DEVELOPMENT OF LOW GI EXTRUDED MULTI-GRAIN SNACK FOR DIABETICS AND ITS QUALITY EVALUATION

DIWAN HASEENA M
(21PFD008)

Thesis submitted to

Avinashilingam Institute for Home Science and Higher Education for Women,
Coimbatore – 641043

In partial Fulfilment of the Requirements for the Degree of Master of Science in
FOOD SERVICE MANAGEMENT AND DIETETICS

May 2023

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Signature of the Supervisor

Signature of the Head of the Department

CERTIFICATE

This is to certify that the thesis entitled, **"Development of Low GI Extruded Multi-Grain Snack For Diabetics and Its Quality Evaluation"** submitted to Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore in Partial fulfilment of the requirements for the award of the degree of Master of Science in Food Service Management and Dietetics, is a record of original research work done by **Ms. Diwan Haseena M** with Register Number 21PFD008 during the period of this study under the Supervision and Guidance of **Dr. R. Radha**, Assistant Professor (SG), Department of Food Service Management and Dietetics, Avinashilingam Institute for Home Science and Higher Education For Women, Coimbatore- 641043, Tamil Nadu, India.

Signature of the Supervisor

Signature of the Candidate

ACKNOWLEDGEMENT

First and the foremost, the investigator places her humble salutations and prayers to **God Almighty** for his uncountable blessings showered upon her and for giving the strength, knowledge, ability and opportunity to undertake this research study and to persevere and complete it satisfactorily throughout the study period.

The investigator pays her reverential homage to **(Late) Dr. T.S Avinashilingam,** Founder, and First Chancellor, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for being a perennial source of inspiration.

Reverential homage is paid to the Doyen of Nutrition Colonel and **(Late) Dr. Rajammal P. Devadas,** Former Vice Chancellor, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for being a perennial source of inspiration.

The investigator expresses her gratitude to **Sri. T.S. K. Meenakshi Sundaram,** Managing Trustee, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for providing an opportunity to conduct the study.

The investigator is grateful to **Dr. S. P. Thyagarajan,** Chancellor, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for providing an opportunity, infrastructure and all amenities to conduct the study.

The investigator owes her special thanks and gratitude to **Dr. V. Bharathi Harishankar,** Vice Chancellor, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for facilitating the completion of the study.

She records her gratitude to **Dr. S. Kowsalya,** Registrar, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for providing all the facilities for the smooth conduct of the study.

She expresses her heartfelt thanks to **Dr. N. Vasugi Raja,** Dean School of Home Science, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for her help and constant support to carry out the research.

The investigator expresses her special thanks and sincere gratitude to **Dr. S. Uma Mageshwari,** Dean Student Affairs, Former Head, Department of Food Service

management and Dietetics, Avinashilingam Institute for Home Science and Higher education For Women, Coimbatore, for her keen interest, valuable help, concern and encouragement which has helped in the successful completion of the study.

The investigator owes her heartfelt thanks and gratitude to **Dr.V. Premala Priyadharsini,** Professor and Head of the Department of Food Service Management and Dietetics, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for her keen interest, valuable help, concern and encouragement which has helped in the successful completion of the study.

The investigator expresses her deep sense of gratitude and whole hearted thanks to her Supervisor **Dr. R. Radha,** Assistant Professor (SG), Department of Food Service Management and Dietetics, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, whose ability to probe beneath text was a true gift and her insight have strengthened this study significantly.

The investigator acknowledges with gratitude the good wishes and encouragement of **all the staff members of the Department of Food Service Management and Dietetics**, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore. The investigator acknowledges her heartfelt gratitude to the Institutional Human Ethical Committee Members of Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for approving her research work.

The investigator expresses her gratitude and thanks to all the **respondents**. Investigator cherish to acknowledge her seniors whose co-operation, timely help, suggestions, constant encouragement and support which made her study successful.

The investigator expresses her heartfelt thanks to **family, friends and relatives** whose motivation, care, concern and all their support morally, spiritually and financially for whom they are the pillar of strength.

The investigator thanks to all the people whose assistance was a milestone in the completion of this study. Their support, encouragement and credible ideas have been great contributors in the grand success of this study.

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I. INTRODUCTION

"To eat is a necessity, but to eat intelligently is an art"

-La Rochefoucauld

Health is an individual's physical, emotional, mental, and social ability to cope with the environment. Having good health is connected to a productive life. When a person leads a healthy lifestyle, the body remains fresh and active, it is the body's natural and metabolic efficiency to adapt to physical, and mental changes the body exhibit. When the body gets good nutrition, it maintains a healthy and fit body for increased longevity in life (Kamraju *et al.*, 2017)

According to Mohamed *et al* (2017) one of the most crucial aspects of health is that it gives the body the ability and immunity it needs to carry out daily activities. Apart from these, several components ensure good health, fitness, and well-being. Cardiovascular aerobic training, a balanced diet, strength training, muscular development, and a balanced lifestyle with good sleep. Health and well-being are important as it helps to keep the body hydrated, have an adequate intake of nutrients, and maintain fitness through regular exercise.

Samar *et al* (2020) stated that non-communicable diseases are increasing in areas of society, government, and also worldwide due to high mortality rates. It can be caused due to factors such as age, genetics, environment, socio-cultural and medical factors. Nutritional interference is very essential in controlling non-communicable diseases. The most preventive step in controlling non-communicable diseases is a change in lifestyle through proper diet and physical activity.

Non-communicable diseases are a diverse group of chronic diseases that are not communicable from one person to another. Non-communicable diseases are identified by World Health Organization (WHO) and categorized as "Group II Diseases"; these are the conditions that cause death. Four main diseases are generally considered to be the most powerful in non-communicable diseases mortality and morbidities such as cardiovascular disease, diabetes mellitus, cancer, and chronic respiratory diseases (Aida *et al.*, 2020).

The way of life and eating habits of people all around the world have changed significantly over the past century. However, this change is not equally mirrored in our genetic composition, leading to an imbalance between calorie intake and energy expenditure, which in turn causes overweight and obesity in both adults and adolescents. Obesity and

overweight are important risk factors for non-communicable chronic degenerative illnesses (Nicolas.2019)

According to Priyanka *et al* (2022), diabetes mellitus is a non-communicable chronic disease that does not allow the body to utilize glucose completely or partially. Diabetes has been classified as type 1, type 2, maturity-onset diabetes of the young (MODY), and gestational diabetes. Diabetes involves inappropriately elevated blood glucose levels. Diabetes is one of the most common and frequent chronic diseases in the country and worldwide.

Type 1 diabetes mellitus is present in children where insulin is not present and are insulin dependent. Type 2 diabetes mellitus affects middle age and old adults who have prolonged hyperglycemia due to poor dietary choices and poor lifestyle. T1DM is characterized by the destruction of beta cells in the pancreas, generally secondary to an autoimmune process. The outcome is the most dreadful. T2DM implies a more insidious appearance where the imbalance between insulin levels and insulin sensitivity causes a functional deficiency of insulin (Amit *et al.,* 2022).

Type 2 Diabetes Mellitus (T2DM), one of the most common metabolic diseases in the world, is brought on by the interaction of two critical factors: reduced insulin secretion by pancreatic beta-cells and impaired insulin sensitivity of tissues. The molecular processes involved in the production and release of insulin, as well as the insulin response in tissues, must be strictly regulated for it to perfectly satisfy the metabolic requirement. As a result, flaws in any of the pathways can result in a metabolic imbalance and T2DM pathogenesis. (Unai *et al.,* 2020)

Lawson *et al* (2009) opines that diabetes is a highly symptomatic disorder, at least before it develops, therefore symptoms are not the main factor in getting people to do what needs to be done. The patients are motivated by other perceptions of their diabetes both short and long-term. This includes the view on the probability of adverse events occurring, the perceived impact on their daily life, perceived self-monitoring, and perceptions of the effectiveness of prevention strategies.

Diabetes management requires significant dietary, exercise, medication, and lifestyle changes that involve blood sugar monitoring. Self-care may be improved by well-being programs that increase motivation and self-efficacy (Christina *et al.,* 2019)

The typical signs of diabetes, such as polyuria, polydipsia, and polyphagia, are frequently present in both type 2 and type 1 diabetes, which both have extremely high levels of hyperglycemia and type 1 diabetes which develops rapidly with severe hyperglycemia. Only type 1 diabetes or type 2 diabetes that has gone undiagnosed for a long time causes severe weight loss. Other typical symptoms of undiagnosed diabetes include unexplained weight loss, exhaustion, restlessness, and physical pain. Mild symptoms or those that appear gradually may also go undetected (Ramachandran. 2014)

Diabetes mellitus is increasing at an alarming rate. Early diagnosis of diabetes and pre-diabetes is essential with the help of the recommended glycosylated hemoglobin for other types except for gestational diabetes. Diabetes screening, especially in underdeveloped countries, is crucial to reducing delays in diagnosis. The development of diabetes involves an interaction between genetic and non-genetic factors. Recent studies provide tools for use of multiple genes as targets for risk assessment, therapeutic strategies, and predicting complications (Akram *et al.,* 2015).

Nita *et al* (2014) stated that type 2 diabetes is considered to start from four to seven years before clinical diagnosis and a large percentage of people already show signs of end-organ damage at that point, screening was suggested in the hope that early diagnosis and treatment would lessen the burden in the long run. In comparison to short- and long-term problems like heart attack and stroke, diabetes screening is practical and has no psychological harm.

Diabetes has been linked to enhanced dietary management in both Type 1 Diabetes Mellitus and Type 2 Diabetes Mellitus, and it is predictive of dietary self-management in older persons with diabetes who believe their illness is severe and that treatment is effective (Harvey *et al.,* 2009).

According to Xueyao *et al* (2020) comparison to people with a normal body mass index (BMI), the risk of getting diabetes was significantly higher in those with central obesity compared to overweight and obese individuals. The complex etiology of obesity involves genetic, environmental, and nutritional variables.

Aftab *et al* (2017) highlight that diabetes and obesity are significant contributors to morbidity and mortality. Both obesity and weight growth enhance a person's risk of developing diabetes. In type 2 diabetes, the deterioration of pancreatic cell function prominently progresses over time. Although aging, obesity, insufficient energy intake,

alcohol consumption, and smoking are all separate risk factors for the development of type 2 diabetes mellitus, they all contribute to the disease. Overeating, smoking, drinking more alcohol, having problems with the neurological and endocrine systems, having high cortisol levels, having abnormal sex hormone secretion levels, not exercising enough, and genetic factors like aging can all contribute to diabetes mellitus.

Tahir *et al* (2017) stated that the role of diet in the development of type 2 diabetes was first proposed by Indians. The disease was found to be most prevalent in affluent people who consume high levels of oil, flour, and sugar. Numerous studies have found that individuals with diabetes are more likely to consume large amounts of carbohydrates and fats. These findings support the hypothesis that consuming high levels of sugar is a significant factor in developing T2DM. Consuming carbonated drinks increases the likelihood of obesity, after adjusting for other factors such as diet, demographic data, anthropometric measurement, and lifestyle choices.

The prevalence of diabetes among adults aged 20 to 79 over the world was predicted to be 10.5% (536.6 million) in 2021 and 12.2% (783.2 million) in 2045. Diabetes prevalence was comparable between genders and was highest in people aged 75 to 79. In 2021, the prevalence was predicted to be higher in urban 12.1% than in rural 8.3% locations and in high-income 11.1% than in low-income 5.5% nations (Sun *et al.*, 2022).

Reddy *et al* (2023) observed that In India, the prevalence of diabetes mellitus among people aged 20 to 79 is 8.9%. In terms of diabetes mellitus prevalence worldwide, India comes in second. The overall lead falls by Chandigarh with 13.6%, followed by Tamil Nādu (10.4%), Punjab (10%), Maharashtra (8.4%), Andhra Pradesh (8.4%), and Karnataka (7.7%). These are the Indian states where diabetes is far more prevalent than in other states.

In comparison to red meat, excessive milk consumption decreases insulin sensitivity in overweight and obese adults with glucose intolerance. The risk of acquiring diabetes and impaired glucose tolerance was significantly increased by excessive consumption of fast food and bakery goods. These foods typically have high levels of simple glucose, little fiber, and lots of fat (Raghuram *et al.*,2021)

Consumption of fat, sugar, carbohydrates, or fiber was still not linked to a higher risk of illness. Increased risk of insulin resistance and T2DM is correlated with high consumption of meat, sweets, and fatty foods. Consuming fruits and vegetables may help prevent T2DM, as they are packed with nutrients, fiber, and antioxidants that can act as a

protective barrier against the disease. Eating white rice on regular basis was associated with an increased risk of T2DM. This underscores the pressing need for people to adopt healthier eating habits, not just among those at high risk for this, but also in the general population (Wagas *et al.*, 2017).

Nita *et al* (2018) stated that fruit-based fructose consumption is better than consuming a comparable amount of glucose. The intake of sugar or starch is because of the additional micronutrients, phytochemicals, and fiber content of fruit. There is a consensus among nutritionists that reducing or avoiding the intake of processed meat, refined grains, and sugar can help prevent T2DM. There are some caveats to this advice though for unprocessed red meat, the evidence of possible harm is weaker and its impact on developing diabetes is smaller in magnitude.

Attention to a diet plan is necessary for an individual to maintain glycaemic control. Dietary guidelines can be tailored based on age, weight, gender, health condition, and occupation. Such plans help promote overall nutritional well-being while managing diabetes complications (Sheeraz *et al.*, 2022)

The metabolization of carbohydrates is heavily influenced by diet. Dietary elements may regulate blood sugar through a number of methods in addition to influencing the level of glucose generated after a meal. Natural substances can reduce blood sugar levels in two key ways: by limiting absorption and raising metabolic rate to encourage insulin secretion. According to the council on herbal medicinal products' recommendations, type 2 diabetes can be supported by using unprocessed plant materials. Because they have been in use for a long period, these materials can be registered as herbal medications. (Agnieszka *et al.*, 2021)

John *et al* (2018) highlights that exercise is often one of the first management options suggested. Exercise is a crucial part of all diabetes and obesity prevention and lifestyle intervention programs, along with nutrition and behavior modification. Improved glucose regulation is made possible through exercise training, whether it be resistance training, aerobic exercise, or a combination. High-intensity interval training is also efficient in terms of time and effectiveness. The sustainability of exercise recommendations for patients remains elusive although exercise is effective, scalable, and affordable for the prevention and management of type 2 diabetes. Adults who lead physically active lifestyles

are known to have a lower chance of acquiring type 2 diabetes, insulin resistance, and impaired glucose tolerance.

Natarajan (2022) has shown in the research that snacking on whole, unprocessed meals are the best because they give the energy needed to get through the day. For agricultural improvement and use, millet has got less research and development attention than other crops. Some of these include biscuits and vermicelli, like other millets, are thought to have particular beneficial characteristics. Millets have been used to create value-added products that have been in various stages of development and standardization.

According to Elzbieta *et al* (2021) using herbs to help control or cure diabetes is an important part of combating this disease, along with eating a healthy diet or taking supplements that contain functional foods. Some of the compounds responsible for plant-based antidiabetic effects include flavonoids, anthocyanins, phenolic acids, and polysaccharides. Additionally, alkaloids and tannins are also common constituents found in high quantities in cinnamon. An herbal infusion is a form of herbs. They provide effective distribution of active compounds in the intestine, and infusing hypoglycemic remedies can be an important part of combating diabetes II, which is known as “the silent epidemic”.

The food industry by-products have been adopted as a strategy worldwide. An important reason is that these value-added products often contain high levels of bioactive components, dietary fibers, vitamins, and minerals which can be used to create new food products for energy production. Cereal-based snacks that are directly expanded have high levels of carbohydrates, fat, and salt while being devoid of nutritional value. They are enjoyed by all generations in large quantities (Antun *et al.*, 2021)

Diabetes prevalence is steadily increasing among the global population. One of the reasons for the prevalence is the consumption of commercially available Ready to Eat snacks which are loaded with saturated fat and calories. Hence an effort was made to develop a healthy nutritious snack in the extruded form with millet as the base. Further herbs are planned to be incorporated to make them a therapeutic food. Hence, the study was carried out with the following objectives, they are

- To develop a healthy multi-grain extruded snack suitable for diabetes.
- To perform sensory evaluation and quality analysis of the developed snack.
- To find out the glycemic Index of the developed snack.

II. REVIEW OF LITERATURE

The review of literature pertaining to the study titled **"Development of Low GI Extruded Multi-Grain Snack for Diabetics and Its Quality Evaluation"** is presented under the following headings

A) Prevalence of non-communicable and chronic metabolic disease.
B) Nutritional importance of millets and value-added millet–based snacks.
C) Importance of GI food for diabetics.
D) Benefits of Hypoglycaemic herbs in the management of diabetes.

A) Prevalence of non-communicable and chronic metabolic disease.

According to Arvind *et al* (2022), non-communicable diseases (NCDs) are one of the major challenges for public health in the 21st century. They cause harm not only due to people's pain but also inflict significant socioeconomic damage on a country's development. Each year, NCDs kill about 41 million people worldwide, including 14 million who die between the age group of 30 and 70. The World Health Organization (WHO) has predicted that if timely interventions aren't done to prevent and control chronic diseases, the number of deaths from these conditions will increase by 55 million people in 2030.

Sahoo *et al* (2021) in his study specified that non-communicable illnesses are typically long-lasting chronic conditions. Diabetes, chronic respiratory illness, cancer, and cardiovascular disease are the four primary forms of noncommunicable diseases (NCDs), according to the World Health Organization1. A silent global epidemic, NCDs are responsible for more than two-thirds of all fatalities each year. The need for ongoing treatment for long-term NCD consequences presents new problems for the healthcare system and complicates NCD prevention and therapy.

Epidemics, which are uncontrolled transmissions of diseases, were a major threat to life expectancy in the early centuries, with medical research achievements such as vaccinations and antibiotics, NCD (Non-Communicable Disease) has become more common in industrialized countries over the past decades (Jaya *et al.,* 2021)

Hitaishi *et al* (2021) stated that cardiovascular diseases, cancer, diabetes mellitus, and chronic pulmonary and mental illness now play a real burden on health systems

throughout developed nations. The susceptibility to NCDs is common across all age groups, with a shift in focus from a communicable disease that primarily affects children to chronic conditions affecting adults. For many years, these illnesses were considered an indication of prosperity and epidemics afflicting developed societies.

Bikash *et al* (2022) highlighted that socioeconomic status is the most important factor impacting the distribution of habitual conditions in and within communities. The relationship between the circumstance of NCDs and profitable status varies extensively with pronounced indigenous differences. The socioeconomic pattern of inequality in the frequency of NCD differs from one country to another and within nations depending on current health and social programs. Studies have set up an association between the frequency of NCDs similar to hypertension and diabetes mellitus and the socioeconomic position of individuals.

In the past, parasitic and infectious diseases were the leading causes of death, but in recent years, NCDs have supplanted them as the leading killers. This may be linked to the evolution of dietary practices and lifestyle choices over time, which is characterized by a change in human disease patterns. The use of sugar-sweetened beverages, iron-rich diets, whole grain products, meat, and healthy dietary patterns all have a clear connection to NCDs (Dana *et al.,* 2020)

The burden of non-communicable diseases and the inequalities associated with them will continue to increase over the next two decades. For example, while Asia and Africa are still largely rural, these two regions are rapidly becoming urbanized more than any other. Recent studies have shown a rapid increase in NCDs and their risk factors, especially BMI and cholesterol levels, in parallel with rapid urbanization (Lal *et.al.,* 2017)

Every cell in the body can utilize glucose. The majority of cells are not "glucose-dependent," or limited to consuming glucose. Red blood cells, white blood cells, and renal papilla cells are some of the cells that are dependent on glucose. Red blood cells rely on glucose and glycolysis as they lack mitochondria for beta-oxidation. For their respiratory push when battling pathogens, white blood cells need glucose. Because its cells have a very low oxygen tension, the inner renal medulla must primarily utilize glucose and glycolysis. (Eric. 2021)

Type 2 Diabetes Mellitus is a growing worldwide problem, with WHO estimates suggesting that 300 million people will be affected by 2025. T2DM is characterized by

supplemental insulin resistance, blood regulation of hepatic glucose, and declining beta cell function, ultimately leading to beta cell failure (Lam *et al.*, 2012)

According to the World Health Organization, the development of T2DM is greatly influenced by a wide range of lifestyle variables, including sedentary behavior, physical inactivity, smoking, and alcohol use. Obesity is the most significant risk factor for T2DM, which may affect the emergence of insulin resistance and the course of the disease, T2DM affects over 90% of diabetes patients, with increased body weight being the main contributing factor.

