DEVELOPMENT AND ACCEPTABILITY OF ANTIOXIDANT RICH DIABETIC FOOD PRODUCTS

MHALO NGULLIE (21PFD015)

Thesis Submitted to the

Avinashilingam Institute for Home Science and

Higher Education for Women, Coimbatore – 641 043

In Partial Fulfilment of the Requirements for the

Degree of Master of Science in

Food Service Management and Dietetics

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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 and acceptability of antioxidant rich diabetic food products"** submitted to Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore in partial fulfillment 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. Mhalo Ngullie** with Register number 21PFD015 during the period of this study under the Supervision and Guidance of **Dr. S. Uma Mageshwari**, Dean Student Affairs and Professor, Department of Food Service Management and Dietetics, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore – 641 043, Tamil Nadu, India.

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INTRODUCTION

I. INTRODUCTION

Let food be thy medicine is a popular statement in 440 BCE mentioned by Hippocrates, a Greek physician. This statement holds true in this modern day that the most effective, practical, and secure intervention to enhance health, and increase longevity, is through the right food choices.

A growing body of research indicates that in humans, nutrition must be tailored to each person's age, sex, heredity, and metabolic risk status and that this is necessary for the entire range of beneficial effects to be experienced. To maximize health and longevity, one must comprehend and make use of nutritional recommendations tailored and customized to meet one's own demands and needs.

A diet that promotes or maintains health is said to be healthy. The body receives the necessary nourishment from a healthy diet, including liquids, vitamins, macronutrients, and enough calories. A balanced diet is necessary for both nutrition and health. The intake of right food has a favorable impact on health and helps to prevent a variety of chronic, non-communicable diseases (NCDs) including diabetes, heart disease, and cancer.

The prevalence of chronic diseases is rising globally across genders and ages and is the main cause of mortality worldwide. According to the World Health Organization (WHO), more than a third of the 40 million fatalities worldwide attributed to non-communicable diseases (NCDs) are premature deaths.

India accounts for more than two-thirds of NCD-related mortality with 5.87 million annual deaths. The number of NCDs in India is predicted to rise in the coming years; by 2025, there will be 52.1 million obese people. By 2030, CVD will be the major cause of death, accounting for 29% of all fatalities. (Jayana K et al; 2019)

Diabetes mellitus remains one of the leading chronic diseases worldwide, with the number of diabetics having quadrupled in the last three decades. With its steadily rising global prevalence, diabetes has emerged as one of the most significant and difficult health problems. The rise in the prevalence of diabetes has coincided with rapid economic

development, which has prompted urbanization and the adoption of contemporary lifestyle practices.

Reports show that India had the second-largest number of persons with type 2 diabetes mellitus (T2DM) in 2017, with over 72 million people. The International Federation (IDF) estimated that in 2015, the number of adults with diabetes was 415 million, and by 2040 it is expected to be 642 million. (Henry CJ et al; 2020)

In India and other developing nations, where people are at the height of their productive lives, the age bracket of 45 to 64 years will have the biggest increase in diabetes cases. (Bansode B; 2019)

The death rates from cardiovascular disease are 1.7 times higher, heart attack hospitalizations are 1.8 times higher, and stroke hospitalizations are 1.5 times higher among diabetics. (Walker RJ et al; 2016) Diabetic individuals have an increased risk of peripheral artery disease, cerebrovascular accidents (CVA), neuropathies, coronary artery disease (CAD), and coronary artery disease (CAD).

India is quickly becoming known as the "diabetes capital" of the globe due to the alarming rise in the number of people with the disease. Diabetes will continue to be prevalent in India as a result of rapid cultural and social change, including aging populations, altered diets, rapid urbanization, lack of regular exercise routines, obesity, and sedentary lifestyles.

Obesity and diabetes have been classified as epidemic diseases of the twenty-first century by the World Health Organisation (WHO). Another element connected to the risk of developing obesity is the change in diet that has led to the so-called nutrition transition (increased intake of animal-source foods, sugar, fats and oils, refined cereals, and processed meals).

Obesity has increased throughout the recent years. Between 25 and 33 percent of individuals globally (or around 2 billion adults) are overweight, and another 33 percent are obese. Obesity is associated with negative health impacts and is known to increase the risk factor for chronic conditions like CVD and type 2 diabetes. The fast pace of life has made obesity and diabetes more prevalent in society by encouraging calorie-dense foods and insufficient physical activity.

