sorghum flakes and RTU white ragi flakes were packed into the MPE pouches and stored at 30±1^{o}C. The overall acceptability and microbial quality of ready-to-use (RTU) millet based complementary health foods during storage at 30±1^{o}C are depicted in Table-41. The overall acceptability scores were consistently decreased during storage. The RTU white ragi based complementary health food, RTU little millet based extruded complementary food and RTU sorghum flakes and RTU white ragi flakes were acceptable up to 180days at 30±1^{o}C when packed in MPE pouches.

The viability of probiotic organisms during storage of the best adjudged RTU malted white ragi based vacuum dried honey blended probiotic complementary health food with SMP, RTU little millet based extruded honey blended probiotic complementary health food with SMP were packed into the MPE pouches and stored at 30±1°C. A progressive decrease in viable count of both *B.bifidum* and *L.acidophilus* was observed during storage (Table-41). Concoran *et al.,* (2004) developed powder containing probiotic lactobacilli in combinations with prebiotics having viability of 10^9cfu/g, which could be used as functional food ingredient in the manufacture of probiotic foods. It is recommended that between 10^5 and 10^8 cfu/g is an acceptable level for live probiotic population in final product (Shah *et al.*, 1995). The viability beyond 6.0 log cfu/g could be maintained only up to 90 days of storage for both the probiotic organisms. In all the samples coliforms and yeast and moulds were absent. Thus, the RTU malted white ragi based vacuum dried honey blended probiotic complementary health food with SMP and RTU little millet based extruded honey blended probiotic complementary health food with SMP could be stored for 90days to harness the benefit of the probiotic products.

SUMMARY

VI. SUMMARY

Investigation was undertaken to explore the possibilities of utilization of millets in formulating complementary food. In the process of investigation malted flours of foxtail millet, little millet, sorghum and white ragi based products were used. The millet based RTC green gram, SMP and WPH containing complementary foods were prepared with the above millets. Formulated best RTC foods were added with honey and probiotic bacteria. The best adjudged formulations were spray dried; fluid bed dried and vacuum dried RTU complementary foods. Further, the extruded RTU millet based complementary foods were formulated. Best adjudged extruded foods were added with honey and probiotic bacteria. Besides the above, the extruded flakes were prepared in the study. The best adjudged products were subjected to bioassay studies by feeding to rats. The storage stability of the best adjudged products of RTC and RTU products was estimated. The results of the investigation to formulate millet based complementary health food have been summarized here under.

6.1 The chemical composition of the raw flours with respect to moisture, fat, protein, carbohydrate, crude fibre, and ash content of the raw wheat flour, raw green gram flour, raw foxtail millet flour, raw little millet flour, raw sorghum and raw white ragi flour was estimated. The chemical composition of the malted flours with respect to moisture, fat, protein, carbohydrate, crude fibre, and ash content of the malted wheat flour, malted green gram flour, malted foxtail millet flour, malted little millet flour, malted sorghum and malted white ragi flour was analyzed. The composition of extruded flours of foxtail, little, sorghum and white ragi were analyzed for moisture, fat, protein, carbohydrate, crude fibre, and ash content. The composition of SMP and WPH used in the study were also analyzed for moisture, fat, protein, carbohydrate, and ash content. From the obtained composition, the energy density of the raw materials was calculated.

6.2 Foxtail millet flour could be completely incorporated by replacing wheat flour. SMP could be incorporated in place of green gram to get better sensory acceptability. Complete replacement of SMP in place of green gram could be done to improve the sensory characteristics. Substitution of SMP with WPH was possible only up to 50 per cent. The little millet flour could be completely replacing the wheat without affecting the sensory acceptability of the resultant product. SMP incorporation in place of green gram improved the sensory acceptability significantly. The overall acceptability scores were 6.59, 7.08, 7.21, 7.37 and 8.02 for 0, 25, 50, 75 and 100 per cent level of SMP incorporation in the little millet based complementary food containing SMP. The awarded overall acceptability scores at 0, 50, 75 and 100 per cent level of WPH were 8.0, 7.72, 7.78 and 7.85 respectively revealed that WPH can be completely incorporated into the little millet based product . Sorghum malt could replace wheat malt only up to 50 per cent level. In SMP added product 100 per cent replacement is possible. WPH can only be incorporated up to 50 percent into the complementary health food. Malted white ragi could be incorporated completely in place of wheat without affecting the sensory acceptability. SMP addition at 100 per cent in place of green gram increased the acceptability of the product significantly. WPH could be incorporated up to 75 percent level in place of SMP. White ragi complementary food was the best among the millets tried in the study.