Parimala *et al* (2022) stated that non-communicable conditions (NCDs) manifest between the fat and the deprived are major predictors of unseasonable mortality and differences in life expectancy among aged people. According to the Global Burden of Conditions (GBC) (2022) report, cardiovascular conditions, habitual lung illness, and diabetes mellitus are the leading causes of death. NCDs claim the lives of nearly 6 million people in India observed that primarily, cardiovascular conditions contribute to further than a third of 34.3 of India's mortality burden and diabetes mellitus accounts for 2.5 of the total burden of mortality. In addition, the frequency of NCDs continues to escalate in India with major public health counter-accusations, generally in aged people.

Pouya *et al* (2019) highlights that the global prevalence in 2019 is estimated to be 9.3% (463 million people), rising to 10.2% (578 million people) by 2030 and 10.9% (700 million people) by 2045. The prevalence is higher in urban (10.8%) than rural (7.2%) areas, and in high-income (10.4%) than low-income countries (4.0%). One in two (50.1%) people living with diabetes do not know that they have diabetes. The global prevalence of impaired glucose tolerance is estimated to be 7.5% (374 million people) in 2019 and is projected to reach 8.0% (454 million people) by 2030 and 8.6% (548 million people) by 2045.

International Diabetes Federation IDF (2022) has stated that the global population of diabetics in 2021 is estimated to be 51 million in North America and the Caribbean, 32 million in South and Central America, 61 million in Europe, 73 million in the Middle East and North Africa, 24 million in Africa, 90 million in South East Asia, 206 million in Western Pacific.

In India, 5.8 million people die each year from chronic diseases, lung diseases, stroke, cancer, and diabetes, which puts India right behind China when it comes to having the second-largest population of older adults in the world. Despite this alarming statistic though

Indian society is still poised to become home to 198 million elderly persons by 2030 (Sunita *et al.,* 2022)

Kanitkar *et al* (2018) have mentioned that the WHO anticipates non-infectious conditions will regard an adding absolute number and proportion of worldwide deaths, rising to about 70 percent of death. Physical exertion, social engagement, and a healthy diet help with habitual conditions and increase the life and quality of life of aged people. Health services need to be strengthened consequently with increased emphasis on crucial service utilization determinants like service vacuity and availability.

Yogita *et al* (2017) in her study observed metabolic abnormalities that include hypertension, obesity, insulin resistance, and atherogenic dyslipidemia. It's explosively associated with an increased threat of developing atherosclerotic cardiovascular complaints. The pathogenesis of metabolic complaint involves both inheritable and acquired factors that play a part in the final pathway of inflammation that leads to CVD. It has come decreasingly applicable in recent times due to the exponential increase in obesity worldwide.

According to World Health Organization, diabetes is a chronic condition initiated by either insufficient insulin production by the pancreas or inefficient insulin utilization by the body. A hormone called insulin controls blood sugar levels. Uncontrolled diabetes frequently causes hyperglycemia, also known as high blood glucose or raised blood sugar, which over time can seriously harm many different bodily systems, including the neurons and blood vessels. 8.5% of persons who were 18 years of age and older had diabetes in 2014. A total of 1.5 million deaths were directly related to diabetes in 2019, and 48% of these deaths occurred in those under the age of 70.

Insulin resistance intermediated increase in circulating free adipose acid (free fatty acids FFA) is believed to play a vital part in the pathogenesis of metabolic patterns. Insulin increases glucose uptake in muscle, and liver and inhibits lipolysis and hepatic gluconeogenesis. Insulin resistance in adipose tissue impairs insulin-intermediated inhibition of lipolysis, leading to an increase in circulation of FFAs that further inhibit the antilipolytic effect of insulin (Naga *et al.,* 2017)

Insulin resistance also contributes to the development of hypertension due to the loss of vasodilator effect of insulin and vasoconstriction caused by FFAs. Mechanisms include increased sympathetic activation and sodium reabsorption. Insulin resistance also causes an increase in serum density, induction of a prothrombic state, and release of pro-

inflammatory cytokines from the adipose tissue that contribute to an increased threat of Cardio Vascular Disease (Swathi *et al.,* 2017)

Rachael (2021) has reported that a dietary pattern with more processed foods, trans fats, and refined carbohydrates is being embraced by more people. As urbanization develops, more consumers are leading sedentary, less active lifestyles. a lack of knowledge, a preference for vegetarian cuisine, and an increase in processed food consumption. Diabetes prevalence is on the rise in India due to a lack of exercise, increased screen time, lifestyle factors, high blood pressure, and high cholesterol levels.

Diabetes has steadily increased in India and around the world over the last three decades, with India counting for a sizable portion of the global burden. India's complaint pattern has shown a switch due to an epidemiological transition therefore, mortality from transmissible, motherly, neonatal, and nutritive conditions (CMNNDs) have dropped significantly, while NCDs and injuries have markedly increased their donation to overall complaint burden and mortality. In India, the total disability-adjusted life years from CMNNDs were 61%, 30 % from NCDs, and 9% from injuries (Viswanath *et al.,* 2021)

Raghuram *et al* (2020) reported that India has a rapidly growing economy and a sizable population of people with diabetes. As health standards among the economically active young population decline, so do its healthcare costs. It is the nation with the second-highest number of cases of diabetes, behind China, with an estimated 65.1 million cases in 2013. By 2035, this is projected to rise to 109.0 million. 24 million cases of diabetic neuropathy, 5 million cases of retinopathy, and 6 million cases of amputation due to diabetes have been recorded by the World Health Organization (WHO).

The incidence of diabetes increased from 7.1% in 2009 to 8.9% in 2019. Impaired glucose tolerance is currently anticipated to affect 25.2 million persons; by 2045, that number is expected to rise to 35.7%. In the world's diabetes epidemic, India is in second place to China with 77 million diabetics. 12.2 million of them—who are expected to number 27.5 million by the year 2045—are over 65. In India, the number of adults with diabetes is believed to be close to 57%, or 43.9 million, undiagnosed (Rajendra *et al.,* 2021)

As per the result of Sanyukta (2022), a large-scale survey conducted across India in 2021, 17.7% of respondents from the city of Bhopal had diabetes. Around 17.6% of diabetic respondents from Chennai and almost 16.7% from Bhubaneshwar agreed with this. This fad was connected to an unhealthy way of life.

With a prevalence of diabetes as high as 20%, double the general population's average of 8%, Chandigarh leads India in terms of diabetes prevalence, followed by Tamil Nadu. A frightening statistic is that 30% of diabetic cases are not really receiving treatment, out of a total of 1444 people, 10.94 had diabetes that could be verified. From 108 million to 442 million individuals worldwide now suffer from diabetes (Kharroubi *et al.*, 2015)

In middle- and low-income countries, the frequency of diabetes has increased relatively slowly. A key contributor to blindness, kidney failure, heart attacks, and stroke is diabetes. Before the age of 70, about half of all deaths linked to high blood sugar happen. According to WHO predictions, diabetes will be the 7th most common cause of death by 2030. In rural Tamil Nadu, the population's prevalence of diabetes was 10.2% (Ajaiya *et al.*, 2017)

B) Nutritional importance of millets and value-added millet–based snacks.

Dayakar *et al* (2017) in their research mentioned that millets offer nutritive security and there's a need for promoting millets as they're largely nutritional. They have been important food masses in mortal history, particularly in Asia and Africa. Sorghum and other millet consumption operation as direct food have significantly declined over the three decades. Sorghum, pearl millet, finger millet, foxtail millet, tiny millet, barnyard millet, and Kodo millet all have nutritional profiles in the nutritional bulletin. In the majority of developing nations, millets are almost exclusively used for human consumption. Millets are gluten-free, hence are useful salutary cereals. In general millets are a rich source of fiber, minerals, and B-complex vitamins.

Millets are unique among cereals because of their abundance of calcium, salutary fiber, polyphenols, and protein. Millets generally contain significant quantities of essential amino acids; they are also advanced in fat content than rice. Millet is gluten-free, thus an excellent option for people suffering from celiac conditions frequently bothered by the gluten content of wheat and other common cereal grains. It is also useful for people who are suffering from atherosclerosis and diabetic heart complaints (Issoufou *et al.*, 2013)

Millets is a functional grain known for its significant health benefits, attributed in large part to its high content of polyphenols and antioxidants (Ameerah *et al.*, 2019)

Mounika *et al* (2022) stated that millets are also rich in micronutrients such as iron, zinc, calcium, and phytochemicals. Natural organic compounds found in plants called

phytochemicals play a role in preventing disease and promoting health. Because of their antibacterial and antioxidant capabilities, examining these phytochemicals aids in identifying bioactive substances implicated in disease prevention. Flavonoids, alkaloids, saponins, tannins, phenols, terpenoids, proteins, and carbohydrates are types of phytochemicals.

Marina (2019) in her research found that millet lowered Glycosylated Haemoglobin levels by 19.14 percent. HbA1c is a measurement of the average blood sugar level over 3 months. Fasting glucose was lowered by 13.5 percent, cholesterol by 13.25 percent, and triglycerides by 13.51 percent. These findings indicate that millet consumption has a beneficial impact on glycemic management and reduces cardiovascular risk factors.

Millet consumption can be beneficial because polyphenols have hypoglycaemic effects. Although millet is usually consumed after processing by heating, germination, and fermentation, the effect of different processing methods on millet polyphenols and their anti-diabetes potential (Han *et al.*, 2022)

Millets are also rich in health-promoting phytochemicals such as phytosterols, polyphenols, phytocyanin, lignins, and phytoestrogen. These phytochemicals act as antioxidants, immunological modulators, and detoxifying agents, preventing age-related degenerative illnesses such as cardiovascular disease, diabetes, and cancer (Nanje *et al.,* 2022)

Millets have nutritional health advantages as they promote the health of the digestive system, lower cholesterol, protect against heart disease, protect against diabetes, reduce the risk of cancer, increase energy levels, and strengthen the muscular system. Their high quantities of calories, calcium, iron, zinc, lipids, and high-quality proteins greatly benefit people. They are also abundant providers of vitamins and dietary fibre (Hassan *et al.,* 2021)

As compared to staple cereals, millets have a higher percentage of dietary fibre and non-starchy polysaccharides and contain 65–75% carbs. High dietary fibre millets have numerous health advantages, including bettering gastrointestinal health, blood lipid profiles, and blood glucose clearance. Millets with low glycemic index and less gluten are beneficial for celiac disease and disorders (Sebola *et al.,* 2021)

Obesity has become an emerging problem that is associated with diseases like diabetes, blood pressure, and cardiac problems. Consumption of millets that are high in fiber

helps in improving bowel function and reducing the prevalence of obesity by proving digestion and absorption in the body thereby reducing the risk of chronic diseases like diabetes. Millets help in satiating hunger satisfaction and help in weight management and reducing obesity (Benhur *et al.,* 2017)

Millets help to reduce problems like constipation, flatulence, bloating, and stomach cramping. With good digestion and absorption, the retention of gastrointestinal illnesses like ulcers and colon cancers. Millets have shown that results by reducing the alpha-glucosidase and pancreatic amylase thereby reducing the postprandial hyperglycemia by reducing the enzymatic hydrolysis of complex carbohydrates. Therefore, the consumption of millet helps control the blood glucose level and also helps in the dermal wound healing process with the help of antioxidants (Kimeera *et al.,* 2019)

Foxtail millet has been identified as a major millet in terms of worldwide production, as it is the sixth-highest-yielding grain. Foxtail millet is one of the oldest cultivated crops. A significant amount of nutrients, including carbohydrates, protein, vitamins, and minerals are present in foxtail millet. Although foxtail millet grains are coarse, only about 79% of them are digested, and the remainder contains both high quantities of fiber and some anti-nutrients (Jaynal *et al.,* 2022)

Xin *et al* (2018) stated that the laxative effects of foxtail millet are advantageous for a healthy digestive system because it is also an excellent source of crude fiber, aids in the digestive process and helps to produce a bowel movement.

The antioxidants, vitamins, minerals, phytochemicals, and other bioactive components found in foxtail millet, as well as its health advantages, also make it a promising functional food. Physiological benefits, including bowel movements, reduced blood cholesterol, and lower blood sugar, are led upon by dietary fiber (Kuldip *et al.,* 2020)

Jelang *et al* (2021) stated that phytochemical such as Polyphenols, flavonoids, isoflavonoids, anthocyanidins, phytoestrogens, terpenoids, carotenoids, limonoids, phytosterols, glucosinolates, and fiber are non-nutritive plant bioactive components that support health and are primarily produced by plants as a form of defense. These ingredients are isolated and used in processed foods, herbal items, dietary supplements, and specialty diets for genetically engineered designer foods. Strong natural antioxidants with free radical scavenging action include carotenoids, tocopherols, ascorbates, lipoic acids, and polyphenols.

Nitya (2017) stated that foxtail millet's dietary fiber has been discovered to exhibit physiochemical qualities that are comparable to those of insoluble fibers, which support gastrointestinal functions and lessen the rise in postprandial blood sugar levels with just a slight impact on blood cholesterol levels. Moreover, foxtail millet facilitates glucose absorption in the gastrointestinal tract and aids in its diffusion. The insoluble dietary fiber from foxtail millet may also limit the action of alpha-amylase, slow down the breakdown of carbs, and postpone the release of glucose. It is well established that doing this will increase insulin sensitivity and reduce the risk of developing diabetes.

Maize or jowar (*Zea mays L.)* is the third leading crop in the world after rice and wheat. Due to its highest yield potential among cereals, it is known as the queen of cereals. In India, the major maize-growing states are Uttar Pradesh, Bihar, Rajasthan, Madhya Pradesh, Andhra Pradesh, Maharashtra, and Karnataka. Maize kernel is an edible and nutritive part of the plant. It contains Vitamin C, Vitamin E, Vitamin B1, Vitamin B2, Vitamin B3, Vitamin B5, Vitamin B6, and folic acid. Potassium is a major nutrient present that has a good sign in the diet. Roasted maize kernels are also used as a coffee substitute. Maize is an essential source of various major phytochemicals such as carotenoids, phenolic compounds, and phytosterols (Tajamul *et al.,* 2016)

Sheng *et al* (2018) stated that the kernel and bran of maize are the key places where phytochemicals are found. The composition of phytochemicals changes depending on the variety of maize. Yellow and red corn contains the most carotenoids, whereas red, blue, purple, and black corn contains the most anthocyanins and phytosterols respectively. The most powerful antioxidant activity is found in corn. The majority of corn's total antioxidant activity is derived from phytochemicals. The overall phenolic content of maize is largely made up of flavonoids and ferulic acids, which also directly influence the level of antioxidant activity.

High consumption of flavonoids, which are found to reduce the risk of chronic diseases. Intake of maize can reduce glucose and insulin response. Regular consumption of maize improves digestive health and can lower the risk of developing chronic diseases like diabetes and obesity (Scott. 2019)

In a study conducted by siyuan *et al* (2018), it is associated with a reduced risk of T2DM. Dietary magnesium, fiber, and vitamin E, which engage in insulin metabolism. Regular consumption of this help regulates insulin levels by the beneficial effect of releasing

a satiety feeling and lowering body mass index (BMI). Resistance starch from maize has exhibited a beneficial effect on postprandial glucose and insulin levels. Resistance starch has benefits on high amylose maize on overweight and obese. This helps in increased insulin sensitivity and less sensitivity change of circulating free fatty acids.

Pearl millet (*Pennisetum glaucum*) is a good source of energy, protein, vitamins, dietary fibers, and minerals. It is high in fat and has better fat digestibility than other cereals. Among all millets, pearl millet has the highest content of macronutrients and is significantly rich in resistant starch and insoluble dietary fibers. Pearl millet effectively helps in maintaining blood sugar levels constant in diabetes patients for a long period.

Pearl millet is an important source of dietary energy and provides nutritional security for people all over the country. Pearl millet is an excellent source of micronutrients like iron and zinc, providing a low-cost solution for combating micronutrient deficiency. Owing to the presence of inhibitors like phytic acid, polyphenols, and fiber. Pearl millet is consumed in the form of large balls rolled from flour, parboiled grains, or fermented beverages. The food value of pearl millet is superior to other cereals in its protein content with an excellent source of amino acids and high vitamin A content (Krishnan *et al.,* 2018)

Pearl millet is beneficial to diabetic people because it has a relatively low Glycemic index, which aids in slow digestion and produces glucose at a slower pace than other foods, allowing for prolonged periods of stable blood sugar levels. Pearl millet is one of the options for celiac disease patients who need to consume a gluten-free diet in order to have a regular and healthy lifestyle. It also includes phenolic compounds and is gluten-free. Moreover, it contains plenty of antioxidants, protecting against cardiac disease (Monika *et al.,* 2020)

Finger millet (*Eleusine coracana*) is important millet grown extensively in various regions of India and Africa and constitutes a staple food for a large segment of the population. The millet diet is known for its high-sustaining power and is usually recommended for diabetes.

Due to its high polyphenol and dietary fiber content, finger millet has been shown to have the ability to lower the risk of developing diabetes mellitus and gastrointestinal issues when consumed regularly. The positive effect of phenolics is attributed to the partial suppression of amylase and alpha-glucosidase during the enzymatic degradation of complex

carbohydrates and the delay of glucose absorption, which eventually reduces postprandial blood glucose levels. (Palanisamy *et al.*, 2014)

Finger millet is considerably rich in micronutrients such as vitamins and minerals, especially because it is a rich source of calcium and has ten times more than wheat, and maize and three times greater than milk. Finger millets are rich in several phenolic compounds, the phenolic compounds exhibit antioxidant properties and free radicals foraging activity that makes finger millet beneficial to health reduces cardiovascular health and acts as an anti-aging food supplement.

The phytochemicals present in finger millet slows down the digestion process resulting in blood glucose level control as well as improving antioxidant level in the body. Finger millet has high fiber contents and a low response towards the glycaemic process means a low ability to enhance blood sugar and absorptivity of starch. The seed cost phenolic of finger millet acts as an inhibitor that helps to reduce postprandial hyperglycemia by restricting the role of enzymes, such as amylase, and alpha-glucosidase which are essential in the hydrolysis of complex carbohydrates (Padmaja *et al.*, 2021)

Finger millet contains tannin, phenol, flavonoids, alkaloids, saponin, glycosides, terpenoids, and steroids, according to a qualitative phytochemical study (Jeremiah. 2019)

Finger millet is a potent source of antioxidants and this has high radical-scavenging activity higher than that of wheat, rice, and other millets. It is also known for several health benefits such as anti-diabetic, anti-tumorigenic, atherosclerosis effect, and antioxidant, which are mainly attributed due to its polyphenol and dietary fiber content (Amir *et al.*, 2014)

Barnyard millet (*Echinochloa frumentacea*) is an ancient millet grown in warm and temperature regions of the world. It is the fourth most producer of minor millet, providing food security to many poor people across the world. When compared to main grains like rice, wheat, and maize, barnyard millets are regarded for their excellent nutritional value and lower price. It is a good source of protein, fiber, carbohydrates, and minerals like iron and zinc (Vellaichamy *et al.*, 2020)

Hardeep *et al* (2020) in their research observed that Barnyard millet is a good source of highly absorbable protein and a good dietary fiber from a nutritional perspective. In barnyard millet, the two main unsaturated fatty acids are linoleic acid and oleic acid. It shows that there is a lot of amylase retrogradation going on, which encourages the development of

higher levels of resistant starch. So, this prescription can be given to people who have diabetes and cardiovascular disease.