The goal of diabetes management is to maintain blood sugar levels close to normal. Modifying the disease risk factors lowers the likelihood of chronic disease as a whole. The cornerstone in the management of diabetes can be positively impacted by certain lifestyle choices, such as changes in diet, proper management of weight, exercise, and taking the right medications (insulin, oral medications).

There is strong evidence from randomized controlled studies that behavioural interventions in order to encourage a nutritious diet, and increased physical activity in patients with impaired glucose tolerance can considerably lower the risk of type 2 diabetes. Race/ethnicity and social determinants of health significantly affect outcomes in patients with diabetes.

Diabetes patients are required to follow a thorough self-management plan that includes managing their nutrition, blood sugar levels, exercise, medication, foot care, and stress. These self-management techniques are essential to an efficient diabetes treatment plan. The management of intermediate risk variables, such as blood pressure, cholesterol, and glycemic control, has a considerable impact on the risk.

It's crucial to educate oneself on the condition and actively engage in its management because issues are typically milder and much less frequent in people with well controlled blood sugar levels.

Also sharing health information and encouraging them to search for relevant information is one of the key strategies in disease prevention. A better understanding of the mechanisms of these relationships/associations will improve the development of cost-effective, culturally tailored programs for patients with diabetes. Hence, there is a need to acquire relevant knowledge to influence the behavior of individuals to improve their current health status, and increase their quality of life, especially those suffering from chronic diseases such as diabetes.

Increased production of reactive oxygen species (ROS) in diabetes mellitus leads to oxidative stress and tissue damage. Oxidative stress is one of the main reasons for the emergence of problems associated with diabetes. When the rate of free radical formation outpaces the antioxidant defense mechanisms, oxidative stress is created. This causes free radicals' harmful consequences.

Free radical species play a significant physiological role in maintaining biological homeostasis, but oxidative stress develops when their generation exceeds the body's antioxidant capacity. The development of insulin resistance and complications from diabetes are both significantly influenced by oxidative stress, which causes pathophysiologic molecular mechanisms and starts a chain reaction of harmful pathways that results in insulin resistance and DM.

The possibility of an increase in chronic diseases and the metabolic disorders they are connected with is still a major issue due to the rising prevalence of excessive consumption and inactivity linked to the Western lifestyle. Due to this, there is still interest in dietary and lifestyle changes for both prevention and treatment.

Free radical production by T2DM results in oxidative stress and a decline in the antioxidant state, according to studies. Reactive oxygen species (ROSs) and a drop in antioxidant levels have been linked to the development of cellular abnormalities and insulin resistance, which are the hallmarks of type 2 diabetes (T2DM).

Since there is no permanent cure for diabetes, the only way is to partially control the condition by using pharmaceuticals to slow the development of problems. Each chemical drug has a unique set of adverse effects. Hence, patients and doctors are increasingly favouring the use of medications derived from natural herbs.

Given that oxidative stress is the root cause of numerous complications associated with diabetes, researchers have extensively investigated the antioxidant effects of various substances, including naturally occurring antioxidants derived from plants, in order to introduce substances that are better and more effective in controlling the progression of diabetes.

A lot of studies have shown that antioxidants such as lycopene, retinol, α- and γ-tocopherol, β-cryptoxanthin, ascorbic acid, α- and β-carotene, lutein and zeaxanthin, which are present in various plants, greatly reduce the complications of diabetes.

The interest in using plants in preventative and therapeutic phytotherapy has been sparked by their high concentration of compounds with antioxidant properties that can scavenge free radicals.

Antioxidants are substances that, when present in extremely low quantities in food or the body, delay, inhibit, or stop oxidative processes that result in food quality deterioration or the emergence and progression of degenerative diseases in the organism.

Free radicals, which are responsible for damage to living things, are neutralised by antioxidants in biological cells. Numerous studies show the importance of antioxidants in maintaining human health as well as in the prevention and treatment of diseases due to their ability to reduce oxidative stress. These antioxidant substances use a range of methods and actions to stop oxidation.