6.3 The Gelatinization studies revealed the onset, peak and endset temperatures were different for different formulations and thus no single time temperature combination could be fixed for cooking time to prepare porridge and the cooking conditions could be stated as bring down to boil and wait till the development of viscosity. The complementary food containing green gram has very few amino acids in the formulated product. The same was true with the SMP containing complementary food but more essential amino acids. However, the product with WPH had almost all the essential amino acids in the product. Comparative study on the rheological characteristics revealed that the viscosity of the porridge of little millet based, sorghum based and white ragi were 34000, 28000, 3000mPa.s respectively. However, it decreased upon increase in the shear rate in all the three cases. The viscosity reduction when the porridge slurry was prepared and after keeping it for few minutes. This resulted in body and texture scores difference upon increasing the level of replacement of type of protein in white ragi based food. In the honey (5%) blended complementary food, the sugar level can be reduced by 2 per cent to get the optimum acceptability of the resultant product. Dry blending of probiotic organisms to have 9 log cfu/g did not affect the sensory characteristics of the product. Upon addition of honey, the viscosity of the porridge of white ragi based product was 3000mPa.s.

6.4 Optimized level of for spray drying was 1:5 dilutions with water, cooking the porridge till boiling and development of viscosity and the optimum temperature for drying of the white ragi based complementary food was 85-90^{o}C to get the moisture of the powder below 5 per cent. In case of fluid bed drying the temperature of 50^{o}C was required to get the moisture below 5 per cent in the dried product. The porridge for vacuum drying should be diluted with 1:2 to 1:3 proportions and subjecting it for vacuum drying at the temperature of 50^{o}C was found optimum to get the desired moisture content of below 5 per cent. Sensory characteristics of RTU and RTC complementary foods were almost similar and are highly acceptable. The complementary food containing green gram has very few amino acids in the formulated product. The same was true with the SMP containing complementary food. However, the product with WPH had almost all the essential amino acids.

6.5 The trend of gelatinization temperatures obtained for the raw flours of maize, wheat, white ragi and sorghum depicted that the onset, peak and end set temperatures was having similarity. Thus, it was decided to use the same process conditions (120±5°C for extrusion,100±2°C for drying and 150°C for roasting) employed during the production of the extruded flours and corn flour for the production of the extruded flours and flakes from wheat, foxtail millet, little millet, sorghum and white ragi. The sensory acceptability of RTU millet based complementary health food added SMP revealed that the little millet based extruded flour was the best among the blends and the viscosity of the porridge was 11600mPa.s initially was decreased slowly as the shear rate is increased. This parameter decides the body and texture of the developed product. Dry blending of honey and probiotic organisms to have 9 log cfu/g did not affect the sensory characteristics of the product.

6.6 From among the millet flakes prepared, sorghum flakes were adjudged best and comparable with that of the wheat flakes followed by the white ragi flakes, little millet flakes and foxtail millet flakes. The millet flakes were served in different media and form such as millet flakes in hot milk, millet flakes in cold milk and millet flakes as masala snacks keeping wheat flakes as control revealed that the in all the three forms the sorghum flakes were the best among the millet blends which was awarded scores near to that of the control wheat flakes followed by white ragi flakes, little millet flakes and foxtail millet flakes.

6.7 The weight gain in all the rats fed with complementary foods was higher compared to the control. The amount of weight increase in the control rats was from 60g to 125gm during the feeding period. However, in complementary food fed rats it ranged from 140gm to 164 gram depending on the type of feed. The complementary food prepared with SMP and WPH have higher PER, FER and NPU values as compared to all other groups of rats fed. The blood glucose levels of the rats were well with in the acceptable range.

6.8 RTU white ragi based complementary food and little millet extruded food was having the shelf life of 6months. Sorghum flakes had the shelf life of 6 months. The HMF content of product stored under MAP at 20:80 CO_2 and N_2 ratio was found to be lesser as compared to other levels of MAP. The MPE with 20: 80 $CO_{2:}N_2$ the better material to control of the increase in FFA during storage. Among the MAP storage packs, the extent of the increase in the PV was least in 20: 80 CO_2:N_2 compared to the other treatments in both the type of packing material.

Ready to cook formulation of foxtail millet could be stored for 45 days at 30±1^{o}C when packed in MPE pouches, where as the RTC formulations of little millet, sorghum and white ragi could be stored for 60days at 30±1^{o}C when packed in MPE pouches. The

RTU vacuum dried white ragi based complementary food was acceptable up to 180days at 30±1^{o}C when packed in MPE pouches. The microbial load was consistently increased as the storage period increased. The little millet based extruded complementary food was having lower initial microbial load and was better stable during storage up to 180 days at 30±1^{o}C when packed in MPE pouches. The sorghum flakes were found to be acceptable up to 6 months at 30±1^{o}C when packed in MPE pouches. The total count of the flakes was the least as the number of heating processes it under goes during the flakes manufacture. In all the samples coliforms and yeast and moulds were absent. The RTU malted white ragi based vacuum dried honey blended probiotic complementary health food with SMP and RTU little millet based extruded honey blended probiotic complementary health food with SMP could be stored for 90days at 30±1^{o}C when packed in MPE pouches to harness the benefit of the probiotic products.