The phytochemicals found in barnyard millet, including phenolic acids, catechins, phytic acid, flavonoids, and tannins, serve as an excellent source of antioxidants in nature. Due to its high concentration of bioactive components, barnyard millet is suggested as a potential healthy substitute for rice and wheat, especially for people with diabetes and heart illness. Due to their delayed glycation, de-hulled types of barnyard millet are advantageous for Type II diabetes (Rajeswari *et al.,* 2021)

Little millet (*Panicum sumatrense*) contains bioactive nutraceuticals such as phenolic compounds, gamma-aminobutyric acid (GABA), carotenoids, and tocopherols (Manisha *et al.,* 2015)

Little millet can be used as a functional food ingredient due to its wide range of phytochemical contents, which include hydroxybenzoic acid and hydroxycinnamic acid derivatives, myricetin, catechin, luteolin, apigenin, daidzein, naringenin, kaempferol, and quercetin (Alok *et al.,* 2022)

Kodo millet (*Paspalum scrobiculatum*) has a similar nutritional value to other conventional grains and, in certain cases, even outperforms them in terms of fiber and minerals compared to both wheat and rice. Kodo millet grains are rich in phytochemicals. Phytochemicals include tannin, polyphenolic compounds, flavonoids, alkyl resorcinol, and coumarins. Foods made from plants have an oxidative quality that affects their flavor, texture, color, and taste. The grain also has phytochemicals including phytic acid, thought to reduce cholesterol, and phytate, associated with a lower risk of cancer. High antioxidant concentrations can be found in Kodo millet (Shikha *et al.,* 2022)

Kodo millets are a rich source of phytonutrients such as total antioxidant activity, total polyphenols, phytic acid, and tannin (Patil *et al.,* 2020)

The consumption of foods mainly based on refined flour has resulted in reduced intake of dietary fibers and other micronutrients as a result of urbanized lifestyle, changes in practices, and levels of physical activity. This may be associated with rising affluence induced by developmental transition contributed to the increasing prevalence of obesity. Millets are considered as food for poor and traditional consumers because of the non-

availability of ready-to-use or ready-to-eat convenience food products from millet (Dadasaheb. 2014)

Deshpande *et al* (2021) mentioned that to achieve nutritional security and fight rising climatic whims and severe diseases, it is essential to diversify food sources by integrating lesser-known millets. Due to its high micronutrient density and presence of bioactive compounds with medicinal potential, it produces a wide range of functional and value-added food products. The economically affluent and health-conscious segments of society are interested in a variety of millets-based value-added products, including cookies, cakes, and pasta.

Bakery products are popular all over the world and production has risen by many folds due to their low cost, varied taste, and textured profiles with attractive packages and longer shelf life. The use of millets in bakery products will not only be superior in terms of fiber content, and micronutrients but also create a good potential for millets to enter the bakery of value-added products. Finger millet and foxtail millet can be used in the preparation of biscuits, muffins, and cakes (Saraswathi *et al.*, 2022)

According to Hameed *et al* (2022), puffed grains can be converted into powders by simple grinding which can further be enriched with additional ingredients. Various combinations of ingredients can be taken and mixed well; this nutritious mix so prepared forms Ready to eat foods. The selection and combination of the ingredients are done based on the requirement of the target groups.

According to Veenu *et al* (2013), fermented foods like dosa and idli are popular and common breakfast foods in India. Millets are a good source of protein in terms of lysine (amino acid) content. Germination and probiotic fermentation cause a significant improvement in the contents of thiamine, niacin, and dietary fibers. The various recipes were prepared including cutlets, weaning mixtures, vermicelli, and biscuits from naturally and mixed fermented millets. The findings indicated that pure culture fermented products can be safely included in the diet of people for improving starch digestibility and increasing the bioavailability of minerals and proteins.

Extruded products like noodles and pasta are widely consumed food products among all age groups in both developed and developing countries. Compared to other products noodles and pasta have a longer shelf life and economic significance. Millets

noodles are prepared by supplementing with lysine to overcome the deficiency of amino acids during heart treatment (Deshpande *et al.*, 2021)

Ready to eat products prepared using a twin-screw hot extruder which combines heating with the act of extrusion to create a shaped cooked product through round-shaped dies. The mixture is combined and passed through a twin-screw extruder to produce expanded snacks that are ready to eat. The snack can be coated with desired spices to create variations in taste and flavor.

The value-added snacks are rich in protein, fiber, iron, zinc, and magnesium**.** Flakes are exclusively prepared from natural whole grains of superior quality with a roller flacking process. Flakes have a low Glycemic index and desirable products for diabetes. They are gluten-free products suitable for celiac disease and they are an excellent source of folic acid, calcium, iron, zinc, and magnesium (Dayakar *et al.*, 2016)

C) Importance of low Glycaemic index food for diabetics.

The GI is a measure of the percentage of the area under the curve (AUC) concerning blood glucose following the ingestion of a test diet compared with the standard diet. Values such as < 50 for Low GI, 55 to 69 for Moderate GI, and > 70 for High GI (Shoba et al., 2020)

The GI value is not based on the characteristics of the individual that consumed; it depends on the food consumed. Hence, dietary management approaches that target weight loss and improved glycemic control in patients with type 2 diabetes may rely on the use of diets with low GI instead of using standard low-fat diets. Foods with low GI such as legumes, lentils, and oats contain carbohydrates that break down slowly during digestion and are slowly assimilated (Omorogieva *et al.*, 2018)

According to Mohammad *et al* (2019), people with prediabetes, Type 1 Diabetes Mellitus, and Type 2 Diabetes Mellitus are unable to successfully control their postprandial blood glucose concentration in the absence of medical care. The Glycemic index of a food represents the effect on postprandial that the carbohydrate portion of the food has compared with glucose or white bread. Low GI foods such as fructose, lower peak postprandial blood glucose excursions and have been shown to have a positive effect on glucose control. Low GI

diets improve body weight, Body Mass Index, total cholesterol, and Low-Density Lipoprotein in people with obesity.

Foods that are composed of carbohydrates that break down quickly during the process of digestion and that are rapidly absorbed into the bloodstream are often termed foods with high glycaemic index (GI). Foods with high GI not only rapidly increase blood glucose, but also insulin responses following the consumption of food (Raghunath *et al.,* 2011)

Laura *et al* (2021) stated that diet and lifestyle remain the cornerstone of the management of diabetes. Low GI dietary patterns are considered an acceptable and safe dietary strategy that can produce a reduction for glycaemic control in diabetes, HbA1c, fasting glucose, and other risk factors, dietary GI on HbA1C levels, a diet with low GI diet had significantly lower values than the high GI diet or control. The Food and Agriculture Organization has recommended the use of the glycemic index food in patients with diabetes and that the glycemic index be used as a useful indicator of the impact of food on the blood glucose response.

Consumption of low glycaemic index foods minimizes large fluctuations in blood glucose levels. This is especially significant in insulin resistance. There is also increasing interest in the use of low-GI foods in the management of obesity. Low GI foods affect weight control by promoting satiety and fat oxidation at the expense of carbohydrate oxidation. Low GI foods are beneficial in reducing postprandial blood glucose and increasing fat oxidation during subsequent exercise. Low GI foods maintain plasma glucose concentration and increase fat oxidation (Bhupinder *et al.,* 2016)

According to Jashandeep *et al* (2022), the Glycemic Index was created to quantify the glycemic responses stimulated by carbohydrates in different foods. GI is an important tool that influences food choices and is used to classify foods based on carbohydrate content. Low GI foods are associated with lower postprandial blood glucose levels, lower insulin demand, reducing in blood lipid levels. Increasing fermentation in the colon and improving satiety. Consumption of low GI foods is certainly correlated with a concentration of modern lifestyle disorders such as being overweight, diabetes, cancer, and heart diseases.

D) Benefits of hypoglycaemic herbs in the management of diabetics.

Reza *et al* (2012) observed that, the antihyperglycemic effect of plants is achieved by enhancing insulin secretion from beta cells, increasing glucose uptake by tissues,

decreasing glucose absorption from the intestine, inhibiting glucose production in the liver, and increasing pancreatic tissue regeneration.

According to Shahida *et al* (2022), diabetes is a metabolic disorder owing to insulin faulty production or the resistance to the action mechanism where the accumulation of glucose is the major effect of diabetes. Benefits of herbal employment include the treatment of secondary ailments in patients along with diabetes including triglyceride reduction, cholesterol level management, body mass index, and cardiovascular disease control.

Hira *et al* (2018) stated that complementary or alternative treatments using herbal draw the attention of many diabetic patients. Numerous herbs are claimed to reduce blood glucose levels, therefore the possibility of having better glycemic control or being less dependent on insulin injection by taking herbs. The selection of herbs might depend on several factors, including availability, affordability as well as the safety profile of the herbs. Medicinal plants such as *Cinnamomum cassia* and Aloe vera are shown to have antidiabetic potential.

Polyxeni *et al* (2010) in the research stated that S-allyl cysteine sulphoxide (SACS), the precursor to the allicin present in **garlic (*allium sativum)***, has been proven to have a strong anti-diabetic impact. Garlic has been utilized in cooking for thousands of years. **Onion (*Allium cepa)***, is a typical vegetable. S-methyl cysteine sulfoxide has anti-diabetic and antioxidant properties. In tissues demonstrating antioxidant impact on lipid oxidation in experimental diabetes, SMCS decreased levels of malondialdehyde, hydroperoxide, and conjugated dienes and markedly improved diabetic state.

Avaram flower (*Cassia auriculata*) acts as Antipyretic, hepatoprotective, antidiabetic, antiperoxidative, antihyperglycemic, and microbicidal properties of the plant have been observed. The flowers are used to treat throat discomfort, diabetes, nocturnal emissions, and urine discharges. They are one of the components of the polyherbal formulation "Diasulin," which has been shown to have an anti-diabetic effect, at the concentration range of 40 mg/dl (Aparna. 2018)

Vilvam (*Aegle marmelos*) is used to treat diabetes, peptic ulcer, diarrhea, and ulcerative colitis. This plant's leaves, fruits, stem, and roots have been employed in traditional remedies for their astringent, antidiarrheal, antidysentery, demulcent, antipyretic, antiscorbutic, aphrodisiac, and antivenomous snake effects. The pancreas will be stimulated

and able to secrete insulin if fresh bitter gourd juice and Aegle marmelos juice are consumed daily. Diabetes in this technologically advanced environment. Aegle Marmalos can be administered in high doses with oral hypoglycemic medications to lower blood sugar levels in patients whose diabetes is not controlled by these medications or in people who have negative side effects from these medications when taken in dosage increments (Thillaivanan *et al.*, 2014)

Nutgrass (*Cyperus rotundus*) over the activities of a single component, the synergistic actions of the chemicals in Cyperus offer an added benefit. Numerous studies conducted over the past ten years have demonstrated that certain substances are analgesic, anti-allergic, anti-arthritic, anti-candida, anti-cariogenic, anti-convulsant, anti-diarrheal, anti-emetic, anti-helminthic, anti-histamine, anti-hyperglycemic, anti-hypertensive, anti-inflammatory, anti-malarial and anti-obesity (Arunagiri *et al.*, 2018)

The study by Varsha *et al* (2010) has shown as **Kotta Karanthai (*Sphaeranthus indicus Linn*.)** is utilized extensively in the Ayurvedic medical system to treat a variety of ill health disorders, including epilepsy, mental illness, hemicrania, jaundice, hepatopathy, and diabetes. Scientific evidence for this plant's hypotensive, anxiolytic, neuroleptic, hypolipidemic, immunomodulatory, antioxidant, and anti-inflammatory properties have been reported in publications. Numerous phytochemical components, including sesquiterpene lactones, flavonoids, and essential oil have been extracted from this plant.

Jamun seeds (*Syzygium cumini L*.) are bitter and sour. The seeds and pulp are used in traditional medicine to treat ringworm, diabetes, and diarrhea. Because anthocyanins are present, ripe fruits have a purplish-black color. Oxalic, tannic, gallic, and other alkaloids contribute to the astringency taste that is experienced. Strong free radical scavengers have been observed for the secondary metabolites. S. cumin contains phenolic and flavonoid chemicals that have antioxidant and anti-inflammatory properties (Gajera *et al.*, 2017)

The study by Manoj *et al* (2022) stated that, in addition to significant amounts of dietary fiber, jamun seeds also contain significant amounts of anthocyanins, chlorophyll, phytosterols, amino acids, vitamin C, vitamin B complexes (thiamine, riboflavin, and folic acid), essential minerals, and trace elements (calcium, iron, sodium, magnesium, zinc, phosphorus, and potassium), essential oil, albumin, and fats. According to the seeds' fatty

acid profiles, lauric, myristic, palmitic, stearic, oleic, linolenic, malvalic, and sterculic acids are the most prevalent fatty acids, and -sitosterol is the major phytosterol.

Sarkarai Kolli (*Gymnema sylvestre*) known as "gurmar" for its well-known ability to break down sugar, this herb has a reputable place in the Ayurvedic medical system. Along with being used for arthritis, diuretic, anemia, osteoporosis, hypercholesterolemia, cardiopathy, asthma, constipation, microbial infections, indigestion, and anti-inflammatory conditions, the herb exhibits a wide range of therapeutic effects that make it an effective natural treatment for diabetes. Due to its favorable effects on blood sugar homeostasis, ability to curb sugar cravings, and ability to encourage pancreatic regeneration, G. Sylvestre has promising futures in the treatment of diabetes. The herbal extract is utilized in dietary supplements because it lowers blood cholesterol (Pragya *et al.,* 2014)

Suparna *et al* (2019) have stated that Gymnema Sylvestre contains a variety of bioactive substances that have been shown to have anti-diabetic and antioxidant properties, including oleanines, gymnemic acid, Gymnema saponins, dammarenes (gymnemasides), anthraquinones, flavones, hentriacontane, pentatriacontane, phytin, resin, tartaric acid, chemical components, and their antidiabetic properties, with a focus on identifying the relationship between antioxidants and antidiabetic substances in connection to lowering blood sugar levels in diabetes.

Turmeric (*Curcumin*) is anti-inflammatory and antioxidant capabilities, as well as the tolerance of its pharmacological profile, contributing to its effectiveness as a nutraceutical. Moreover, curcumin has a potential function in both the prevention and treatment of a variety of diseases due to its broad range of effects, including its anti-bacterial, anti-diabetic, anti-viral, and anti-cancer characteristics. The most important component of turmeric, curcumin, coexists with other substances that have structural resemblances to curcuminoids. (Francesca *et al.,* 2019)

Ledyane *et al* (2021) have observed that turmeric help in reducing levels of tumor necrosis factor, leptin, resistin, glucose, and insulin in people with type 2 diabetes, increases adiponectin secretion, and reduces insulin resistance. The compounds may affect glucose homeostasis, complications of diabetes, and vascular risk in T2DM patients. curcuminoids as supplements can improve the lipid profiles and overall antioxidant capacity of T2DM patients.

According to World Health Organization**, Aloe vera (*Aloe*)** is renowned for its healing and medicinal properties. Vitamins, minerals, carbohydrates, amino acids, anthraquinones, enzymes, lignin, saponins, and salicylic acid are all considered to be active elements in the Aloe species, which is deemed to be the most physiologically active. Barbaloin is a polyphenol chemical that has antioxidant properties and is in charge of lipid peroxidation and free radical-mediated cytotoxicity. steroids, terpenes, phytosterols, and carotenoids. Aloe vera provides a range of therapeutic benefits, including those for diabetes, arthritis, cancer, and tumors. Aloe vera has also been touted as a treatment for immune system inadequacies, digestive disorders, and constipation (Mukesh *et al.*, 2021)

Herbs may lower blood glucose, each herb contains several components, only a few of which may be therapeutically effective. **Ginger *(Gingerol)*** has the highest therapeutic potency, it acts as an anti-tumor, antioxidant, and anti-diabetic. The anti-diabetic effect of ginseng lowered HbA1C to normal range and improved insulin sensitivity.

According to Hongxiang *et al* (2009), the hypoglycemic effects of **bitter melon *(Momordica charantia)*** include polypeptides, alkaloids, and bioactive components like antioxidants. A hypoglycemic herb decreases blood sugar levels by improving insulin sensitivity, improving insulin output, decreasing the glycemic effect of food, improving the function of the beta cells that make insulin, and altering the way the body absorbs, stores, and releases sugar**.**

Before the discovery of insulin and hypoglycemic drugs, diabetes patients were treated with medicinal herbs which is a traditional treatment. Hypoglycemic herbs have a positive effect in reducing blood glucose levels or complications due to hyperglycemia. These herbs impose anti-diabetic activity as oxidative stress is the cause of a wide variety of other diseases. Hypoglycemic herbs have antioxidant property which helps to reduce the toxic effects and prevent free radicals to enter which leads to long-term complications in diabetics (Behzad *et al.*, 2018)

III. METHODOLOGY

The study titled **"Development of Low GI Extruded Multi-Grain Snack for Diabetics and its Quality Evaluation"** was carried out in the following phases

Phase I: Selection of millets, herbs and spices for the development of extruded multi-grain snack.
Phase II: Development of extruded multi-grain value-added snack and its sensory evaluation
Phase III: Quality analysis (texture analysis, nutrient analysis, microbial analysis, shelf-life analysis, phytochemical analysis, antioxidant analysis and toxicity analysis) of the developed extruded value-added multi-grain snack.
Phase IV: Determination of the Glycaemic Index of the extruded snack.

Phase I: Selection of millets, herbs and spices for the development of extruded multi-grain snack

Consuming processed food increases the prevalence of diabetes. Food products that have undergone processing have high levels of calories, saturated fat and carbohydrates. Currently, extruded snacks are very popular, but there are only a few items that are high in nutrients. Extruded multi-grain snacks with millet as the base are developed with the objective of developing a healthy snack for diabetes. The planned extruded multi-grain snacks with millets that are rich in fiber make them an ideal snack for diabetics.

Many herbs are known to have medicinal properties and several are well-known and documented for their effectiveness in reducing blood sugar levels. Herbs also have several therapeutic characteristics apart from lowering glucose levels like decreasing insulin resistance, reducing body inflammation and other diabetic side effects (Nambirajan *et al.,* 2018, Naseer *et al.,* 2018, Desai *et al.,* 2019)

Millets are selected in such a way that it is kept in a hygienic pack and is free of any other pests or insects that may be present in the cereals.

Maize, finger millet, pearl millet and foxtail millet were procured from a local shop situated in Coimbatore.

Maize

Maize or corn **(*Zea mays*)** is chosen because it is rich in dietary fibers as it helps lowers high blood pressure, averts anemia, and lower blood glucose levels. Maize is a source of Carbohydrates, Proteins, and Vitamin A (carotenoids)as well as phytochemical compounds (Pineda *et al.,* 2018, Hayk. 2019). Nutraceutical properties of phenolic and anthocyanin compounds in the maize offer antioxidants with the ability to be used to prevent the incidence of diseases (Rouf *et al.,* 2016,)

Finger Millet

It is determined that finger millet or ragi **(*Eleusine coracana*)** contains sufficient amounts of nutrients such as carbohydrates, protein, fibers, vitamins, and minerals. When compared to rice, or wheat, ragi has a higher concentration of polyphenols and dietary fibers (Pragya *et al.,* 2012). The low glycemic index of ragi reduces appetite and keeps the digestive process moving forward, which keeps blood sugar levels within a safe range, and this was the reason behind choosing finger millet (Anil *et al.,* 2016, Dinesh *et al.,* 2016,)

Pearl Millet

The selected pearl millet or kambu **(*Pennisetum glaucum*)** is rich in protein, dietary fiber, minerals, vitamins, and polyphenols. It can be used as an alternative for those who are gluten intolerant because it is gluten-free and this constitutes the justification for choosing finger millet. Pearl millet consumption provides significant protection against free radical-mediated diseases like diabetes since they are a rich source of antioxidants (Rateesh *et al.,* 2018, Savita *et al.,* 2018)

Foxtail Millet

Foxtail millet or Thinai **(*Setariaitalica*)** has been identified as it is rich in vitamin B12 which is essential for maintaining a healthy heart and smooth functioning of the nervous system. It is also full of protein, dietary fiber and a wide range of minerals and vitamins. Foxtail millet is an excellent alternative to rice since it has a longer satiety value. Being a food with a low glycaemic index, it is the best option for lowering blood sugar and glycosylated hemoglobin (Roshan *et al.,* 2017). This justifies the selection of foxtail millet.