In order to mitigate the negative consequences of oxidative stress, exogenous antioxidants can work with endogenous antioxidants. Examples include carotenoids, vitamin C, vitamin E, and minerals (Cu, Mn, Zn, Se, and Fe) as well as polyphenols (flavonoids, phenolic acids, stilbenes, and lignans). Polyphenols may reduce the prevalence of T2DM by reducing postprandial glucose levels, managing glucose transport, changing insulin signalling pathways, and avoiding pancreatic cell damage. Vitamins A, C, and carotenoids activate the body's innate antioxidant and immunomodulatory systems in addition to directly or indirectly scavenging free radicals.

The harsh side effects of modern synthetic pharmaceuticals and the rising contraindications to their use, however, have sparked an increased interest in the use of therapeutic plants. The majority of medications used to treat conditions linked to oxidative stress come from medicinal plants, particularly those with antioxidant properties.

Phytochemicals control the activity of α-glucosidase and lipase, lower glycaemic levels, enhance pancreatic function, and work in concert with hypoglycaemic medications to treat diabetes. As fruits, vegetables, and seeds have antioxidant capabilities, using them to reduce diabetes problems is supported by the overall findings of numerous studies. Also, a lower incidence of type 2 diabetes mellitus has been linked to increased intake of specific foods having antioxidant capabilities.

According to the World Health Organization (WHO), 80% of the world's population currently uses medications with a plant origin as their primary form of medical care.

There are several drugs that are approved to treat hyperglycemia in type 2 diabetes patients such as sulfonylurea, thiazolidinedione, incretin, and dipeptidyl-peptidase 4

inhibitors. These medicines work by reducing insulin resistance and improving insulin secretion. Because using each medication will result in unfavourable side effects in the long run, there is a lot of interest in developing alternative remedies for controlling diabetes and related problems. which is why natural foods are getting greater attention because of their bioavailability and lack of adverse effects.

Nutrition treatment is a crucial and affordable option for managing the condition without any of the alleged drug-related adverse effects. Apart from the main meals snacking is a part of the human diet as well as it is a crucial component for individuals with diabetes to keep the blood sugar levels at bay. Depending on the raw materials and other additives used in the formulation, it encourages the gradual release of carbohydrate and causes low postprandial blood glucose.

Therefore, the study entitled "Development and acceptability of antioxidant rich diabetic food products for diabetes" was framed and carried out with the following objectives:

- Develop antioxidant rich diabetic food products.
- Assess the developed product with regard to acceptability and nutrient content.

REVIEW OF LITERATURE

II. Review of Literature

The review of literature pertaining to the study **"Development and acceptability of antioxidant rich diabetic food products"** is reviewed under the following headings:

A. Diabetes Mellitus- An Overview

B. Diet and Diabetes

C. Functional dietary foods for diabetes

DIABETES MELLITUS - AN OVERVIEW

Diabetes mellitus (DM) is a steadily well-established disease associated with a disorder in carbohydrate metabolism which is turning out to be more pervasive overall with its raising extent. (Olagunju A et al; 2022)

It is a chronic condition defined by glucose intolerance and includes a variety of abnormalities of the intermediate metabolism. T2DM has significantly increased in frequency and incidence around the world, and its consequences are the main causes of illness and early mortality. (Hou Y et al; 2018).

Diabetes is now the sixth greatest cause of mortality globally and is one of the most common human illnesses after cardiovascular disorders (WHO). Diabetes mellitus (DM) has a diverse aetiology and is defined by insulin resistance and impaired glucose homeostasis. (Abudawood M; 2019)

One of the most concerning issues in modern public health, particularly for lower middle-income countries, is the diabetes epidemic. The prevalence of diabetes in these nations is expected to rise by 67% between 2010 and 2030. In low- and middle-income nations in 2015, there were five million diabetes-related fatalities reported. (Basit A et al; 2018)

Even though the same year, more than 12% of global health expenditures were spent on treating the condition and its complications. The likelihood of diabetic complications

increasing is due to the estimated 50% of diabetes patients who are unaware of their condition.

It is generally known that type 2 diabetes mellitus and insulin resistance are both significantly influenced by fat (T2DM). (Papatheodorou k et al; 2018)

According to reports, type I and type II diabetic patients have a 15% higher risk of premature death and a life expectancy that is lowered by roughly 10 and 20 years, respectively. According to 2017 International Diabetes Federation (IDF) figures, 8.8% of people aged 20 to 79 worldwide have diabetes and men are affected by diabetes more frequently than women in urban areas compared to rural areas.