The present investigation was developed millet based food complementary health food formulations using malted foxtail millet, malted little millet flour, malted sorghum and malted white ragi flour containing green gram, SMP and WPH. Further, the best adjudged formulations were spray dried, fluid bed dried and vacuum dried to make them ready to use (RTU) or ready to reconstitute (RTR). The process of manufacturing them was standardized for making them suitable for commercial exploitation. Extruded RTU millet based formulations were also developed in the study. The storage stability of the developed product, feasibility of incorporation of probiotic organisms in to the formulation, cost economics and its nutritional quality were also dealt in this project. The developed technology could be a an avenue for the utilization of millets as ready to use millet based complementary health food that will bring the small millets to the main stream food basket.

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VII. BIBLIOGRAPHY

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ABSTRACT

VIII. ABSTRACT

Investigation was undertaken to explore the possibilities of utilization of millets in formulating complementary food. Malted flours of foxtail millet, little millet, sorghum and white ragi based Ready to cook (RTC) products with green gram, SMP and WPH were prepared. Optimized level of for spray drying was 1:5 dilutions with water, cooking the porridge till boiling and development of viscosity spray drying of complementary food at 85-90^{o}C out let temperature. Fluid bed drying at 50^{o}C was required to get the moisture below 5 per cent in the dried product. The porridge with 1:2 to 1:3 proportions of food: water prepared and subjecting it for vacuum drying at the temperature of 50^{o}C was found optimum. Sensory characteristics of ready to use (RTU) and RTC complementary foods were almost similar and are highly acceptable. The little millet based extruded flour based RTU product with SMP was best. Dry blending of honey and probiotic organisms to have 9 log cfu/g did not affect the sensory characteristics of the product. Among millet flakes, sorghum flakes were adjudged best and comparable with that of the wheat flakes followed by the white ragi flakes, little millet flakes and foxtail millet flakes. The complementary food prepared with SMP and WPH had higher PER, FER and NPU values as compared to all other groups. The blood glucose levels of the rats were well within the acceptable range. RTC malted complementary food had shelf life of 1.5 to 2 months and RTU foods and flake were acceptable for 6 months. Storing of RTU product under MAP at 20:80 CO_2 and N_2 ratio in Metallized Polyester (MPE) was found to be best. RTU probiotic foods could be stored for 90days at 30±1^{o}C when packed in MPE pouches to harness the benefit of the probiotic products. The developed technology could be a an avenue for the utilization of millets as ready to use millet based complementary health food that will bring the small millets to the main stream food basket.

ANNEXURES

ANNEXURE-I

Composition of vitamin mixture used for bioassay studies

Sl. No.	Particulars	Quantity (in each tablets)
1	Vitamin A	0.0061
2	Vitamin D2	0.0032
3	Vitamin E	0.0276
4	Vitamin C	0.0394
5	Vitamin K1	0.0002
6	Vitamin B1	0.0008
7	Vitamin B2	0.0008
8	Vitamin B3	0.0063
9	Vitamin B5	0.0022
10	Vitamin B6	0.0013
11	Vitamin B7	0.0000
12	Vitamin B9	0.0001
13	Vitamin B12	0.0001
14	Carrier	0.1120

ANNEXURE-II

Sensory score card for Complementary Food

Name of the judge : **Date:_____________**

Name of the product :

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

Score system:

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

Characteristics	**Sample code**							
Colour and appearance								
Flavour								
Body and texture/Consistency								
Overall acceptability								

Comments if any:

Signature

ANNEXURE-III

Cost of production of ready-to-cook (RTC) malted foxtail millet complementary Food* (kg product)

Sl. No.	Ingredients	Cost (Rs)
1	Foxtail millets and Malting charges	83.5
2	SMP	28.5
3	Sugar	6.5
4	Packaging cost	10.0
Total		**128.5**

Cost of production per KG of ready-to-cook malted foxtail millet based complementary food developed in this study: Rs. 128.5/kg

***** Cost calculation was based on the prevailing current market price of ingredients used in the formulation and conversion charges by the factories

ANNEXURE-IV

Cost of production of ready-to-cook (RTC) malted little millet complementary Food* (kg product)

Sl. No.	Ingredients	Cost (Rs)
1	Little millets and Malting charges	83.5
2	SMP	28.5
3	Sugar	6.5
4	Packaging cost	10.0
Total		**128.5**