Avaram Flower

Avaram flower **(*Cassia auriculata*)** is selected because it contains antioxidants that are naturally found. Terpenoids, tannins, flavonoids, saponins, cardiac glycosides, and steroids are all present in the flower. The flower has anti-diabetic properties (Gayathri *et al.,* 2018, Sankhari. 2019)

Guava Leaf

Guava leaves **(*Psidium guajavae folium*)** were chosen as it contains antioxidants, antimicrobial agents, and anti-inflammatory qualities all present in abundance in guava leaves. The leaves are a rich source of antioxidants and fiber, which helps stabilize blood sugar levels naturally (Elixabet *et al.,* 2017, Sumra *et al.,* 2018)

Jamun Powder

Since Jamun powder **(*Eugenia jambolana*)** is a rich source of protein, fiber, flavonoids, antioxidants, calcium, iron, potassium, manganese, Vitamin C, and Vitamin B6 it is selected in the development of extruded multi-grain snack. Jamun seeds are great for diabetics since they boost the synthesis of insulin (Abinaya *et al.*,2013, Desai *et al.,* 2019)

Turmeric powder

Turmeric is selected as it contains curcuminoids and it has powerful anti-inflammatory and antioxidant properties. It can eliminate free radicals from the body as an antioxidant. High levels of free radicals can hasten the aging process, prolong chronic inflammation, and impair healthy cells (Hamid *et al.,* 2014, Susan *et al.,* 2017, Javad *et al.,* 2020)

Olive oil

Olive oil was picked up as it is recommended for the treatment and prevention of Type II diabetes because of its favorable composition of bioactive components and glycemic control. Olive oil is one of the finest oils for diabetes because it has a very low GI and contains no carbs. It lowers cholesterol and blood sugar levels. Its significant antioxidant content reduces oxidative stress and inflammation brought on by excessive sugar levels (Schwingshackl *et al.,* 2017, Erika *et al.,* 2022)

Maize (*Zea mays*)

Finger Millet (*Eleusine coracana*)

Pearl Millet (*Pennisetum glaucum*)

Foxtail Millet (*Setariaitalica*)

Aavaram flower (*Cassia auriculata*)

Jamun seed (*Eugenia jambolana*)

Guava leaf (*Psidium guajavae folium*)

Figure I: Ingredients Selected for the Development of Extruded Multi-Grain Snack

The present study was approved by the Institutional Human Ethics Committee proposal No. IHEC/22-23/FSMD-07 and the approval number is AUW/IHEC/FSMD-22-23/XPD-07. (Annexure I)

Phase II: Development of extruded multi-grain value-added snacks and its sensory evaluation:

Process of Extrusion of multi-grain snack

Millet (maize, finger millet, foxtail millet, and pearl millet) were selected for the development of extruded multi-grain snack.

↓

Selected millets were sieved to remove dirt and dust

↓

Sieved millets were washed in cold water

↓

Soaked at the temperature of 32°C

↓

Conditioned at the temperature of 32°C for five minutes

↓

After pre-processing, the millets were then combined and loaded into Single screw Extruder which works at the temperature of 500°C

Processing of Herbal mix

Herbs (aavaram flower, guava leaf and jamun seed) were selected

↓

Herbs were cleaned by agitating with hands to remove wilted or holes in the flower and leaf

↓

After cleaning, it was spread on a dry clean cloth

↓

Herbs were blotted gently and it was left for a few minutes for the excess water to be absorbed

↓

Herbs were shade dried by spreading on a dry clean cloth until it becomes crisp and it was then finely pulverized

↓

Pulverized herbs were then stored in airtight container for longer shelf life

i. Pre-Processing of millets

Cleaning- The procured millets were cleaned to remove the dirt, dust, and foreign matter by sieving.

Washing- The cleaned millets were washed in cold water in order to remove dirt, dust, chemicals, and bugs. This helps keep the millet free from foreign substances.

Soaking- The millets were soaked at the temperature of 32°C in water to ensure that the phytic acid in them is broken down, as the phytic acid present in millets impairs the absorption of minerals like iron, zinc, and calcium (Devi *et al.*, 2014)

Conditioning- The millets were conditioned prior to the extrusion process for maintaining the moisture content. The water was drained and soaked grains were conditioned for five minutes at 32°C.

Processing of herbs

Cleaning-The selected herbs were cleaned by agitating with hands to remove the ones that were wilted, yellow or had holes in the leaves or flowers.

- The herbs were rinsed into a deep bowl of cold water, once the dirt has sunk to the bottom of the bowl, remove the herbs.
- The cleaned herbs were spread out on a dry clean cloth.
- Herbs were blotted with a towel before gently rolling them up. Left the bundle to set for a few minutes until the excess water has been absorbed.
- Herbs were shade dried until it becomes crisp.
- The dried herbs were powdered and stored in an airtight container.

ii. Processing

- The millets (maize, finger millet, foxtail millet, and pearl millet) chosen were cleaned to get rid of the dirt, soaked in water, conditioned and the tempered grains were loaded into a single screw extruder. At a temperature of 500°C the millets were extruded.
- To get the required shape, taste, and texture of the extruded snack, the product was tested with various combinations of millet with maize as the base.

Table – I Combination of Millets Used for the Development of Extruded Multi-Grain Snack

Ratio	Trail 1 (T_1)	Trail 2 (T_2)	Trail 3 (T_3)	Trail 4 (T_4)	Trail 5 (T_5)
Maize (*Zea mays*)	800 g	800 g	800 g	600 g	500 g
Foxtail millet (*Setariaitalica*)	200 g	-	-	200 g	100 g
Finger millet (*Eleusine coracana*)	-	200 g	-	-	300 g
Pearl millet (*Pennisetum glaucum*)	-	-	200 g	200 g	100 g

The **initial trial** extrusion was made from maize 800 g and foxtail millet 200 g, which did not produce the exact shape or size of the corn puff.

The **second trial** included maize 800 g and finger millet 200 g however, the millet puff was hard and the shape was improper for a multi-grain snack.

The **third trial** of the multi-grain snack contained maize 800 g and pearl millet 200 g; yet, the millet puff had a tiny size and an excellent flavor.

The **fourth trial** of the multi-grain snack contained maize 600 g, foxtail millet 200 g, and pearl millet 200 g; the millet puff was small, and the millet puff was off flavor due to increased temperature and had excellent taste.

In the **fifth trial** of the multi-grain snack, maize 500 g, foxtail millet 100 g, finger millet 300 g, and pearl millet 100 g were combined. This resulted in the snack having the ideal shape, size, texture, and flavor.

The herbs used were avaram flower (*Cassia auriculata*), guava leaf (*Psidium guajavae folium*), and jamun seeds (*Eugenia jambolana*). The herbs were all well-cleaned before being dried in the shade and pulverized. Then to increase the acceptability chili powder and salt

were added in the right proportion. The herbs incorporated in the developed extruded multi-grain snack enhanced the flavor and taste.

iii. Value addition and Standardization of the developed extruded multi-grain snack

Table -II Millet Combination in the Development of Extruded Multi-Grain Snack

Millet Combination (Trial 5)	Quantity
Maize (*Zea mays*)	500 g
Foxtail millet (*Setariaitalica*)	100 g
Finger millet (*Eleusine coracana*)	300 g
Pearl millet (*Pennisetum glaucum*)	100 g

As the fifth trial was successful with the ideal shape, color, texture, taste, and flavor this was finalized.

TABLE III

Ratio of Herbs Added to the Extruded Multi-Grain Snack

Millet Ratio (T_5)	**HERBS ADDED TO THE DEVELOPED EXTRUDED SNACK**		
Maize- 500 g Foxtail millet- 100 g Finger millet- 300 g Pearl millet- 100 g	Variation 1	A- Aavaram flower powder (0.5g)	T_5V1_A
		B- Aavaram flower powder (1.0g)	T_5V1_B
		C- Aavaram flower powder (1.5g)	T_5V1_C
		D- Aavaram flower powder (2.0g)	T_5V1_D
	Variation 2	A- Guava Leaf powder (0.5g)	T_5V2_A
		B- Guava Leaf powder (1.0g)	T_5V2_B
		C- Guava Leaf powder (1.5g)	T_5V2_C
		D- Guava Leaf powder (2.0g)	**T_5V2_D**
	Variation 3	A- Jamun seed powder (0.5g)	T_5V3_A
		B- Jamun seed powder (1.0g)	T_5V3_B
		C- Jamun seed powder (1.5g)	T_5V3_C
		D- Jamun seed powder (2.0g)	T_5V3_D

Variation 1 Extruded multi-grain snack with 0.5g of value addition

Aavaram flower powder
(*Cassia auriculata*)

Guava leaf powder
(*Psidium guajavae*

Jamun seed powder
(*Eugenia jambolana*)

Variation 2 Extruded multi-grain snack with 1.0g of value addition

Aavaram flower powder
(*Cassia auriculata*)

Guava leaf powder
(*Psidium guajavae folium*)

Jamun seed powder
(*Eugenia jambolana*)

Variation 3 Extruded multi-grain snack with 1.5g of value addition

Aavaram flower powder
(*Cassia auriculata*)

Guava leaf powder
(*Psidium guajavae folium*)

Jamun seed powder
(*Eugenia jambolana*)

Variation 4 Extruded multi-grain snack with 2.0g of value addition

Aavaram flower powder
(*Cassia auriculata*)

Guava leaf powder
(*Psidium guajavae folium*)

Jamun seed powder
(*Eugenia jambolana*)

Figure II: Ratio of Herbs added to the Developed Extruded Multi-Grain Snack

Selected Millets

Soaked millets

Conditioned millets

Extrusion process of the millets

Extruded millets

Figure III: Processing of the Developed Extruded Multi-Grain Snack

TRIAL 1 (Maize- 800 g Foxtail millet- 200g)	
TRIAL 2 (Maize-800g Finger millet-200g)	
TRIAL 3 (Maize-800g Pearl millet-200g)	
TRIAL 4 (Maize-600g Finger millet-200g Foxtail millet-200g)	
TRIAL 5 (Maize-500g Foxtail millet-100g Finger millet-300g Pearl millet-100g)	

Figure IV: Trials followed in the Development of Extruded Multi-Grain Snack

iv. Sensory Evaluation for the Developed Extruded Multi-Grain Snack

The developed extruded multi-grain snack was evaluated for sensory attributes by a group of 20-panel members (aged 18-24) from Avinashilingam Institute for Home Science and Higher Education for women. The developed multi-grain snack was placed in the food lab for the panel members to evaluate. The evaluation was carried out for all the sensory parameters like appearance, flavor, texture, taste, colour, and overall acceptability was determined using a nine-point hedonic scale (1= dislike extremely to 9 = like extremely). Score card for the developed extruded multi-grain snack is enclosed as Annexure II.

Figure V: Sensory Evaluation of the Developed Extruded Multi-Grain

Phase III: Quality analysis of the extruded value-added multi-grain snack.

The developed extruded multi-grain snack was evaluated for its texture, nutrient, microbial, shelf-life, phytochemical, antioxidant and toxicity.

i. Texture analysis for the developed extruded multi-grain snack

Texture analysis is helpful to evaluate the textural qualities such as hardness, brittleness, adhesiveness, tensile strength and crispiness of the developed product.

The texture analyzer named EZ-SX Short Model was used for testing food texture. The report of the analysis is attached as Annexure III

ii. Nutrient analysis for the developed extruded multi-grain snack

Nutrient analysis such as energy, carbohydrate, protein, fat, fiber, sugar, sodium, calcium, zinc, iron, magnesium, vitamin A, vitamin B, vitamin C, moisture, and ash content was done using the method FSSAI/IS/AOAC:2016. The report of the analysis is enclosed as Annexure IV

iii. Shelf-life analysis for the developed extruded multi-grain snack

To determine the quality of the developed extruded multi-grain snack, shelf life was observed till changes occur in parameters such as appearance, color, flavor, texture and taste. Several types of storage, packaging like stainless steel container, glass container, plastic container, and eco-friendly Ziplock cover with 51 microns thickness in accordance with Government norms were used to store the multi-grain snack. The different storage containers were observed until the texture of the multi-grain snack was lost. The analysis was carried out until the physical changes and the differences between the first-day shelf life and till the texture changes were noticed. The analysis was done to compare the changes that occur every day from the first day to the last day of shelf life with respect to changes in texture, flavor, and taste. The snack that had been kept was then submitted for microbiological testing on the first and last days of its shelf-life.

iv. Microbial Analysis for the developed extruded multi-grain snack

In microbial analysis, the amount of fungal development in food samples is detected and measured using Total Yeast and Mold Counts (TYMC), which also makes it possible to identify any current live yeast and mold species. The number of aerobic, mesophilic organisms that can survive in mild temperatures between 20 and 45 °C is known as the total plate count. This count, which takes into account both pathogens and nonpathogens, is used to gauge how hygienic the food is being prepared and to estimate the bacterial population in the food sample. The microbial analysis was done as per IS5402 (part-I);2021 for total plate

count and IS5402;1999 for yeast and mold test method for the developed extruded multi-grain snack. The analysis report is included in Annexure V.

Extruded snacks stored in Stainless steel container

Extruded snacks stored in Glass container

Extruded snacks stored in Plastic container

Extruded snacks stored in Zip Lock cover

Figure VI: Shelf-life Analysis of the Developed Extruded Snack

v. Antioxidant analysis for the developed extruded multi-grain snack

Antioxidants aids in sustaining food and preventing oxidative degradation. Antioxidants help to remove reactive oxygen species from the body. To ensure the integrity of healthy foods and to assess the efficacy of dietary antioxidants in the prevention and treatment of oxidative stress-related illnesses. The analysis was done using the DPPH assay test method for the developed extruded multi-grain snack. The analysis report is provided in Annexure VI.

vi. Phytochemical analysis for the developed extruded multi-grain snack

In phytochemical analysis, 17 metabolites such as (Alkaloids, Flavonoids, Sterols, terpenoids, Anthraquinone, Anthocyanin, Protein, Phenolic compounds, quinones, Carbohydrates, Tannin, Saponins, Cardiac glycoside, Glycoside's test, Lignin, Coumarins and Volatile oils) were analyzed for the developed extruded multi-grain snack. This analysis is effective in identifying bioactive elements present in the developed extruded multi-grain snack and the analysis report is enclosed as Annexure VII.

vii. Toxicity analysis

Toxicity analysis is an important method to evaluate the safety of the developed extruded multi-grain snack.

The report of the analysis is enclosed as Annexure VIII

Phase IV: Determination of the Glycaemic Index of the extruded snack.

An informed consent form was signed by the volunteers involved in this study. This consent form was given and the volunteers were informed about the aim, objective, and procedure that was followed during the study process. This study was practiced with full coordination, acceptance, and willingness of the volunteers. The subject informed consent form in English and in the regional language (Tamil) is enclosed in Annexure X.

The main objective of the study is to determine the GI of the developed extruded multi-grain snack. Blood glucose levels were assessed among overnight fasting (12 hrs) subjects (n=5). Blood glucose levels were assessed using the strip method with the help of a hand-held glucometer. The subjects were encouraged to warm their hands to increase blood flow. Blood samples were collected at intervals of 30 min for 2 hours (0, 30, 1 hr, and 2 hr). The blood glucose concentrations were determined using a glucometer with the glucose test strip.

According to Jenkin *et al* 2023, the glycemic index is the glycemic response of a fixed amount of available carbohydrates from a test food to the same amount of available carbohydrates from a standard food consumed by the subject. The carbohydrate content of the developed extruded multi-grain snack was analysed. 100 g of the developed extruded multi-grain snack contains 120 g of carbohydrate. 42 g of developed extruded multi-grain snack yields 50 g of carbohydrate. Hence, 42 g of the snack was given to the subjects.

FASTING TRIAL -1

The subjects were requested to have a fasting period of 12 hours or overnight before the day of the trial.

DAY-1

On the day of the trial, the first fasting blood glucose level is measured using a one-touch ultra-glucometer. Then the subject was given a reference food glucose containing 50 g of available carbohydrates for which the blood sample was taken at an interval of 30 minutes 1 and 2 hours. Then the GI is calculated by plotting the values in the graph.

WASHOUT (DAY-2 & 3)

On day 2 & 3, washout period was given to the subjects and the subjects were requested to have a fasting period of 12-hour fasting or overnight fasting.

DAYS- 4, 5 & 6

On days 4, 5 & 6, variation–1 of the extruded snack (42 g) coated with 2 grams of avaram flower powder was given to the subjects. Prior to the consumption, the fasting blood glucose level was measured. The snack was then given and blood glucose level is measured at the end of 30 minutes, 1 hour, and 2 hours after consumption. Then the GI is calculated by plotting the values in the graph and finding the area under the graph.

The glycemic index was calculated using the formula given by Wolver and Jenkins(1986)

$$\text{Glycemic Index (GI)} = \frac{\text{Area under glucose curve of multi-grain snack}}{\text{Area under glucose of reference meal}} \times 100$$

WASHOUT (DAY-7 & 8)

On day 7 & 8, washout period was given to the subject, and the subject was requested to have a fasting period of 12-hour fasting or overnight fasting.

DAYS-9, 10 & 11

On days 9, 10 & 11, variation–2 of the extruded snack (42 g) coated with 2 grams of guava leaf powder was given to the subjects. Prior to the consumption, the fasting blood

glucose level was measured. The snack was then given and blood glucose level is measured at the end of 30 minutes, 1 hour, and 2 hours after consumption. Then the GI is calculated by plotting the values in the graph.

WASHOUT (DAY-12 & 13)

On day 12 & 13, washout period was given to the subjects and the subjects were requested to have a fasting period of 12-hour fasting or overnight fasting.

DAYS-14, 15 & 16

On days 14, 15 & 16, variation–3 of the extruded snack (42 g) coated with 2 grams of jamun seed powder was given to the subjects. Prior to the consumption, the fasting blood glucose level was measured. The snack was then given and blood glucose level is measured at the end of 30 minutes, 1 hour, and 2 hours after consumption. Then the GI is calculated by plotting the values in the graph.

	Low	**Medium**	**High**
Glycemic Index	Less than or 55	56-69	70 or more
Glycemic Load	Less than or 10	11-19	20 or more

(ADA., 2010)

Figure VII: Monitoring the Blood Glucose level for the volunteers after the consumption of the developed extruded multi-grain snack

IV. RESULTS AND DISCUSSIONS

The results pertaining to the study titled **"Development of Low GI Extruded Multi-Grain Snack for Diabetics and its Quality Evaluation"** is discussed under the following headings

I: Development of extruded multi-grain snack and standardization
II: Quality analysis (texture analysis, nutrient analysis, microbial analysis, shelf-life analysis, phytochemical analysis, antioxidant analysis and toxicity analysis) of the developed extruded multi-grain snack

I. Development of extruded multi-grain snack and standardization

Development of the extruded multi-grain snack was carried out in various combinations and trials were done to standardize the product. The combinations used are projected in Table IV.

TABLE IV

COMBINATION OF MILLETS USED FOR THE DEVELOPMENT OF EXTRUDED MULTI-GRAIN SNACK

Ratio	**Trail 1 (T_1)**	**Trail 2 (T_2)**	**Trail 3 (T_3)**	**Trail 4 (T_4)**	**Trail 5 (T_5)**
Maize (*Zea mays*)	800 g	800 g	800 g	600 g	500 g
Foxtail millet (*Setariaitalica*)	200 g	-	-	200 g	100 g
Finger millet (*Eleusine coracana*)	-	200 g	-	-	300 g
Pearl millet (*Pennisetum glaucum*)	-	-	200 g	200 g	100 g

Table IV projects the combination of ingredients used in the development of the extruded multi-grain snack. Five trials were done with different combinations of chosen millets. The product obtained from first 4 trials were not in desired shape and the taste was not acceptable. But the fifth trial was successful with the combination of maize 500 g, foxtail millet 100 g, finger millet 300 g, and pearl millet 100 g and has the ideal shape, color, texture, taste, and flavor which was very much acceptable. This was considered as the final product and standardized for 1 kg. Sensory evaluation was followed for the developed extruded multi-grain snack.

TABLE V

VALUE ADDITION OF THE DEVELOPED EXTRUDED MULTI-GRAIN SNACK

Table V contains different ingredients and their quantities that are used for the extruded multi-grain snack.

Millet Ratio (T_5)	**HERBS ADDED TO THE DEVELOPED EXTRUDED SNACK**		
Maize- 500 g Foxtail millet- 100 g Finger millet- 300 g Pearl millet- 100 g	Variation 1	A- Aavaram flower powder (0.5g)	T_5V1_A
		B- Aavaram flower powder (1.0g)	T_5V1_B
		C- Aavaram flower powder (1.5g)	T_5V1_C
		D- Aavaram flower powder (2.0g)	T_5V1_D
	Variation 2	A- Guava Leaf powder (0.5g)	T_5V2_A
		B- Guava Leaf powder (1.0g)	T_5V2_B
		C- Guava Leaf powder (1.5g)	T_5V2_C
		D- Guava Leaf powder (2.0g)	**T_5V2_D**
	Variation 3	A- Jamun seed powder (0.5g)	T_5V3_A
		B- Jamun seed powder (1.0g)	T_5V3_B
		C- Jamun seed powder (1.5g)	T_5V3_C
		D- Jamun seed powder (2.0g)	T_5V3_D

Table V reveals the different combinations of herbal powders added to the extruded snack. Each variation has a different proportion of herbal mixes. Herbs added to the the developed extruded snack in the ratio of 0.5g, 1.0g, 1.5g, and 2.0g respectively. According to FSSAI guidelines, 3-5 g of herb powder is accepted for human consumption. In this case, the herbs that were added to the developed extruded multi-grain snack with a maximum of 2 g.

These variations were subjected to sensory evaluation to determine the acceptable combination of developed extruded multi-grain snack.