Diabetes, a silent killer, is one of the most common diseases in today's world. Pre-diabetes is the condition that comes before diabetes, and in most cases, this finally results in the development of diabetes. Fasting plasma glucose (FPG) testing and an oral glucose tolerance test are the two most often used modalities for the diagnosis of pre-diabetes and diabetes, respectively (OGTT).

Diabetes can affect everyone, but numerous studies, some dating back to 1969, have shown that Asians, particularly those from South Asia, Southeast Asia, or the Indian subcontinent, are more prone to the disease than persons of other racial or ethnic backgrounds.

According to a 1985 study carried out in Southall, West London, Asians had a diabetes prevalence that was at least 3.8 times greater than that of Europeans and five times higher for patients between the ages of 40 and 64. (khan RMM et al; 2019)

The rise in the condition's prevalence has been linked to several known risk factors, including the adoption of a western lifestyle, sedentary lifestyle, a lack of physical activity, and a diet high in calories. (Tsalamandris S et al; 2019)

Global prevalence of diabetes

The International Diabetes Federation Diabetes Atlas states that in 2021, 537 million adults aged 20 to 79 had diabetes globally, and by 2045, that figure is projected to climb to

783 million. The numerous factors that contribute to the diabetes epidemic include genetic and epigenetic predispositions, bad eating habits, excess weight, obesity, and sedentary lifestyles. In order to lessen the burden of diabetes mellitus, it is crucial to conduct accurate and objective assessments of the disease state, risk factors, and co-morbidities. (Bae JH et al; 2022)

An expected 10.5% of individuals all over the globe were experiencing diabetes in 2021. It is anticipated that by 2024, the number of diabetic patients will ascend to 783 million. (Tan Y *et al*, 2022).

By 2045, China (140.5 and 147.2 million) and India (101.0 and 134.2 million) will continue to have the highest burden of diabetes. The Western Pacific has the most elevated number of individuals with diabetes (163 million), South-East Asian area (88 million), Europe (59 million), Middle East and North Africa (55 million), North America and Caribbean (47.6 million). (Pradeepa R; 2021).

According to estimates, the prevalence was higher in high-income nations (11.1%) compared to low-income countries (5.5%) and in urban regions (12.1%) than in rural ones (8.3%) in 2021. Compared to high (12.2%) and low-income (11.9%) nations, middle-income nations are predicted to see the largest spike in the prevalence of diabetes between 2021 and 2045. (Sun H et al; 2022)

The number of adults with DM is predicted to rise by 20% in industrialised nations during the next 20 years and by 70% in developing countries.(Athyros VG et al; 2018)

The prevalence of GDM in Asian women is higher than in US women. Globally, the prevalence of GDM ranges from 5% to 25.5% and varies with race, ethnicity, age, body composition, and screening and diagnostic criteria. (Choudhury AA; 2021)

Prevalence of diabetes in India

Diabetes is a global epidemic health problem that is quickly spreading throughout low- and middle-income nations like India with more than half of the people still undiagnosed

(Mathur P et al; 2022). In the year 2000, it was predicted that by 2030, there would be close to 80 million people living with DM in India. However, the expected disease load has arrived in India about ten years sooner, with 77 million people estimated to have diabetes in 2019. By 2045, 130 million individuals in India are expected to have diabetes, according to the updated projection (Brar AS et al; 2022).

The quickly changing dynamics of the T2DM pandemic relate to the dramatic progress of urbanization; an unfortunate current eating regimen and low physical activity patterns are viewed as significant drivers. (Viswanathan V *et al*; 2019)

The Indian population has a higher prevalence rate of GDM compared to some other populations in Southeast Asia. The number of Indians with diabetes increased from 26 million in 1990 to 65 million in 2016 and the estimated prevalence for 2025 is 79.4 million. (Unnikrishnan B *et al*; 2020)

Diabetes is a major disease in India with prevalence rates ranging from 14% in urban areas to 13.2% in rural areas. According to a study in India, women with GDM have a three times higher lifetime chance of developing T2DM 16 years after the index pregnancy compared to pregnant women without GDM. In India, one-third (33%) of women with GDM had a history of maternal diabetes. DM is becoming more prevalent worldwide, especially in developing countries such as India. (Choudhury AA; 2021)