Cost of production per KG of ready to cook malted little millet based complementary food developed in this study : Rs. 128.5/kg

***** Cost calculation was based on the prevailing current market price of ingredients used in the formulation and conversion charges by the factories

ANNEXURE-V

Cost of production of ready-to-cook (RTC) malted sorghum based complementary Food* (kg product)

Sl. No.	Ingredients	Cost (Rs)
1	Sorghum and Malting charges	68.5
2	SMP	28.5
3	Sugar	6.5
4	Packaging cost	10.0
Total		**113.5**

Cost of production per KG of ready to cook malted sorghum based complementary food developed in this study: Rs. 113.5/kg

***** Cost calculation was based on the prevailing current market price of ingredients used in the formulation and conversion charges by the factories

ANNEXURE-VI

Cost of production of ready-to-cook (RTC) malted white ragi complementary Food* (kg product)

Sl. No.	Ingredients	Cost (Rs)
1	White ragi and Malting charges	73.5
2	SMP	28.5
3	Sugar	6.5
4	Packaging cost	10.0
Total		**118.5**

Cost of production per KG of ready to cook malted white ragi complementary food developed in this study : Rs. 118.5/kg

***** Cost calculation was based on the prevailing current market price of ingredients used in the formulation and conversion charges by the factories

ANNEXURE-VII

Cost of production of Ready-to-Use (RTU) Vacuum/Spray dried white ragi complementary food* (kg product)

Sl. No.	Ingredients	Cost (Rs)
1	Millets and Malting charges	73.5
2	SMP	28.5
3	Sugar	6.5
4	Processing charges/ Conversion charges	45.0
5	Packaging cost	15.0
Total		**168.5**

Cost of production per KG of Ready to Use White ragi Vacuum/Spray dried Complementary Food developed in this study: Rs. 168.5/kg

***** Cost calculation was based on the prevailing current market price of ingredients used in the formulation and conversion charges by the factories

ANNEXURE-VIII

Cost of production of Ready-to-Use (RTU) extruded little millet Complementary Food* (kg product)

Sl. No.	Ingredients	Cost (Rs)
1	Millets	30.0
2	Processing charges/ Conversion charges	60.0
3	SMP	28.5
4	Sugar	6.5
5	Packaging cost	15.0
Total		**140.0**

Cost of production per KG of Ready to Use extruded little millet Complementary Food developed in this study: Rs. 140.0/kg

***** Cost calculation was based on the prevailing current market price of ingredients used in the formulation and conversion charges by the factories

ANNEXURE-IX

Cost of production of probiotic RTC, RTU and extruded complementary food* (kg product)

Sl. No.	Ingredients	Cost (Rs)		
		RTC	RTU Malted	RTU Extruded
1	Millets and Malting charges	73.5	73.5	30.0
2	SMP	28.5	28.5	28.5
3	Sugar	6.5	6.5	6.5
4	Processing charges/ Conversion charges	-	45.0	60.0
5	Honey	15	15.0	15.0
6	Probiotic bacteria (*L.acidophilus*) or Probiotic bacteria (*Bifidobacteria*)	60 or 130	60 or 130	60 or 130
7	Packaging cost	15.0	15	15
Total Cost of production per KG of probiotic complementary health food developed in this study per Kg of the product		**198.5** **or** **268.5**	**243.5** **or** **313.5**	**215** **or** **285**

***** Cost calculation was based on the prevailing current market price of ingredients used in the formulation and conversion charges by the factories

ANNEXURE-X

Cost of production of Ready-to-Use Sorghum flakes*

(kg product)

Sl. No.	**Ingredients**	**Cost (Rs)**
1	Millets	30.0
2	Sugar, vitamin and mineral mixture and other ingredients and preservatives cost	45.0
3	Processing charges/ Conversion charges	50.0
4	Packaging cost	15.0
Total		**140.0**

Cost of production per KG of Ready to Use Sorghum flakes developed in this study : Rs. 140/kg

***** Cost calculation was based on the prevailing current market price of ingredients used in the formulation and conversion charges by the factories

ANNEXURE-XI

Cost of production of Ready-to-Use White ragi flakes*

(kg product)

Sl. No.	Ingredients	Cost (Rs)
1	Millets	30.0
2	Sugar, vitamin and mineral mixture and other ingredients and preservatives cost	45.0
3	Processing charges/ Conversion charges	50.0
4	Packaging cost	15.0
Total		**140.0**

Cost of production per KG of Ready to Use White ragi flakes developed in this study : Rs. 140/kg

***** Cost calculation was based on the prevailing current market price of ingredients used in the formulation and conversion charges by the factories