II. Quality Analysis of the Developed Extruded Multi-Grain Snack

A. Sensory Evaluation

Sensory evaluation of the developed extruded multi-grain snack was conducted by the panel of 20 members, between the age group of 18-24 years from Avinashilingam Institute for Home Science and Higher Education for women. The evaluation was done using a nine-point hedonic scale (1= dislike extremely to 9 = like extremely). Based on the scores, mean and standard deviation was calculated for all the variations.

A total of twelve variations were created with differences in the quantity of herbs added. Variation 1 was created by adding Aavaram flower powder to the extruded snack in the ratios 0.5g, 1.0g, 1.5g, and 2.0g respectively leading to four combinations. Similarly, guava leaf powder was added in variation 2 and jamun seed powder was added in variation 3 leading to a total of twelve variations. All twelve variations were given to semi-trained panel members for organoleptic evaluation.

Based on the overall score variation 2 (Extruded multi-grain snack with guava leaf powder) scored high. The sensory parameters of the four combinations in variation 2 is projected in Table VI.

TABLE VI

SENSORY EVALUATION OF THE DEVELOPED EXTRUDED MULTI-GRAIN SNACK

Sensory evaluation was done for the developed multi-millet snack, and the results are shown in Table VI.

S.no	Combination	Appearance	Color	Flavor	Texture	Taste	Overall acceptability
1	Multi-grain snack + 0.5 g of guava leaf powder (T_5V2_A)	8.2±0.8	7.8±0.6	7.9±0.8	7.8±0.6	7.9±0.7	7.9±0.6
2	Multi-grain snack + 1.0 g of guava leaf	8.1±0.7	8.1±0.5	8.1±0.7	8.1±0.5	7.8±0.8	8±0.5

	powder (T_5V2_B)						
3	Multi-grain snack + 1. g of guava leaf powder (T_5V2_C)	8±0.9	7.7±0.6	7.8±0.5	7.7±0.6	7.6±0.8	8.1±0.7
4	Multi-grain snack + 2.0 g of guava leaf powder (T_5V2_D)	8.1±0.9	7.8±0.8	7.9±0.7	7.8±0.8	8.1±0.7	8±0.7

(9 = like extremely, 8= like very much, 7= like moderately, like slightly, 5= neither like nor dislike, 4= dislike slightly, 3= dislike moderately, 2= dislike very much and 1= dislike extremely)

From Table VI it is evident that variation 2 (Extruded multi-grain snack with guava leaf powder) has the highest score when compared to the other combinations. According to the sensory scores given by the panel members, the product was evaluated for its appearance, color, texture, flavor, taste and the overall score was calculated. Based on the highest score variation (T_5V2_D) was selected as final product.

B. Glycemic Index and Glycemic Load Analysis

To determine the GI of developed extruded snack, blood glucose levels were assessed for overnight fasting (12 hrs) subjects (n=5). Using the strip method with the help of a hand-held glucometer blood glucose was analyzed. The subjects were encouraged to warm their hands to increase blood flow. Blood samples were collected at the end of 30 min for 2 hours (0, 30, 1 hr, and 2 hr). The blood glucose concentrations were determined using a glucometer with the glucose test strip.

The GI was calculated using the formula,

$$\text{Glycemic Index (GI)} = \frac{\text{Area under glucose curve of multi-grain snack}}{\text{Area under glucose of reference meal}} \times 100$$

The GL was calculated using the formula,

$$\text{Glycemic load} = \frac{\text{Available carbohydrates (g)} \times \text{GI}}{100}$$

TABLE VII

GLYCEMIC INDEX AND LOAD OF THE DEVELOPED EXTRUDED MULTI-GRAIN SNACK

Glycemic Index of Extruded Snack

S.No	Variations	Quantity administered (g)	Glycemic Index values	GI Category
1	T_5V1_D *	**42 g** (42g of the developed extruded snack yields 50g of carbohydrates)	61	Moderate
2	T_5V2_D **		55	Low
3	T_5V3_D ***		64	Moderate

T_5V1_D *= Aavaram flower powder mixed in the developed extruded multi-grain snack.

T_5V2_D **= Guava leaf powder mixed in the developed extruded multi-grain snack.

T_5V3_D ***= Jamun seed powder mixed in the developed extruded multi-grain snack.

Glycemic Load of Extruded Snack

S.No	Variations	Quantity administered (g)	Glycemic Index	Glycemic Load
1	T_5V1_D *	**42 g** (42g of the developed extruded snack yields 50g of carbohydrates)	61	25.62
2	T_5V2_D **		55	23.1
3	T_5V3_D ***		64	26.88

Table VII highlights the data on the glycemic index and glycemic load of the developed extruded multi-grain snack

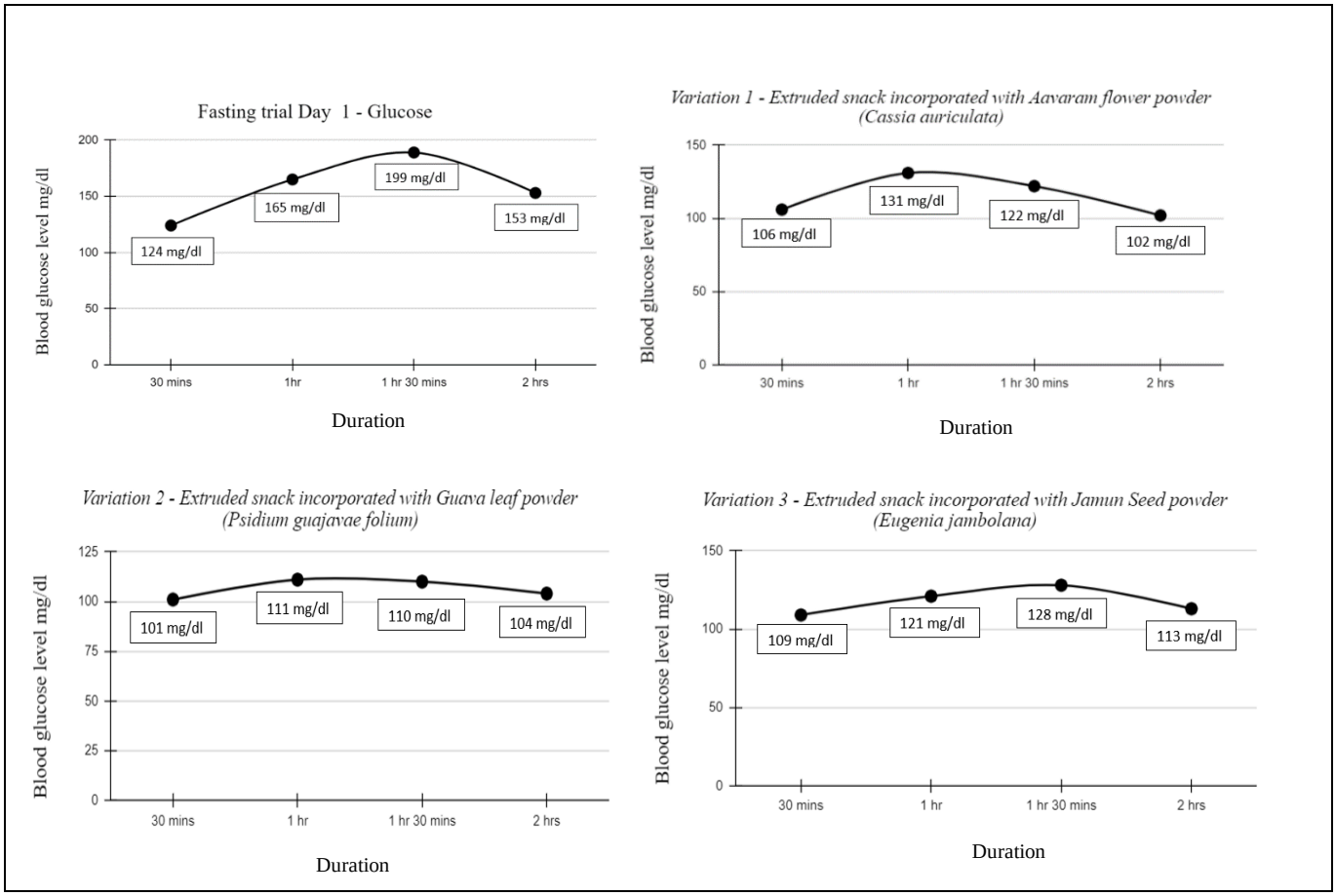


Figure VIII: Blood glucose response after consumption of the reference food and the developed extruded multi-grain snack

From Table VII it is evident that aavaram flower powder mixed extruded multi-grain snack (variation I) and Jamun seed powder mixed extruded multi-grain snack (variation 3) were in medium GI category. Guava leaf powder mixed extruded multi-grain snacks (variation 2) was low in GI category (55). According to the glucose response, variation 2 is low in GI. The mean change in the glucose response curve for the reference and the developed extruded multi-grain snack are shown in figure 8.

Shobana *et al.,* 2018 stated in their study that extruded finger millet-based vermicelli have moderate GI content. When compared to the product developed by Shobana *et al.,* 2018 the developed extruded multi-grain snack has significantly low GI content.

According to Table VII, variation 2 (Guava leaf powder mixed muti-grain snack) is significantly low in GI (55).

C. Nutrient Analysis

TABLE VIII

NUTRIENT CONTRIBUTION OF THE DEVELOPED EXTRUDED MULTI-GRAIN SNACK

The nutrients of the developed millet-based snack was analyzed, and the result are shown in Table VIII.

NUTRIENTS	NUTRITIVE VALUE
Energy (Kcal)	761
Carbohydrate (g/100g)	120
Dietary Fiber (g/100g)	3
Total Sugar (g/100g)	0.12
Protein (g/100g)	9
Total Fat (g/100g)	12
Sodium (mg/100g)	2481
Calcium (mg/100g)	22
Iron (mg/100g)	4.47
Zinc (mg/100g)	2.284
Magnesium (mg/100g)	52
Vitamin A (mcg)	642
Vitamin B (mg/100g)	1.164
Vitamin C (mg/100g)	667
Moisture (%)	3.63
Ash content (%)	1.97

Table VIII, highlight that 100 g of the developed extruded multi-grain snack contains, 60 g of carbohydrates, 9 g of protein, and 3 g of fiber. It also contains 22 g of calcium, 4.47 mg of iron, 642 mcg of vitamin A, 1.164 mg of vitamin B, 667 mg of vitamin C, 2.284 mg of zinc, 52 mg of magnesium, 2481 mg of sodium, 3.63% of moisture and 1.97% of ash content.

This study result is in line with the study done by Wadikar *et al* 2014, wherein the developed multi-millet extruded snack contributes 79g of carbohydrates, 7 g of protein, and 3 g of fiber per 100 g. The carbohydrate content is low, protein is high and fiber content is equal as compared to the research done by Wadikar *et al* 2014. When compared to the snack developed by Wadikar *et al* 2014 the extruded multi-grain snack developed has high nutritive value.

D. Texture Analysis

The textural properties of the developed extruded product was analyzed for the parameters like hardness, work of shear, adhesive force, energy node, break force sensitivity and stickiness.

TABLE IX

TEXTURE ANALYSIS OF THE DEVELOPED EXTRUDED MULTI-GRAIN SNACK

Texture analysis of the developed millet-based snack is shown in Table IX

S. No	Parameters	Hardness (N)	Adhesive force (N)	Energy 1st node (J)	Break force sensitivity (N)
1.	Multi-grain snack	73.5	0.015	0.125	73.5

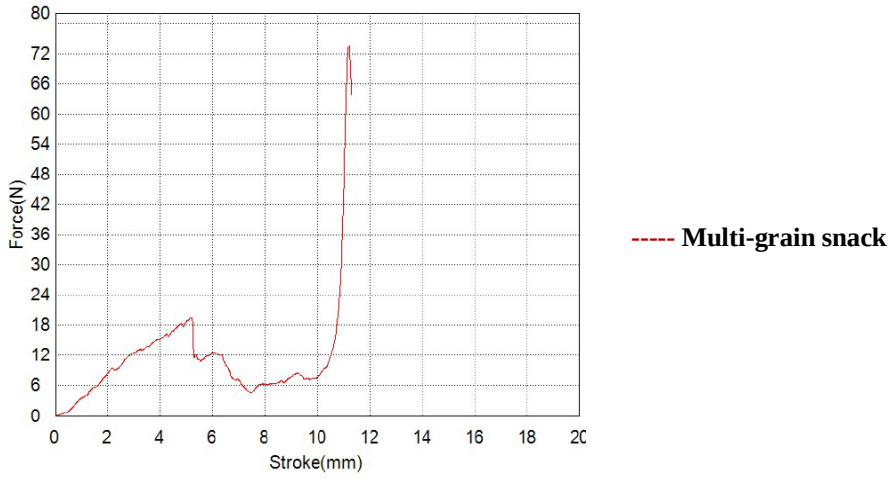


Figure IX: Hardness of the Extruded Snack

The hardness work done refers to the effort necessary to break down the bonds within a food, the hardness indicates the maximum force needed to compress a food between the molars.

Breakage happens when the load suddenly drops. Sensitivity, which is represented as a percentage of hardness. The ideal hardness of an extruded snack was determined using the test findings. The average hardness of the tested materials was 884 g force. The texture analyzer, equipped with a plastic shear blade, needed this amount of force to break the banana chip. Through this, the researcher shows if the banana chip is too hard or soft (Labomat, Instruments and specialties)

From table IX it is evident that hardness is 73.5 which is normal. A study done by Anton *et al* 2007 has shown that extruded snack has a hardness of 162.2. When compared to the study, the developed extruded multi-grain snack correlated with textural characteristics which together account for a product with high acceptability.

E. Antioxidant Assay

An antioxidant assay was carried out by the DPPH method for the developed extruded multi-grain snack.

Table X highlights the determination of antioxidant that is present in the developed extruded multi-grain snack.

TABLE X

ANTIOXIDANT ASSAY OF THE DEVELOPED EXTRUDED MULTI-GRAIN SNACK- ASCORBIC ACID AS STANDARD

Concentration (µg/ml)	Percentage Inhibition
3	62.30
6	70.49
9	83.61
12	90.16
15	95.90

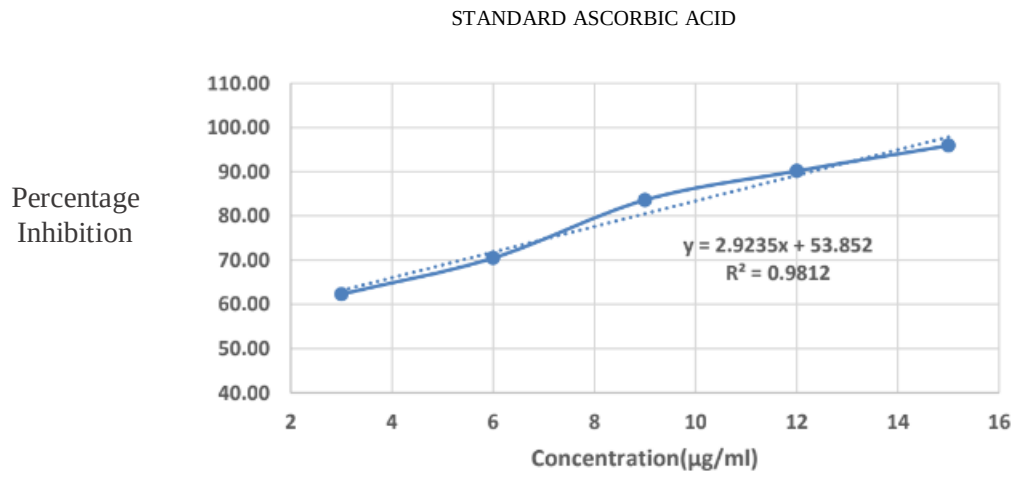


Figure X: Antioxidant assay of the developed extruded multi-grain snack

TABLE XI

ANTIOXIDANT ASSAY OF THE DEVELOPED EXTRUDED MULTI-GRAIN SNACK

Concentration (µl)	Percentage Inhibition
10	54.10
50	50.82
150	48.36
250	39.34
350	36.89
500	34.43
750	27.87

The developed extruded snack showed better antioxidant potential when compared to standard ascorbic acid by the DPPH scavenging assay method. The extruded multi-grain snack was taken in the concentration of 2.62 mg/ml H2O as solvent. Since the sample was not completely soluble only the soluble portions were used for analysis.

The developed extruded snack that has the capacity to scavenge free radicals was evaluated using the DPPH (2,2-diphenyl-1-picrylhydrazyl) technique. Ascorbic acid is a well-known antioxidant and free radical scavenger used as standard. It has been shown that the concentration of ascorbic acid has a correlation with the food product's capacity to scavenge

DPPH radicals when it is present in a significant proportion. As an inhibition percentage is the expression of food's capacity to scavenge free radicals (Scalzo. 2008)

From Table XI, it is noticed that the antioxidant assay for the developed extruded multi-grain snack has a positive correlation (R^2=0.981) was found between standard ascorbic acid and extruded snack.

The results are in line with the study done by Bisharat *et al.,* (2015), Antioxidant potential and quality characteristics of vegetable-enriched corn-based extruded snacks. A positive correlation of (R^2=0.796) was found between phenolic content and antioxidant activity of the extrudates.

The positive correlation of the developed extruded snack was R^2=0.981whcih is higher than the snack developed by Bisharat *et al.,* 2015.

F. Toxicity Analysis

The Brine shrimp lethality assay (toxicity) was carried out for the developed extruded multi-grain snack.

TABLE XII

BRINE SHRIMP LETHALITY ASSAY(TOXICITY) OF THE DEVELOPED EXTRUDED MULTI-GRAIN SNACK

S.No	Sample code	Concentration (µg/ml)	Mortality of brine shrimp (no. of shrimps dead)					
			1	2	4	6	24	%Mortality (24 hr)
1	Extruded multi-grain snack	100	0	0	0	1	2	7
		250	0	0	0	0	1	3
		500	0	0	0	1	2	7
		1000	0	0	0	0	2	7
		1500	0	0	0	1	3	10
2	**Control $k_2Cr_2O_7$**	**1 (µg/ml)**	**30**	**-**	**-**	**-**	**-**	**100**
3	**Blank**	**Saline water**	0	0	0	0	0	0

Figure XI: Brine Shrimps present in the developed extruded multi-grain snack

Table XII highlights the mortality of brine shrimps that is present in the developed extruded multi-grain snack. The sample (extruded multi-grain snack) is not toxic ask$_2$Cr$_2$O$_7$which shows the maximum lethality of shrimps at higher concentrations. The shrimps in the sample (Extruded multi-grain snack) are found to be non-toxic in lower concentrations (100 µg/ml) as well as in higher concentrations (1500 µg/ml).

G. Phytochemical Analysis

Phytochemical screening was analyzed for the developed extruded multi-grain snack and the results are projected in Table XIII.