Prevalence of diabetes in south India

The recent Secular Trends in Diabetes in India study, reported that diabetes increased from 18.6% in 2006 to 21.9% in 2016 in urban and rural areas of Tamil Nadu. In the Chennai Urban Population Study cohort, diabetes and prediabetes incidence rates were reported as 20.2 and 13.1 per 1000 person-years, respectively, while in the Chennai Urban Rural Epidemiology Study (CURES) cohort reported the Incidence rates reported for diabetes, prediabetes, and any dysglycemia were 22.2, 29.5, and 51.7 per 1000 person-years, respectively. In Kerala, the incidence rates of type 2 diabetes and impaired fasting glucose (IFG) were 24.5 per 1000 person-years and 45.01 per 1000 person-years, respectively. In Puducherry, the incidence rate of diabetes was reported as 21.5 per 1,000 person-years in rural areas. (Pradeepa R; 2021)

At least 50 of the 640 districts surveyed in Tamil Nadu, Kerala, Andhra Pradesh, and Odisha showed that more than one in ten women aged 35 to 49 years have a high prevalence of diabetes. According to the Global Burden of Disease Study, 2018, in 2016, the prevalence was highest in Tamil Nadu and Kerala. (Jacob Koshy; The Hindu; June 7, 2020)

A recent community-based study in Tamil Nadu revealed GDM prevalence in three settings: 17.8% in urban, 13.8% in semi-urban, and 9.9% in rural areas. (Mishra S *et al*; 2018)

Classification of Diabetes

There are a wide range of types of diabetes mellitus. The most well-known sorts of diabetes are type 1, type 2, and gestational diabetes. (Malode LL; 2021)

Type 1 Diabetes:

T1DM is an autoimmune disease associated with aberrant immune responses to specific-cell autoantigens, causing insulin reduction. (Li B;2019)

It can be diagnosed in both children and adults and can develop earlier than other diseases. It can be categorized as insulin-dependent diabetes or juvenile diabetes because in this case, the patient needs to take insulin routinely. (Mazhar M *et al*; 2021)

According to the previous nomenclature as insulin-dependent diabetes mellitus (IDDM) or juvenile diabetes, accounts for about 5-10% of all diabetes cases. The rate of development of this pancreatic cell-specific autoimmunity and the disorder itself is in most cases rapid, as in infants and children (juvenile onset), or may be gradual, as in adults (late onset). In some cases, in children and adolescents, there is sudden cell death and subsequent failure, which can lead to diabetic ketoacidosis (DKA), often referred to as the first onset of the disease. In others, the course of the disease is very slow, with a slight increase in fasting blood glucose, which assumes a severe hyperglycemic form with or without ketoacidosis, only in the presence of physiological stresses such as severe infections or the onset of other diseases. LADA “Latent Autoimmune Diabetes in Adults (LADA),” also known as “slowly progressing insulin-dependent diabetes.” is the most common form of adult-onset autoimmune diabetes and accounts for 2–12% of all diabetic cases in the adult population. (Bandy MZ *et al;* 2020)

Etiology:

Genetics: Type 1 diabetes is partially hereditary, with several genes, including some HLA genotypes, being known to influence diabetes risk. (Awuchi CG *et al*; 2020)

Environmental factors: Many environmental stresses are associated with type 1 diabetes, including infant and adult nutrition, vitamin D insufficiency, exposure to viruses associated with islet inflammation (eg: enteroviruses) early in life, and reduced gut microbiome diversity.

The greatest observed increase in the incidence of type 1 diabetes is in children younger than 15 years of age. Obesity is associated with an increased presentation of type 1 diabetes, with β-cell stress possibly providing a mechanistic underpinning. (DiMegilo LA *et al*; 2018)

Viruses: Viruses represent important triggers for T1DM pathogenesis. Children exposed to rubella during fetal life have an increased incidence of T1DM, alongside other autoimmune diseases. Enteroviruses may play an important role in the early stages of T1DM development by activating innate immunity.

Diet and gut microbiota: The importance of diet in the development of T1DM remains controversial. Associations of early introduction of cow's milk into the infant diet have been reported in several studies with an increased risk of disease, supporting that exposure of infants to insulin found in milk triggers the autoimmune response. Early inclusion of grains in the diet, nitrate exposure from water intake, inadequate intake of omega-3 fatty acids, and vitamin D deficiency have also been considered. (Paschou SA; 2018)

Type 2 Diabetes:

Type 2 diabetes mellitus (T2DM) is a class of diabetes, the most well-known sort of DM characterized by hyperglycemia, it is supposedly a far-reaching illness influencing a huge part of the populace in numerous nations. (Olagunju AI et al; 2022)

T2DM, also known as non-insulin dependent diabetes mellitus (NIDDM) or adult-onset diabetes and accounts for approximately 90-95% of all diabetes cases. This type of diabetes is characterized by two major insulin-related abnormalities: insulin resistance and cellular dysfunction. In the absence of severe physiological stress, patients with T2DM often do not require insulin therapy, both at the time of disease onset and afterwards, throughout their

lives. T2DM progresses very slowly and asymptomatically, with even mild hyperglycemia developing over years and remaining largely unrecognized as such until the onset of classic symptoms occurs. (Bandy MZ et al; 2020)

It is due to the loss of insulin discharge by the cells, which is frequently, by insulin obstruction. The body doesn't deliver or utilize insulin well. Type 2 Diabetes can create at whatever stage in life. Although, this sort of diabetes generally happens in middle-aged and older individuals. (Malode L.L et al; 2021)

Many individuals with type 2 diabetes have evidence of prediabetes (impaired glucose tolerance and/or impaired fasting sugar) before meeting the criteria for type 2 diabetes. The progression from prediabetes to overt type 2 diabetes can be reversed or slowed by medications and/or lifestyle changes that reduce hepatic glucose production or improve insulin sensitivity. (Awuchi CG *et al*;2020)

Etiology:

Genetics: T2DM has been more commonly associated with aging, obesity, family history of diabetes. It is more common in people belonging to certain racial or ethnic groups and its observed strong association with first-degree blood relatives strongly suggests the role of genetic factors in the etiology of this disease, but these factors are complex and remain largely unspecified.

Environmental factors:

Lifestyle: T2DM has is associated with people who are obese, physical inactivity, and adoption of modern lifestyles with previous GDM in women, and with pathophysiological conditions such as hypertension and dyslipidemia.

Abdominal fat: The increased body fat percentage, a feature of obesity, is such an important risk factor for T2DM that not only the total amount but also the distribution of body fat itself determines the development of insulin resistance and subsequent hyperglycemia. Increased abdominal fat or visceral obesity has been commonly associated with this type of diabetes compared to increased gluteal/subcutaneous fat or peripheral obesity. (Bandy M *et al*; 2020)

Gestational diabetes mellitus:

GDM is a form of diabetes during pregnancy which is characterized by impaired glucose tolerance as a result of maternal pancreatic cell dysfunction, leading to a lack of insulin to regulate glucose homeostasis during pregnancy. (Alejandro EU *et al*; 2020)

The term gestational diabetes was coined by Carrington in 1957, it did not gain wider acceptance until after the publications by John O'Sullivan in 1961 and 1964. (Choudhury AA;2021) (McIntyre D *et al;* 2019)

Although it can occur at any time during pregnancy, GDM generally affects pregnant women during the second and third trimesters. According to the American Diabetes Association (ADA), GDM complicates 7% of all pregnancies. Women with GDM and their offspring have an increased risk of developing type 2 diabetes mellitus in the future. (Goyal R; 2018)

While GDM usually resolves after delivery, it can have long-lasting health consequences, including an increased risk of type 2 diabetes (T2DM) and cardiovascular disease (CVD) in the mother, as well as future obesity, CVD, T2DM and/or GDM in the mother-child. This contributes to a vicious circle of obesity and diabetes between generations, affecting the health of the population as a whole. (Plows JF *et al*; 2018)

Hyperglycemia has many consequences in pregnancy and is estimated to affect about 16.9% of all pregnancies. The Asia Pacific region has the largest number of individuals with GDM. Because Asian populations are more prone to abdominal obesity and low muscle mass with increased insulin resistance compared to their Western counterparts, the Asia-Pacific region has the highest prevalence of GDM. It is associated with several short- and long-term health consequences for women and their children.