TABLE XIII

PHYTOCHEMICAL SCREENING OF THE DEVELOPED EXTRUDED MULTI-GRAIN SNACK

S.No.	Metabolite	Test performed	Observation	Results	Figure No.
1.	Alkaloids	+Mayer's reagent	Absence of Cream colored precipitate	-	
		+ Dragendorff's reagent	Absence of reddish-brown precipitate	-	
2.	Flavonoids	Alkaline test	Intense yellow	+	1

			coloration with dil. NaOH turnscolorless on addingdil.HCl		
		$+H_2SO_4$	Presence of reddish Orange color	+	2
		+lead acetate	Absence of white Precipitate	-	
		Shinoda test	Absence of crimson Pink color	-	
3.	Sterols (Libermann test)	$+CHCl_3$+ Acetic anhydride +Conc.H_2SO_4	Presence of reddish brown ring	+	3
4.	Terpenoids (Libermann test)	+ $CHCl_3$+ Acetic anhydride + Conc. H_2SO_4	Absence of green color	-	
5.	Anthraquinone (Borntrager's test)	+ $FeCl_3$ + Conc.HCl+diethyl ether +Ammonia	Presence of reddish-orangecolor	+	4
6.	Anthocyanin	HCl Test	No Colour change	-	
7.	Proteins	+2%Ninhydrin reagent	Absence of Purple color	-	
		$+2\%CuSO_4$+ 95%ethanol+KOHpellet	Absence of blue color	-	
		+conc. HNO_3	Absence of Yellow Coloration	-	

8.	Phenolic compounds	+5% neutral $FeCl_3$	Absence of bluish-greencolored solution	-	

		Gelatin test	Absence of white precipitate	-	
		Ellagic acid test	Absence of nigger brown precipitate	-	
9.	Quinones	Conc.HCl	Absence of yellow precipitate	-	
		Alcoholic KOH	Absence of reddish solution	-	
10.	Carbohydrates	Molisch's test	Presence of a Violet ring	+	5
		Fehling's test	Presence of Red precipitate	+	6
11.	Tannin	Braymer's test	Absence of bluish-greencolor	-	
		+Gelatin test	Absence of white precipitate	-	
		10% NaOH test	Absence of emulsion	-	
12.	Saponins	Shaken with water	Absence of foam	-	
13.	Cardiac glycosides	+Baljet reagent	Absence of yellow-orangecolor	-	
		Bromine water test	Absence of yellow precipitate	-	
		Keller-killani test	Absence of brown ring	-	

14.	Glycoside's test	Borntrager's test	Absence of pink-colored solution	-	
		Aq.NaOH test	Absence of yellow-colored solution	-	
15.	Lignin	+Gallic acid	Absence of olive-green color	-	
16.	Coumarins	Fluorescence test	No yellow fluorescence	-	
		+10%NaOH + $CHCl_3$	Absence of yellow color	-	
17.	Volatile oils	Fluorescence test	No pinkish fluorescence	-	

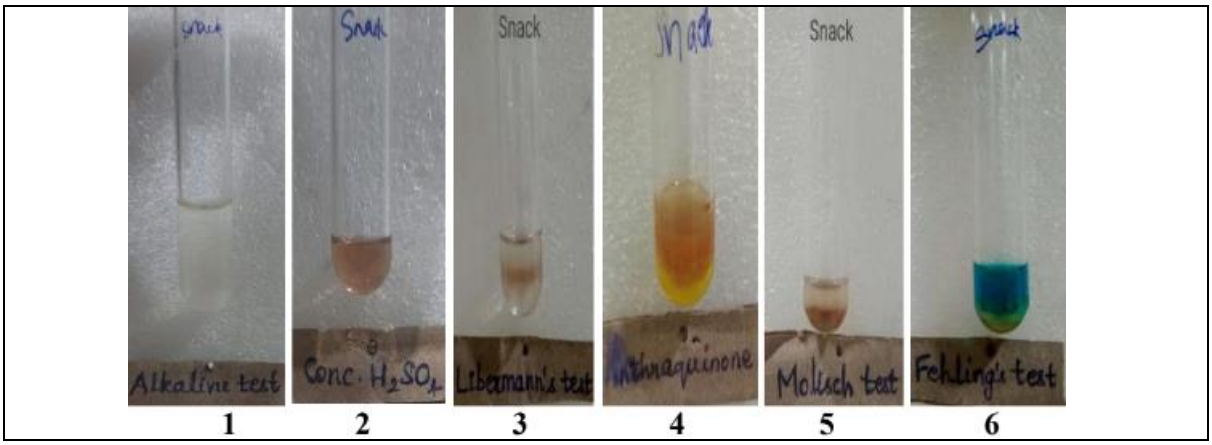


Figure XII: Phytochemical screening of sample (extruded multi-grain snack)

From Table XIII it is evident that phytochemicals like flavonoids, sterols, anthraquinone, and carbohydrates are present in the developed extruded multi-grain snack. The role of flavonoids, anthraquinone has the potential that contributes to the prevention of diabetes mellitus (Xiao. 2022 and Mohammed *et al* 2019).

The results are in line with the research done by Enaim *et al* 2022 on the title Phytochemical content and antioxidant activity of extruded product made from yellow corn supplemented with apple pomace powder. There is increased phytochemical content (Phenols, flavanols, and flavonoids) in the extruded ready-to-eat products made with yellow corn. This makes it possible to obtain a formulation of an extruded food rich in phenolic compounds with the potential to contribute to the prevention of oxidative stress.

H. Shelf-life analysis

The developed extruded multi-grain snack was stored in a stainless-steel container, glass container, plastic container, and eco-friendly ziplock cover to observe the changes that occur in appearance, color, flavor, texture, and taste during storage time.

The developed extruded multi-grain snack was stored in four different containers, visual and physical characteristics were analyzed every day. The changes in texture and appearance were noted for a period of time. On day 14 there was no significant change in flavor and taste.

Extruded multi-grain snacks were stored in four different containers and their physical appearance (Texture) were observed. The result is presented in Table XIII.

TABLE XIV

TEXTURE OBSERVATION OF THE DEVELOPED EXTRUDED MULTI-GRAIN SNACK

Texture	Stainless steel container	Glass container	Plastic container	Eco-friendly ziplock cover
Day 1	Crispy	Crispy	Crispy	Crispy
Day 3	Crispy	Crispy	Crispy	Crispy
Day 5	Crispy	Crispy	Crispy	Pliable
Day 7	Crispy	Crispy	Crispy	Pliable
Day 9	Crispy	Crispy	Crispy	Pliable
Day 11	Crispy	Crispy	Crispy	Pliable
Day 13	Crispy	Pliable	Pliable	Pliable
Day 15	Crispy	Pliable	Pliable	Pliable

From Table XIV, it is noticed that the extruded multi-grain snack has significant changes in texture for all 15 days. The extruded snack was crispy and crunchy when it was stored in a stainless-steel container. The change in texture was observed when it was stored in a glass container, plastic container, and eco-friendly ziplock cover.

There was no change in taste when the extruded snack was stored in a stainless-steel container. The changes in texture were observed when it was stored in a glass container, plastic container, and eco-friendly ziplock cover. As a result, the developed extruded multi-grain snack can be stored in an air-tight stainless-steel container for a longer shelf life.

Textural changes were observed on day 14, and the product was pliable and not palatable. Hence, the product was analyzed for its microbial status.

I. Microbial Analysis

Microbial analysis for the developed extruded multi-grain snack was analyzed on a weekly basis to determine their storability.

Tables XV and XVI highlight the data for day 1 and day 15 on the total plate count, yeast, and mold analysis was done for the developed extruded multi-grain snack.

TABLE XV

MICROBIAL ANALYSIS OF THE DEVELOPED EXTRUDED MULTI-GRAIN SNACK- DAY 1

S. No	Parameters	Normal Range	Result
1.	Total Plate count	Not more than 50,000 per gram	330 CFU/g
2.	Yeast and mold	Not more than 10 per gram	<10 CFU/g

TABLE XVI

MICROBIAL ANALYSIS OF THE DEVELOPED EXTRUDED MULTI-GRAIN SNACK- DAY 15

S. No	Parameters	Normal Range	Result
1.	Total Plate count	Not more than 50,000 per gram	370 CFU/g
2.	Yeast and mold	Not more than 10 per gram	<10 CFU/g

Tables XV and XVI contain the microbial data of the total plate count, yeast, and mold of the developed extruded multi-grain snack. According to FSSAI guidelines 2006, the total plate count should not be more than 50,000 per gram, and yeast, and mold count should not be more than 10 per gram. Day 1 contains 330/g and <10/g which is a normal range and has a low microbial load. Day 15 contains 370/g and <10/g which is a normal range. In this study, the level of contamination of the extruded snack is minimal and within the standard range given by FSSAI. The microbial load of the stored extruded snack was within the recommended safe limit. Hence, this indicates that the extruded snack was stable under the storage condition.

Omowunmi *et al* 2021 in their research on microbiological changes during storage of extruded snacks produced from yellow cassava substituted with processed sesame seed flour. It was evident from their study that the total plate count, yeast, and mold count were increased with a storage period of four weeks.

V. SUMMARY AND CONCLUSION

Diabetes is one of the most prevalent chronic disorder. Type I diabetes, arising from a lack of insulin production in the pancreas, and type II diabetes, which results from insulin resistance. The complications of diabetes are cardiovascular disease, kidney failure, liver damage, and hypertension. As a result, managing diabetes mellitus can be done with the help of proper medications and low glycemic index foods. Consumption of millets can reduce the prevalence of diabetes as millets are rich in phytochemicals and antioxidants. Herbs contain antioxidants that would be the right choice to maintain blood glucose levels. Cereal-based snacks such as cookies, bread and savories have high levels of carbohydrates, fat, and salt which cause nutrition-related diseases. Extruded products, due to their lower fat content, can be promoted as a healthy choice for diabetes.

Hence, "**A study on Development of Low GI Extruded Multi-grain Snack for Diabetics and Its Quality Evaluation**" was carried out with the objective of developing multi-grain extruded snack for diabetics.

In the development of extruded snack, ingredients such as maize (*Zea mays*), foxtail millet (*Setariaitalica*), finger millet (*Eleusine coracana*), pearl millet (*Pennisetum glaucum*), aavaram flower (*Cassia auriculata*), Guava Leaves (*Psidium guajavae folium*), Jamun seeds (*Eugenia jambolana*), turmeric powder and olive oil were selected. Millets and herbs are low in GI and have a therapeutic effect in lowering the blood glucose level.

- The process of extrusion was carried out in different combination of millets that were selected. The millets were cleaned, soaked, conditioned and loaded into the single screw extruder (machine) for the development of millet-based snack. The selected herbs were also cleaned, washed, shade dried, pulverized into powder and stored.
- Five trials were done with different combinations of chosen millets. The product obtained from first 4 trials were not in desired shape and the taste was not acceptable. But the fifth trial was successful with the combination of maize 500 g, foxtail millet 100 g, finger millet 300 g, and pearl millet 100 g and has the ideal shape, color, texture, taste, and flavor which was very much acceptable.
- For the developed extruded snack, several combinations of herbal powders were incorporated. The amount of herbal mixtures varies depending on the variations. The developed extruded snack each had 0.5g, 1.0g, 1.5g, and 2.0g of herbs added to them.

FSSAI regulations state that 3-5 g of herb powder is allowed to be consumed by humans. A maximum of 2 g of herbs were added to the developed extruded multi-grain snack.

- With different quantities of addition of herbs, a total of twelve variations were developed. Aavaram flower powder was added to the extruded snack in ratios of 0.5g, 1.0g, 1.5g, and 2.0 g to make variation 1, which resulted in four combinations. Similarly, guava leaf powder was added in variation 2 and jamun seed powder in variation 3. Sensory evaluation for the developed extruded multi-grain snack was conducted by panel members using a nine-point hedonic scale. The product was evaluated for its appearance, color, flavor, texture and taste. Based on the scores extruded multi-grain snack incorporated with guava leaf powder (2g) was selected as the final product.
- The glycemic index was analyzed for the developed snack by testing the blood glucose level for the volunteers. Blood samples were collected at the end of 30 min for 2 hours (0, 30,1 hr and 2 hrs). According to the glucose response curve for the reference and the developed extruded multi-grain snack, the developed snack incorporated with guava leaf powder has a low glycemic index (55).
- Quality analysis such as texture, nutrient analysis, microbial, shelf-life, phytochemical, antioxidant and toxicity were analyzed for the developed extruded multi-grain snack.
- The extruded multi-grain snack developed was analyzed for its textural property which is under the normal range (73.5 N). Nutrients such as energy (761 Kcal), carbohydrate (120 g/100g), protein (9 g/100g), dietary fiber (3 g/100g), 22 g of calcium, 4.47 mg of iron, 642 mcg of vitamin A, 1.164 mg of vitamin B, 667 mg of vitamin C, 2.284 mg of zinc, 52 mg of magnesium, 2481 mg of sodium, 3.63% of moisture and 1.97% of ash content were present in the developed extruded multi-grain snack.
- Microbial load (330 CFU/g) was under the guidelines given by FSSAI, 2006, this indicates that the extruded snack was stable under storage conditions and had a longer shelf life for a period of time. On day 14 the change in appearance, texture, color and taste was observed.
- Phytochemicals like flavonoids, sterols, protein, carbohydrates and anthraquinone were present in the developed extruded snack which are beneficial in lowering the blood glucose level also contribute to the prevention of oxidative stress.

- Antioxidants for the developed extruded multi-grain snack were analyzed by the DPPH method with ascorbic acid as standard. The increase in the inhibition percentage indicated the high antioxidant property of the product.
- The brine shrimp lethality assay method was followed to analyze the toxic elements of the developed extruded snack. From the analysis, the product was found to be non-toxic.

CONCLUSION

The prevalence of diabetes is rising significantly among people worldwide. Short and frequent meal intake aids in the better management of diabetes mellitus. Consuming commercially available Ready to Eat snacks, which are high in calories and saturated fat, is one of the cause for the occurrence. Therefore, an effort was made to develop a nutritious, healthy snack using millet as the base, to turn them into therapeutic food, by incorporating herbs to increase the medicinal property of the developed snack. Thus, the developed low GI extruded multi-grain snack can be taken up as a start-up or micro industry to promote the healthy snack among diabetics, consequently improving the nutritional status of the diabetic population.

BIBLIOGRAPHY

1. Ali, M. A., Kamraju, M., & Vani, M. (2017). Importance of health and fitness in life. *Int Fed Comp Sci Sports*, 41-3.
2. Budreviciute, A., Damiati, S., Sabir, D. K., Onder, K., Schuller-Goetzburg, P., Plakys, G., & Kodzius, R. (2020). Management and prevention strategies for non-communicable diseases (NCDs) and their risk factors. *Frontiers in public health*, 788.
3. Sapra, A., Bhandari, P., & Wilhite Hughes, A. (2021). Diabetes Mellitus (Nursing). *In StatPearls Publishing.*
4. Kharroubi, A. T., & Darwish, H. M. (2015). Diabetes mellitus: The epidemic of the century. *World journal of diabetes*, *6*(6), 850.
5. Massey, C. N., Feig, E. H., Duque-Serrano, L., Wexler, D., Moskowitz, J. T., & Huffman, J. C. (2019). Well-being interventions for individuals with diabetes: A systematic review. *Diabetes Research and Clinical Practice*, *147*, 118-133.
6. Harvey, J. N., & Lawson, V. L. (2009). The importance of health belief models in determining self-care behaviour in diabetes. *Diabetic Medicine*, *26*(1), 5-13.
7. Ramachandran, A. (2014). Know the signs and symptoms of diabetes. *The Indian journal of medical research*, *140*(5), 579.
8. Forouhi, N. G., & Wareham, N. J. (2010). Epidemiology of diabetes. *Medicine*, *38*(11), 602-606.
9. Sun, H., Saeedi, P., Karuranga, S., Pinkepank, M., Ogurtsova, K., Duncan, B. B., ... & Magliano, D. J. (2022). IDF Diabetes Atlas: Global, regional and country-level diabetes prevalence estimates for 2021 and projections for 2045. *Diabetes research and clinical practice*, *183*, 109119.
10. Reddy, V. R. S., Hariharan, A. S., Rajesh, M., Darshan, J. C., Prasanna, S., & Nithyamala, I. Prevalence of Diabetes Mellitus among Young Indians and Psycho-Educational Intervention for Effective Treatment.
11. Sami, W., Ansari, T., Butt, N. S., & Ab Hamid, M. R. (2017). Effect of diet on type 2 diabetes mellitus: A review. *International journal of health sciences*, *11*(2), 65.
12. Forouhi, N. G., & Wareham, N. J. (2022). Epidemiology of diabetes. *Medicine*.
13. Rajput, S. A., Ashraff, S., & Siddiqui, M. (2022). Diet and Management of Type II Diabetes Mellitus in the United Kingdom: A Narrative Review. *Diabetology*, *3*(1), 72-78.
14. Ahmad, A., Khan, A., Khan, S., & Khan, M. (2017). Causes, complications and management of diabetes mellitus. *Chronicle Journal of Food and Nutrition*, *1*(1), 1-4.
15. Kirwan, J. P., Sacks, J., & Nieuwoudt, S. (2017). The essential role of exercise in the management of type 2 diabetes. *Cleveland Clinic journal of medicine*, *84*(7 Suppl 1), S15.
16. Di Daniele, N. (2019). The role of preventive nutrition in chronic non-communicable diseases. *Nutrients*, *11*(5), 1074.
17. Galicia-Garcia, U., Benito-Vicente, A., Jebari, S., Larrea-Sebal, A., Siddiqi, H., Uribe, K. B., ... & Martín, C. (2020). Pathophysiology of type 2 diabetes mellitus. *International journal of molecular sciences*, *21*(17), 6275.
18. Nagarathna, R., Anand, A., Nanda, S., Patil, S. S., Singh, A., Rajesh, S. K., & Nagendra, H. R. (2020). Is the Indian Dietary Pattern Associated WithType 2 Diabetes? A Pan-India Randomized Cluster Sample Study. *Annals of Neurosciences*, *27*(3-4), 175-182.
19. Rahati, S., Shahraki, M., Arjomand, G., & Shahraki, T. (2014). Food pattern, lifestyle and diabetes mellitus. *International journal of high risk behaviors & addiction*, *3*(1).
20. Kaur, P., Waghmare, R., Kumar, V., Rasane, P., Kaur, S., & Gat, Y. (2018). Recent advances in utilization of flaxseed as potential source for value addition. *OCL*, *25*(3), A304.
21. Studzińska-Sroka, E., Galanty, A., Gościniak, A., Wieczorek, M., Kłaput, M., Dudek-Makuch, M., & Cielecka-Piontek, J. (2021). Herbal infusions as a valuable functional food. *Nutrients*, *13*(11), 4051.

22. Jozinović, A., Šubarić, D., Ačkar, Đ., Babić, J., Orkić, V., Guberac, S., & Miličević, B. (2021). Food industry by-products as raw materials in the production of value-added corn snack products. *Foods*, *10*(5), 946.
23. Singh, H., & Bharti, J. (2021). Non-Communicable Diseases and Their Risk Factors.
24. Sahoo, K. C., Kanungo, S., Mahapatra, P., & Pati, S. (2021). Non-communicable diseases care during COVID-19 pandemic: A mixed-method study in Khurda district of Odisha, India. *The Indian Journal of Medical Research*, *153*(5-6), 649.
25. Patel, S., Sharma, A., & Tiwari, R. (2022). Prevalence of Non-communicable Diseases among Elderly Women. *National Journal of Community Medicine*, *13*(1), 7-12.
26. Khura, B., Mohanty, P., Patnaik, L., Pradhan, K. B., Khubchandani, J., & Padhi, B. K. (2022). Socioeconomic Inequalities in the Prevalence of Non-Communicable Diseases among Older Adults in India. *Geriatrics*, *7*(6), 137.
27. Kanitkar, S. A., Kalyan, M., Gaikwad, A., Deshmukh, S., & Saha, R. (2018). Prevalence of Non Communicable Diseases in Elderly. *Journal of the Indian Academy of Geriatrics*, *14*(3).
28. Rochlani, Y., Pothineni, N. V., Kovelamudi, S., & Mehta, J. L. (2017). Metabolic syndrome: pathophysiology, management, and modulation by natural compounds. *Therapeutic advances in cardiovascular disease*, *11*(8), 215-225.
29. Lam, D. W., & LeRoith, D. (2012). The worldwide diabetes epidemic. *Current Opinion in Endocrinology, Diabetes and Obesity*, *19*(2), 93-96.
30. Wu, Y., Ding, Y., Tanaka, Y., & Zhang, W. (2014). Risk factors contributing to type 2 diabetes and recent advances in the treatment and prevention. *International journal of medical sciences*, *11*(11), 1185.
31. Sangma, J. J. D., Suneetha, W. J., Kumari, B. A., & Devi, K. S. (2021). Advanced Study on Phytochemical Screening for Antioxidant Properties of Germinated Foxtail Millet. *New Ideas Concerning Science and Technology Vol. 8*, 152-160.
32. Siyuan, S., Tong, L., & Liu, R. (2018). Corn phytochemicals and their health benefits. *Food Science and Human Wellness*, *7*(3), 185-195.
33. Ogbeba, J. (2019). Phytochemical and antibacterial property of finger millet (Eleusine coracana) on some selected clinical bacteria. *Access Microbiology*, *1*(1A), 135.
34. Krishnan, R., & Meera, M. S. (2018). Pearl millet minerals: effect of processing on bioaccessibility. *Journal of food science and technology*, *55*, 3362-3372.
35. Kaur, H., & Sharma, S. (2020). An overview of Barnyard millet (Echinochloa frumentacea). *Journal of Pharmacognosy and Phytochemistry*, *9*(4), 819-822.
36. Rajeswari, N., & Priyadharshini, V. P. (2021). Evaluation of Nutritional and Nutraceutical Content of Polished and Unpolished Barnyard Millet-An Analytical Study. *Current Research in Nutrition and Food Science*, *9*(3), 1067.
37. Dayakar Rao, B., Bhaskarachary, K., Arlene Christina, G. D., Sudha Devi, G., Vilas, A. T., & Tonapi, A. (2017). Nutritional and health benefits of millets. *ICAR_Indian Institute of Millets Research (IIMR), Rajendranagar, Hyderabad*, *112*, 33.
38. Abedin, M. J., Abdullah, A. T. M., Satter, M. A., & Farzana, T. (2022). Physical, functional, nutritional and antioxidant properties of foxtail millet in Bangladesh. *Heliyon*, *8*(10), e11186.
39. jaynal: A self-controlled clinical trial. *Nutrients*, *10*(10), 1509.
40. Verma, K. C., Joshi, N., Rana, A. S., & Bhatt, D. (2020). Quality parameters and medicinal uses of foxtail millet (Setaria italica L.): A review. *Journal of Pharmacognosy and Phytochemistry*, *9*(4), 1036-1038.
41. Guha, M., Sreerama, Y. N., & Malleshi, N. G. (2015). Influence of processing on nutraceuticals of little millet (Panicum sumatrense). In *Processing and Impact on Active Components in Food* (pp. 353-360). Academic Press.
42. Dey, S., Saxena, A., Kumar, Y., Maity, T., & Tarafdar, A. (2022). Understanding the Antinutritional Factors and Bioactive Compounds of Kodo Millet (Paspalum scrobiculatum) and Little Millet (Panicum sumatrense). *Journal of Food Quality*.

43. Patil, R. B., Vijayalakshmi, K. G., & Vijayalakshmi, D. (2020). Physical, functional, nutritional, phytochemical and antioxidant properties of kodo millet (Paspalum scrobiculatum). *Journal of Pharmacognosy and Phytochemistry*, *9*(5), 2390-2393.
44. Kannayiram, G., Kumar, A., Sandhya, A., Gayathri, S., & Emiyal, D. (2020). An Invitro Study on Predicted Glycemic Index and Bioactive Component of Fortified-Bread Using Senna Auriculata. *International Journal of Research in Pharmaceutical Sciences*, *11*(4), 5248-5258.
45. Kamala, A., Middha, S. K., & Karigar, C. S. (2018). Plants in traditional medicine with special reference to Cyperus rotundus L.: a review. *3 Biotech*, *8*(7), 1-11.
46. Gajera, H. P., Gevariya, S. N., Hirpara, D. G., Patel, S. V., & Golakiya, B. A. (2017). Antidiabetic and antioxidant functionality associated with phenolic constituents from fruit parts of indigenous black jamun (Syzygium cumini L.) landraces. *Journal of food science and technology*, *54*(10), 3180-3191.
47. Kumar, M., Zhang, B., Nishad, J., Verma, A., Sheri, V., Dhumal, S., ... & Lorenzo, J. M. (2022). Jamun (Syzygium cumini (L.) Skeels) Seed: A Review on Nutritional Profile, Functional Food Properties, Health-Promoting Applications, and Safety Aspects. *Processes*, *10*(11), 2169.
48. Tiwari, P., Mishra, B. N., & Sangwan, N. S. (2014). Phytochemical and pharmacological properties of Gymnema sylvestre: an important medicinal plant. *BioMed research international*.
49. Laha, S., & Paul, S. (2019). Gymnema sylvestre (Gurmar): A potent herb with anti-diabetic and antioxidant potential. *Pharmacognosy Journal*, *11*(2).
50. Mounika, D., Sangeetha, U., & Sireesha, G. (2022). Estimation of phytochemicals in Millets and selected Millet products. *Indian J. Applied & Pure Bio*, *37*(3), 810-820.
51. Saeedi, P., Petersohn, I., Salpea, P., Malanda, B., Karuranga, S., Unwin, N., ... & IDF Diabetes Atlas Committee. (2019). Global and regional diabetes prevalence estimates for 2019 and projections for 2030 and 2045: Results from the International Diabetes Federation Diabetes Atlas. *Diabetes research and clinical practice*, *157*, 107843.
52. www.nutricereals.dac.gov.in (International Diabetes Federation IDF 2022)
53. Pradeepa, R., & Mohan, V. (2021). Epidemiology of type 2 diabetes in India. *Indian Journal of Ophthalmology*, *69*(11), 2932.
54. Pivari, F., Mingione, A., Brasacchio, C., & Soldati, L. (2019). Curcumin and type 2 diabetes mellitus: prevention and treatment. *Nutrients*, *11*(8), 1837.
55. Marton, L. T., Pescinini-e-Salzedas, L. M., Camargo, M. E. C., Barbalho, S. M., Haber, J. F. D. S., Sinatora, R. V., & Cincotto dos Santos Bueno, P. (2021). The effects of curcumin on diabetes mellitus: a systematic review. *Frontiers in Endocrinology*, *12*, 669448.
56. Sharma, M. K., Chauhan, J., Kumar, M., Joshi, C. K., Sharma, S., & Lai, C. (2021). Prospects of Aloe vera and its Bioactive Compounds in Diabetes: Critical Review. *Journal of Pure and Applied Microbiology*, *15*(4), 1781-1798.
57. Westman, E. C. (2021). Type 2 diabetes mellitus: A pathophysiologic perspective. *Frontiers in Nutrition*, *8*.
58. Nagarathna, R., Bali, P., Anand, A., Srivastava, V., Patil, S., Sharma, G., ... & Nagendra, H. R. (2020). Prevalence of diabetes and its determinants in the young adults indian population-call for yoga intervention. *Frontiers in endocrinology*, *11*, 507064.
59. Gowda, N. N., Siliveru, K., Prasad, P. V., Bhatt, Y., Netravati, B. P., & Gurikar, C. (2022). Modern processing of Indian millets: a perspective on changes in nutritional properties. *Foods*, *11*(4), 499.
60. Ceasar, S. A., & Maharajan, T. (2022). The role of millets in attaining United Nation's sustainable developmental goals. *PLANTS PEOPLE PLANET*.
61. Kaur, P., Purewal, S. S., Sandhu, K. S., Kaur, M., & Salar, R. K. (2019). Millets: A cereal grain with potent antioxidants and health benefits. *Journal of Food Measurement and Characterization*, *13*(1), 793-806.
62. Suma Pushparaj, F., & Urooj, A. (2014). Antioxidant activity in two pearl millet (Pennisetum typhoideum) cultivars as influenced by processing. *Antioxidants*, *3*(1), 55-66.

63. Ramashia, S. E., Mashau, M. E., & Onipe, O. O. (2021). Millets Cereal Grains: Nutritional Composition and Utilisation in Sub-Saharan Africa. In *Cereal Grains-Volume 1*. IntechOpen.
64. Maitra, S., Pine, S., Shankar, T., & Pramanick, B. (2020). Nutrient management in foxtail millet: a review. *Indian Journal of Natural Sciences*, *10*(60), 23156-23160.
65. Rouf Shah, T., Prasad, K., & Kumar, P. (2016). ra—A potential source of human nutrition and health: A review. *Cogent Food & Agriculture*, *2*(1), 1166995.
66. Corn Nutrition and Health Benefits Author Prof. Hayk S. Arakelyan. Full Professor in Medicine, Doctor of Medical Sciences, Ph.D , Grand Ph.D .Senior Expert of Interactive Clinical Pharmacology , Drug Safety, Treatment Tactics, General Medicine and Clinical Research *(1) (PDF) Corn Nutrition and Health Benefits*. Available from: https://www.researchgate.net/publication/333021434_Corn_Nutrition_and_Health_Benefits.
67. Kumar, A., Metwal, M., Kaur, S., Gupta, A. K., Puranik, S., Singh, S., ... & Yadav, R. (2016). Nutraceutical value of finger millet [Eleusine coracana (L.) Gaertn.], and their improvement using omics approaches. *Frontiers in plant science*, *7*, 934.
68. Chandra, D., Chandra, S., & Sharma, A. K. (2016). Review of Finger millet (Eleusine coracana (L.) Gaertn): a power house of health benefiting nutrients. *Food Science and Human Wellness*, *5*(3), 149-155.
69. Singh, P., & Raghuvanshi, R. S. (2012). Finger millet for food and nutritional security. *African Journal of Food Science*, *6*(4), 77-84.
70. Singh, R. K., Muthamilarasan, M., & Prasad, M. (2017). Foxtail millet: an introduction. *The foxtail millet genome*, 1-9.
71. Devi, N. L., Shobha, S., Alavi, S., Kalpana, K., & Soumya, M. (2014). Utilization of extrusion technology for the development of millet based complementary foods. *Journal of food science and technology*, *51*(10), 2845.
72. Krishnan, R., & Meera, M. S. (2018). Pearl millet minerals: effect of processing on bioaccessibility. *Journal of food science and technology*, *55*, 3362-3372.
73. Rani, S., Singh, R., Sehrawat, R., Kaur, B. P., & Upadhyay, A. (2018). Pearl millet processing: a review. *Nutrition & Food Science*, *48*(1), 30-44.
74. Nambirajan, G., Karunanidhi, K., Ganesan, A., Rajendran, R., Kandasamy, R., Elangovan, A., & Thilagar, S. (2018). Evaluation of antidiabetic activity of bud and flower of Avaram Senna (Cassia auriculata L.) In high fat diet and streptozotocin induced diabetic rats. *Biomedicine & Pharmacotherapy*, *108*, 1495-1506.
75. Sankhari, J. (2019). Effectiveness of Cassia auriculata Flower (Avaram Poo) Extract in Reducing Blood Glucose Among Pre-Diagnosed Type 2 Diabetes Mellitus Clients in Selected Area of Puducherry, India. *Life: Int. J. Health Life-sciences*, *5*(1), 126-136.
76. Díaz-de-Cerio, E., Verardo, V., Gómez-Caravaca, A. M., Fernández-Gutiérrez, A., & Segura-Carretero, A. (2017). Health effects of Psidium guajava L. leaves: an overview of the last decade. *International journal of molecular sciences*, *18*(4), 897.
77. Naseer, S., Hussain, S., Naeem, N., Pervaiz, M., & Rahman, M. (2018). The phytochemistry and medicinal value of Psidium guajava (guava). *Clinical phytoscience*, *4*(1), 1-8.
78. Kannan, A., & Puraikalan, Y. D. (2015). Development and effects of Jamun seed powder incorporated cookies. *International Journal of Pharmacognosy and Phytochemical Research*, *5*, 1934-1935.
79. Desai, G. B., Kshirsagar, R. B., & Sawate, A. R. (2019). Effect of jamun (Syzygium cumini) seed powder extract on physico-chemical and organoleptic properties of beverage. *The Pharma Innovation J*, *8*, 1003-1010.
80. Nasri, H., Sahinfard, N., Rafieian, M., Rafieian, S., Shirzad, M., & Rafieian-Kopaei, M. (2014). Turmeric: A spice with multifunctional medicinal properties. *Journal of HerbMed Pharmacology*, *3*(1), 5-8.
81. Hewlings, S. J., & Kalman, D. S. (2017). Curcumin: A review of its effects on human health. *Foods*, *6*(10), 92.

82. Sharifi-Rad, J., Rayess, Y. E., Rizk, A. A., Sadaka, C., Zgheib, R., Zam, W., ... & Martins, N. (2020). Turmeric and its major compound curcumin on health: bioactive effects and safety profiles for food, pharmaceutical, biotechnological and medicinal applications. *Frontiers in pharmacology*, *11*, 01021.
83. Schwingshackl, L., Lampousi, A. M., Portillo, M. P., Romaguera, D., Hoffmann, G., & Boeing, H. (2017). Olive oil in the prevention and management of type 2 diabetes mellitus: a systematic review and meta-analysis of cohort studies and intervention trials. *Nutrition & diabetes*, *7*(4), e262-e262.
84. Omowunmi, O. O., & Motunrayo, E. L. Microbiological Changes During Storage of Extruded Snacks Produced from Yellow Cassava Substituted with Processed Sesame Seeds Flours.
85. Kasprzak, K., Oniszczuk, T., Wojtowicz, A., Waksmundzka-Hajnos, M., Olech, M., Nowak, R., ... & Oniszczuk, A. (2018). Phenolic acid content and antioxidant properties of extruded corn snacks enriched with kale. *Journal of Analytical Methods in Chemistry*, *2018*.
86. Xiao, J. (2022). Recent advances in dietary flavonoids for management of type 2 diabetes. *Current Opinion in Food Science*, *44*, 100806.
87. Mohammed, A., Ibrahim, M. A., Tajuddeen, N., Aliyu, A. B., & Isah, M. B. (2020). Antidiabetic potential of anthraquinones: a review. *Phytotherapy Research*, *34*(3), 486-504.
88. Anton, A. A., & Luciano, F. B. (2007). Instrumental texture evaluation of extruded snack foods
89. Wadikar, D. D., Kangane, S. S., Parate, V., & Patki, P. E. (2014). Optimisation of a multi-millet ready-to-eat extruded snack with digestibility and nutritional perspective.
90. Omowunmi, O. O., & Motunrayo, E. L. Microbiological Changes During Storage of Extruded Snacks Produced from Yellow Cassava Substituted with Processed Sesame Seeds Flours.
91. Kasprzak, K., Oniszczuk, T., Wojtowicz, A., Waksmundzka-Hajnos, M., Olech, M., Nowak, R., ... & Oniszczuk, A. (2018). Phenolic acid content and antioxidant properties of extruded corn snacks enriched with kale.
92. Xiao, J. (2022). Recent advances in dietary flavonoids for management of type 2 diabetes.
93. Mohammed, A., Ibrahim, M. A., Tajuddeen, N., Aliyu, A. B., & Isah, M. B. (2020). Antidiabetic potential of anthraquinones: a review.
94. ACOSTA, D. F. R., GÓMEZ, J. E. B., DUQUE, J. F. S., GALINDEZ, J. Z. Z., & CRUZ, J. A. M. (2022). Antioxidant potential of extruded snacks enriched with hyper-protein quinoa flour and vegetable extracts.
95. Wani, S. A., & Kumar, P. (2019). Influence on the antioxidant, structural and pasting properties of snacks with fenugreek, oats and green pea.
96. Bisharat, G. I., Lazou, A. E., Panagiotou, N. M., Krokida, M. K., & Maroulis, Z. B. (2015). Antioxidant potential and quality characteristics of vegetable-enriched corn-based extruded snacks.

ANNEXURE I

INSTITUTIONAL HUMAN ETHICS COMMITTEE

Avinashilingam

Institute for Home Science and Higher Education for Women
(Deemed to be university under Category 'A' by MHRD, Estd. u/s 3 of UGC Act 1956) Re-accredited with 'A^{++}' Grade by NAAC.
Recognised by UGC Under Section 12 B
Coimbatore- 641043, Tamil Nadu, India

05.01.2023

To
Ms. M. Diwan Haseena,
Department of Food Service Management and Dietetics
Avinashilingam Institute for Home Science and
Higher Education for Women
Coimbatore- 641043

Dear Diwan Haseena,

Ref: Your proposal No. IHEC/22-23/FSMD-07 entitled "Development of Low GI Extruded Multi-Grain Snack for Diabetics and its Quality Evaluation" submitted for approval of IHEC 21.11.2022

The Institutional Human ethics Committee of our University hereby grants approval to your research proposal No. IHEC/22-23/ FSMD-07 entitled "Development of Low GI Extruded Multi-Grain Snack for Diabetics and its Quality Evaluation" submitted by you. The Approval number for the same is AUW/IHEC/FSMD- 22-23/XPD-07.

We wish you all the best in your research endeavours.

Regards

5.1.23

Dr. A Thirumani Devi
Member Secretary

Institutional Human Ethics Committee

ANNEXURE II

SCORE CARD FOR SENSORY EVALUATION OF THE DEVELOPED LOW GI MULTI-GRAIN SNACK

Name: Date:
Class:

Attributes	Variation I				Variation II				Variation III			
	A	B	C	D	A	B	C	D	A	B	C	D
Appearance												
Colour												
Flavour												
Texture												
Taste												
Overall acceptability												
Total Score												

9- Like extremely

8- Like very much

7- Like moderately

6- Like slightly

5- Neither like nor dislike

4- Dislike slightly

3- Dislike extremely

2- Dislike very much

1- Dislike extremely

ANNEXURE III

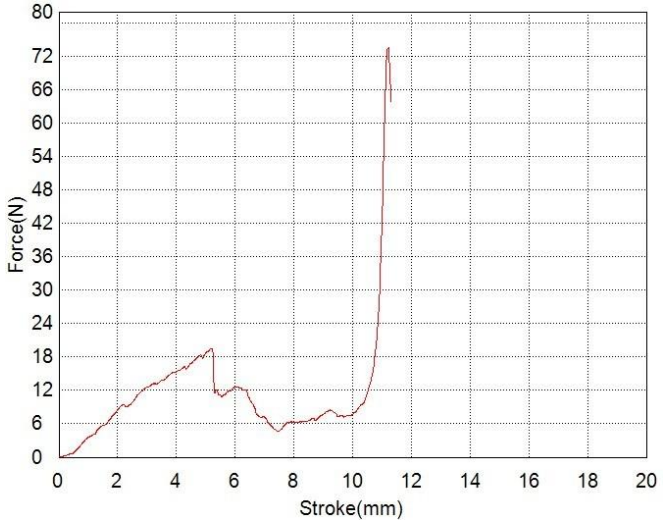
Multi-Grain Snack

Key Word		Product Name	Lays chips
Test File Name		Method File Name	Chips.xmel
Report Date	1/31/2023	Test Date	1/31/2023
Test Mode	Texture	Test Type	Compression
Speed	1mm/sec	Shape	Plate
No of Batches:	1	Qty/Batch:	1

Name	Hardness_Force	Peak_Max. 1_Force	Brittleness	Energy1
Parameters	Calc. at Entire Areas	1th Node - Sensitivity: 10(%FS)1th		1th Node- Next Node
Unit	N	N	N	J
Multi-grain Sna	73.5968	-.-	-.-	0.12550
Average	73.5968	-.-	-.-	0.12550
Standard Deviation	-.-	-.-	-.-	-.-
Range	0.00000	-.-	-.-	0.00000

Name	Resilience	Adhesive_Force_Force	Adhesiveness	Cohesiveness
Parameters		2th Time	2th Node- Next Node	
Unit		N	J	
Multi-grain Sna	-.-	0.01550	0.00000	-.-
Average	-.-	0.01550	0.00000	-.-
Standard Deviation	-.-	-.-	-.-	-.-
Range	-.-	0.00000	0.00000	-.-

Name	Break_Force
Parameters	Sensitivity: 10
Unit	N
Multi-grain Sna	73.5968
Average	73.5968
Standard Deviation	-.-
Range	0.00000



----- **Multi-grain snack**

ANNEXURE IV

TAMIL NADU AGRICULTURAL UNIVERSITY
FOOD QUALITY TESTING LABORATORY
Post Harvest Technology Centre
Coimbatore – 641 003

TC-7591

ULR – TC759122000000065F
Date: 14.03.2023

TEST REPORT

Name & Address of the customer:	Name of the product	:	Multigrain snack
M/s. M. Diwan Haseena	Sample ID	:	2728
Avinashilingam Institute for Home Science and Higher education for women, Coimbatore.	No. of samples	:	1
	Quantity received	:	50 g
	Packaging condition	:	Polythene cover
	Date of Receipt	:	16.02.2023
	Date of Testing	:	13.03.2023
	Date of Completion	:	13.03.2023
	Sampling	:	Sampling not conducted by us

S.No	Parameters	Result	Method of Analysis
1.	Carbohydrate (%)	60.27	IS 1656:2006

----------End of Report----------

14/3/23

(Dr.S. Karthikeyan)
Authorized signatory

ANNEXURE V

Greenlink Analytical and Research Laboratory (India) Private Ltd.
S.F. No. 414/1, Tex Park Road, Opp. Good Luck Syndicate,
Civil Aerodrome Post, Coimbatore - 641 014. Tamilnadu, INDIA.
Tel : +91 422 2901999 | Mob : +91 95245 81999, +91 95249 81999
Email : enquiry@greenlinklabs.com, info@greenlink.in

NABL ISO / IEC 17025:2017 ISO 9001:2015

TEST REPORT

Report No.	GLARL/TRE/1484	Date	20.03.2023

Details of Customer	
Customer Name and Address	Ms. Diwan Haseena Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore.
Customer Reference	-

Details of Sample			
Sample Received Date	14.03.2023	Sample-By	Customer
Nature of the sample	Food Product	Description	Corn Puff Cooked
Sample Code	GLARL/F/03/23/1484	Received condition	Good
Analysis Started on	15.03.2023	Analysis Completed on	18.03.2023

Result of Analysis

S.No	Characteristic	Test Method	Unit	Results
1.	Energy	FSSAI/IS/AOAC	Kcal	761.9
2.	Dietary Fibre		g/100g	2.586
3.	Total Sugar		g/100g	0.12
4.	Protein		g/100g	8.97
5.	Total Fat		g/100g	12.28
6.	Sodium		mg/100g	2481
7.	Calcium		mg/100g	22
8.	Iron		mg/100g	4.47
9.	Zinc		mg/100g	2.284
10	Magnesium		mg/100g	52
11	Vitamin A		mcg	642
12	Vitamin B1		mg/100g	1.164
13	Vitamin C		mg/100g	667
14	Moisture		%	3.63
15	Ash content		%	1.97

****End of Report****

CBE - 14

Authorized Signatory
(M.Amsaveni)
Technical Manager

ANNEXURE VI

SRI SHAKTHI
FOOD TESTING LABORATORY

43-B, Mettupalayam Road, Vellakinar Pirivu, Thudiyalur, Coimbatore - 641 034. Tamil Nadu, INDIA.
Mob : +91 72220 96666, +91 89030 26999, E-mail : srishakthiftl@gmail.com

Accredited by NABL Through Certificate Number TC-10001 dated 18.10.2021 as per ISO / IEC 17025 : 2017

Sponsored by Ministry of Food Processing Industries, Government of India.

TEST REPORT

Test Report No:2023/02/06/SSFTL/22-23/NN-535/001	Issue Date:14.02.2023	Page 1 of 1

CUSTOMER DETAILS	
Customer Name & Address	Ms.Diwan Haseena.M Housing Unit Kavundampalayam, Coimbatore.
Customer Reference	Test Request dt 06.02.2023

SAMPLE DETAILS			
Product Category	Food and Agricultural Products	Sample Code	SSFTL/22-23/NN-535-001
Sample Name	Extruded Multi Grain Snack(Corn Puff)	Sample Conditions at Receipt	Good
Sample Description	Received in Sterile Container	Sample Received on	06.02.2023
Sample Quantity	30 g (Approx.)	Test Commenced on	07.02.2023
Sampled by	Drawn by customer	Test Completed on	12.02.2023
Sampling Procedure	-----	Testing performed at	Sri Shakthi Food Testing Laboratory, Coimbatore

TEST RESULTS –BIOLOGICAL PARAMETERS

Sl. No.	PARAMETERS	TEST METHOD	UNIT	RESULTS
1	Total Plate Count	IS 5402 (Part 1) : 2021	CFU/g	330
2	Yeast and Mould	IS 5403 : 1999	CFU/g	<10

Remarks:

- Result Related Only to the Sample Tested.

End of the Report

S.Nithiya 140223
Checked by
Name : Mrs.S.Nithiya
Designation : Junior Microbiologist

Sri Shakthi Food Testing Laboratory Coimbatore

M. Karthikeyan 14-02-23
Authorized Signatory
Name : M.Karthikeyan
Designation : Senior Microbiologist

SRI SHAKTHI
FOOD TESTING LABORATORY

43-B, Mettupalayam Road, Vellakinar Pirivu, Thudiyalur, Coimbatore - 641 034. Tamil Nadu, INDIA.
Mob : +91 72220 96666, +91 89030 26999, E-mail : srishakthiftl@gmail.com

Accredited by NABL Through Certificate Number TC-10001 dated 18.10.2021 as per ISO / IEC 17025 : 2017

Sponsored by Ministry of Food Processing Industries, Government of India.

TEST REPORT

Test Report No:2023/02/21/SSFTL/22-23/NN-555/001	Issue Date:02.03.2023	Page 1 of 1

CUSTOMER DETAILS	
Customer Name & Address	Ms.Diwan Haseena.M Housing Unit Kavundampalayam, Coimbatore.
Customer Reference	Test Request dt 21.02.2023

SAMPLE DETAILS			
Product Category	Food and Agricultural Products	Sample Code	SSFTL/22-23/NN-555-001
Sample Name	Extruded Multi Grain Snack(Corn Puff)	Sample Conditions at Receipt	Good
Sample Description	Received in Zip Lock Cover	Sample Received on	21.02.2023
Sample Quantity	10 g (Approx.)	Test Commenced on	22.02.2023
Sampled by	Drawn by customer	Test Completed on	27.02.2023
Sampling Procedure	-----	Testing performed at	Sri Shakthi Food Testing Laboratory, Coimbatore

TEST RESULTS –BIOLOGICAL PARAMETERS

Sl. No.	PARAMETERS	TEST METHOD	UNIT	RESULTS
1	Total Plate Count	IS 5402 (Part 1) : 2021	CFU/g	370
2	Yeast and Mould	IS 5403 : 1999	CFU/g	<10

Remarks:

- Result Related Only to the Sample Tested.

End of the Report

Checked by
Name : Mrs.S.Nithiya
Designation : Junior Microbiologist

Sri Shakthi Food Testing Laboratory Coimbatore

Authorized Signatory
Name : M.Karthikeyan
Designation : Senior Microbiologist

ANNEXURE VII

Avinashilingam Institute for Home Science and Higher Education for Women
(Deemed to be University Estd. u/s 3 of UGC Act 1956, Category A by MHRD)
Re-accredited with A++ Grade by NAAC. CGPA 3.65/4, Category I by UGC
Coimbatore - 641 043, Tamil Nadu, India

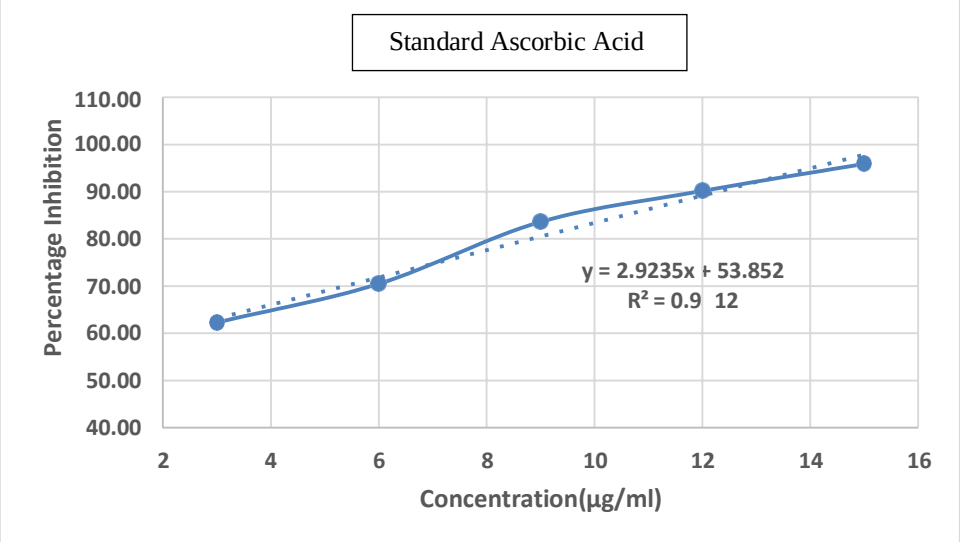
Bharat Ratna Prof.CNR Rao Research Centre

Results of Antioxidant Assay of samples

Method: DPPH Assay

Standard: Ascorbic acid

Concentration (µg/ml)	% Inhibition
3	62.30
6	70.49
9	83.61
12	90.16
15	95.90



Sample Code – Extruded multigrain snackConcentration: 2.62mg/mL H2O

Concentration (µl)	% Inhibition
10	54.10
50	50.82
150	48.36
250	39.34
350	36.89
500	34.43
750	27.87

NOTE: SAMPLE WAS NOT SOLUBLE COMPLETELY, ONLY SOLUBLE PORTIONS WERE USED FOR THIS STUDY

The results of Antioxidant assay of samples submitted by Ms.Diwan Haseena, M.Sc.FSMDof our Institution are given in the above Table and Photographs.

Attested by

Bharat Ratna Prof.C.N.R Rao Research Centre
Avinashilingam Institute for Home Science and Higher Education for Women,
Coimbatore-641043

Dr.P.Lalitha
Professor of Chemistry
Dean i/c, Research and Development Cell
& Co-ordinator, Bharat Ratna Prof C.N.R Rao Research Centre

ANNEXURE VIII

Avinashilingam Institute for Home Science and Higher Education for Women
(Deemed to be University *Estd.u/s* 3 of UGC Act 1956, Category A by MHRD)
Re-accredited with 'A++' Grade by NAAC.
Recognised by UGC Under Section 12 B Coimbatore-641 043, TamilNadu, India

Bharat Ratna Prof.C.N.R Rao Research Centre

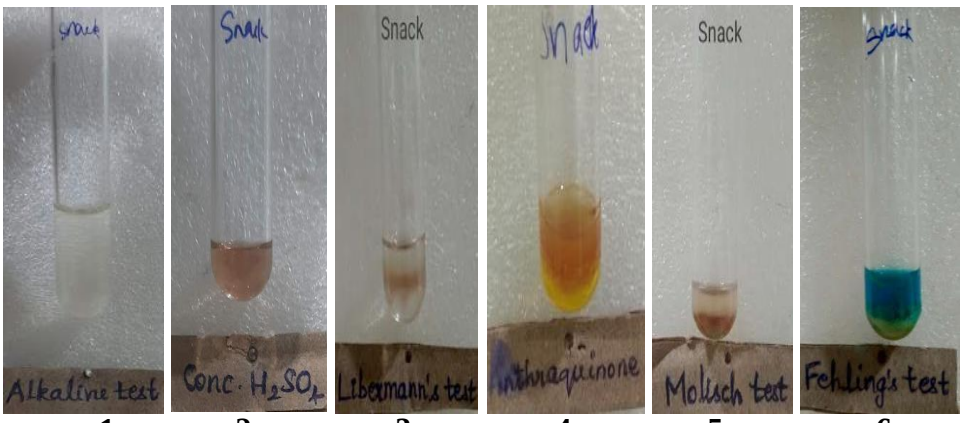
Results of Phytochemical Screening of samples

Sample code: Extruded Multi-grain Snack

S.No.	Metabolite	Test performed	Observation	Results	Figure No.
1.	Alkaloids	+Mayer's reagent	Absence of Cream coloured precipitate	-	
		+ Dragendorff's reagent	Absence of reddish brown precipitate	-	
2.	Flavonoids	Alkaline test	Intense yellow colouration with dil. NaOH turning colourless on adding dil.HCl	+	1
		+H_2SO_4	Presence of reddish Orange colour	+	2
		+lead acetate	Absence of white Precipitate	-	
		Shinoda test	Absence of crimson Pink colour	-	
3.	Sterols (Libermann test)	+$CHCl_3$+ Acetic anhydride +Conc.H_2SO_4	Presence of reddish brown ring	+	3
4.	Terpenoids (Libermann test)	+ $CHCl_3$+ Acetic anhydride + Conc. H_2SO_4	Absence of green colour	-	
5.	Anthraquinone (Borntrager's test)	+ $FeCl_3$ + Conc.HCl+diethyl ether +Ammonia	Presence of reddish orange colour	+	4
6.	Anthocyanin	HCl Test	No Colour change	-	
7.	Proteins	+2%Ninhydrin reagent	Absence of Purple colour	-	
		+2%$CuSO_4$+ 95%ethanol+KOHpellet	Absence of blue colour	-	
		+conc. HNO_3	Absence of Yellow Colouration	-	
8.	Phenolic compounds	+5% neutral $FeCl_3$	Absence of bluish green coloured solution	-	

		Gelatin test	Absence of white precipitate	-	
		Ellagic acid test	Absence of nigger brown precipitate	-	
9.	Quinones	Conc.HCl	Absence of yellow precipitate	-	
		Alcoholic KOH	Absence of reddish solution	-	
10.	Carbohydrates	Molisch's test	Presence of Violet ring	+	5
		Fehling's test	Presence of Red precipitate	+	6
11.	Tannin	Braymer's test	Absence of bluish green colour	-	
		+Gelatin test	Absence of white precipitate	-	
		10% NaOH test	Absence of emulsion	-	
12.	Saponins	Shaken with water	Absence of foam	-	
13.	Cardiac glycosides	+Baljet reagent	Absence of yellow orange colour	-	
		Bromine water test	Absence of yellow precipitate	-	
		Keller-killani test	Absence of brown ring	-	
14.	Glycoside's test	Borntrager's test	Absence of pink coloured solution	-	
		Aq.NaOH test	Absence of yellow coloured solution	-	
15.	Lignin	+Gallic acid	Absence of olive-green colour	-	
16.	Coumarins	Fluorescence test	No yellow fluorescence	-	
		+10%NaOH + $CHCl_3$	Absence of yellow colour	-	
17.	Volatile oils	Fluorescence test	No pinkish fluorescence	-	

Figures



1 2 3 4 5 6

The results of Phytochemical Screening of sample submitted by M. Diwan Haseena, II M.Sc FSMD of our institution are given in the above table and photographs.

Attested by

Bharat Ratna Prof.C.N.R Rao Research Centre
Avinashilingam Institute for Home Science and Higher Education for Women,
Coimbatore-641043

Dr.P.Lalitha
Professor of Chemistry,
Director R&D Cell i/c & Co-ordinator,
Bharat Ratna Prof. CNR Rao Research Centre.

ANNEXURE IX

Avinashilingam Institute for HomeScience and Higher Education for Women

(Deemed to be University Estd. u/s 3 of UGC Act 1956, Category 'A' by MHRDRe-accredited with A++ Grade by NAAC. CGPA 3.65/4, Category I by UGC) Coimbatore - 641 043, Tamil Nadu, India

Bharat Ratna Prof.CNR Rao Research Centre

Results of Brine Shrimp Lethality Assay

Number of Samples submitted: 1

Sample Code – Extruded Multi-grain Snack

Preparation of Samples

The given sample (Extruded Multi-grain Snack) is weighed and diluted to prepare 1mg/ml stock solution. The samples (Extruded Multi-grain Snack) of different volume 100, 250, 500, 1000, 1500µl are added to each beaker containing saline solution respectively.

Procedure

- 30 shrimps ➟ Introduced into the solution mixture of saline (25ml) and sample solution of various concentration.
- The movement of shrimp is monitored at intervals of 1, 2, 4, 6, 24 hours.
- Blank solution : 30 shrimps in Brine solution
- Positive control : Potassium dichromate (1mg/ml)

S. No	Sample Code	Concentration (µg/ml)	Mortality of Brine shrimp (no. of shrimps dead) (h)					
			1	2	4	6	24	% Mortality (at 24h)
1.	Extruded Multi-grain Snack	100	0	0	0	1	2	7
		250	0	0	0	0	1	3
		500	0	0	0	1	2	7
		1000	0	0	0	0	2	7
		1500	0	0	0	1	3	10

2.	**Control $K_2Cr_2O_7$**	**1 (mg/ml)**	**30**	**-**	**-**	**-**	**-**	**100**
3.	**Blank**	**Saline water**	0	0	0	0	0	0

N= 30.

- The mortality of shrimp is calculated after 24 hours for Sample solution as well as Blank and Positive control.

Attached are the images of sample (Extruded Multi-grain Snack) and the shrimps present in it respectively.

Fig. 1

Fig. 1a

- The sample (Extruded Multi-grain Snack) is comparatively not toxic than $K_2Cr_2O_7$ which shows maximum lethality of shrimps at higher concentration.
- The shrimps in the sample (Extruded Multi-grain Snack) are found to be non-toxic in lower concentration as well as in higher concentration.
- After 24h, three shrimps are found to be mortal at highest concentration

The results of Brine Shrimp Lethality Assay of sample (Extruded Multi-grain Snack) submitted by Ms. M. Diwan Haseena, II MSc FSMD of our institute is given in the above table and photographs.

Attested by

P.Lalitha 22/3/23

Bharat Ratna Prof.C.N.R Rao Research Centre
Avinashilingam Institute for Home Science and Higher Education for Women,
Coimbatore-641043

Dr.P.Lalitha
Professor of Chemistry,
Dean i/c, R&D
& Co-ordinator, Bharat Ratna Prof.CNR Rao Research Centre

ANNEXURE X
INFORMED CONSENT FORM

I am briefed about the purpose and conduct of the study entitled "DEVELOPMENT OF LOW GI EXTRUDED MULTI-GRAIN SNACK FOR DIABETICS AND ITS QUALITY EVALUATION" conducted by M. Diwan Haseena. I understand that I will be asked to give a Blood sample for the purpose of analyzing the glycemic index of the developed multi-grain snack. I hereby give my consent to them to interview me and collect biologicalsamples from me. I am affixing my signature / left thumb impression to indicate my consentand willingness to participate in this study (i.e., willingly abide by the project requirements)

Signature / Left thumb impression of the Study Volunteer / Legal Representative:

Signature of the Interviewer with the date:

Signature of the Witness with the name:

தகவலறிந்த ஒப்புதல் படிவம்

எம். திவான் ஹசீனாவால் நடத்தப்பட்ட "நீரிழிவு நோயாளிகளுக்கான குறைந்த ஜி.ஐ. பல தானிய சிற்றுண்டியின் வளர்ச்சி மற்றும் அதன் தர மதிப்பீடு" என்ற தலைப்பில் ஆய்வின் நோக்கம் மற்றும் நடத்தை பற்றி நான் விளக்கினேன். வளர்ந்த பல தானிய சிற்றுண்டியின் கிளைசெமிக் குறியீட்டை பகுப்பாய்வு செய்யும் நோக்கத்திற்காக இரத்த மாதிரியை வழங்குமாறு என்னிடம் கேட்கப்படும் என்பதை நான் புரிந்துகொள்கிறேன். என்னை நேர்காணல் செய்யவும், என்னிடமிருந்து உயிரியல் மாதிரிகளை சேகரிக்கவும் நான் இதன் மூலம் அவர்களுக்கு என் சம்மதத்தை அளிக்கிறேன். இந்த ஆய்வில் பங்கேற்பதற்கான எனது சம்மதம் மற்றும் விருப்பத்தைக் குறிக்க எனது கையொப்பம் / இடது கட்டைவிரல் பதிவை ஒட்டுகிறேன் (அதாவது, திட்டத் தேவைகளுக்கு விருப்பத்துடன் இணங்குகிறேன்)

ஆய்வு தன்னார்வலர்/ சட்டப் பிரதிநிதியின் கையொப்பம் / இடது கட்டைவிரல் பதிவு:

தேதியுடன் நேர்காணல் செய்பவரின் கையொப்பம்:

பெயருடன் சாட்சியின் கையொப்பம்:

ANNEXURE XI
BLOOD GLUCOSE LEVELS FOR THE SELECTED SUBJECTS

Time	30 mins (mg/dl)	1 hour (mg/dl)	1 ½ hour (mg/dl)	2 hours (mg/dl)
Day 1				
Subject 1	116	179	254	191
Subject 2	128	217	180	126
Subject 3	124	153	176	137
Subject 4	103	139	199	178
Subject 5	153	138	184	134
MEAN	124	165	199	153
Day 2 (washout)				
Day 3				
Subject 1	96	116	167	112
Subject 2	99	115	177	98
Subject 3	106	140	105	97
Subject 4	118	103	129	107
Subject 5	123	123	121	127
Day 4				
Subject 1	105	150	136	101
Subject 2	100	148	110	92
Subject 3	109	147	97	94
Subject 4	99	145	103	93
Subject 5	111	132	121	119
Day 5				
Subject 1	107	155	135	111
Subject 2	97	134	113	95
Subject 3	102	130	99	99
Subject 4	101	106	107	96
Subject 5	123	125	113	102
MEAN	106	131	122	102
Day 6 (Washout)				

Day 7				
Subject 1	107	102	114	104
Subject 2	103	105	117	103
Subject 3	117	108	105	107
Subject 4	110	123	131	111
Subject 5	113	111	106	131
Day 8				
Subject 1	76	107	126	125
Subject 2	92	133	107	91
Subject 3	94	96	95	86
Subject 4	108	95	104	112
Subject 5	110	123	109	106
Day 9				
Subject 1	94	114	122	92
Subject 2	96	121	109	102
Subject 3	102	108	102	96
Subject 4	92	122	107	91
Subject 5	105	117	111	101
MEAN	101	111	110	104
Day 10 (washout)				
Day 11				
Subject 1	104	133	131	141
Subject 2	109	120	133	94
Subject 3	91	106	112	103
Subject 4	110	114	141	125
Subject 5	115	113	116	124
Day 12				
Subject 1	105	151	119	107
Subject 2	104	123	143	111
Subject 3	100	114	127	104
Subject 4	107	124	130	111
Subject 5	107	117	112	118
Day 13				
Subject 1	103	131	125	102
Subject 2	105	112	144	110
Subject 3	98	119	130	113
Subject 4	102	123	135	126
Subject 5	105	115	125	112
MEAN	109	121	128	113