GDM is fully treatable but requires careful medical monitoring throughout pregnancy. Treatment may require blood glucose measurements, dietary changes and, in most cases, possibly insulin. Although gestational diabetes can be short-term, untreated gestational diabetes can be harmful to the health of the mother or fetus. (Awuchi CG *et al*;2020)

Etiology:

Genetics- GDM is associated with a family history of type 2 diabetes mellitus , and certain ethnicities, including Asians. (Amiri FN *et al*;2021)

Overweight or obesity- Maternal obesity is one of the most significant risk factors for GDM

Age- Women who are older than 25 are at a greater risk for developing GDM

Race- Women who are African-American, American Indian, Asian American, Hispanic or Latino, or Pacific Islander have a higher risk of GDM

PCOS- PCOS is an ovulation syndrome in women caused by hyperandrogenism, infertility, and anovulation in. ,,m, reproductive age. Women with PCOS who become pregnant are more likely to develop GDM. This increase is mainly due to obesity. As a result, insulin resistance and hyperinsulinemia are widely considered to be the most plausible explanations for the mechanisms underlying the development of PCOS. (Choudhury AA; 2021)

Complications:

All forms of diabetes increase the risk of long-term complications. These usually develop after several years (10 to 20) but may be the first symptoms in people who have otherwise not received diagnosis before that time. (Awuchi CG et al; 2020)

Poor awareness, a fatalistic attitude, and consequently delayed diagnosis, inadequate treatment, and genetic predisposition are some reasons for the high burden of complications. (Misra A et al; 2018)

Microvascular complications:

Persistent hyperglycemia in uncontrolled diabetes mellitus can cause several acute and chronic complications. Diabetes mellitus is a leading cause of cardiovascular disease (CVD), blindness, kidney failure and lower-limb amputations. Acute complications include hypoglycemia, diabetic ketoacidosis, hyperglycemic hyperosmolar state, and hyperglycemic diabetic coma. Chronic microvascular complications are nephropathy, neuropathy and retinopathy. (Goyal R; 2018)

Diabetic kidney disease: DKD, often referred to as diabetic nephropathy, is a progressive disease defined by reduced kidney function due to hyperglycemia, often associated with albuminuria. Individuals with diabetes may also have non-specific kidney disease, in which their impaired kidney function is the result of risk factors unrelated to or indirectly related to their diabetes, such as hypertension, obesity, or dyslipidemia. DKD remains the most common cause of end-stage renal disease (ESKD), which in turn is associated with increased mortality. Although kidney disease occurs in equal proportions (~30%) in individuals with

T1D and T2D, high rates of co-occurring kidney disease are risk factors in individuals with T2D (such as hypertension and obesity).

Diabetic retinopathy: Hyperglycemia can cause progressive damage to the blood vessels in the retina, which can lead to bleeding, retinal detachment, and blindness. Diabetic retinopathy can be classified as an early, more common, non-PDR form, characterized by weakened blood vessels, and a more severe, late-stage PDR form, characterized by the growth of new fragile and leaky blood vessels through the retina and into the vitreous. It is the most common complication of diabetes, with an overall prevalence in individuals with diabetes of 35%, with large variability across ethnic groups and populations around the world. The severity of diabetic retinopathy is related to the duration of diabetes, age at diagnosis, HbA1c levels, blood pressure, insulin use, and the presence of proteinuria. (Cole B.J; 2020)

Diabetic neuropathy: The progression of diabetic neuropathic complications is greatly accelerated by HG after long years. Patients with long-term diabetes can have one or more types of neuropathies.

a. Peripheral Neuropathy: Diabetic peripheral neuropathy is one of the major complications affecting patients with DM. Chronically elevated blood glucose levels and the resulting activated polyol pathway with reduced blood supply to endoneural tissue are all associated with reduced protective nitric oxide formation and Na+/K+-ATPase dysfunction. At the same time, neural cell regeneration is greatly reduced due to the inhibition of insulin-like growth factors. All of this leads to worsening of oxidative stress and acceleration of neuro degradation.

b. Autonomic Neuropathy: Diabetes and Gastrointestinal Dysfunction: Autonomic neuropathy can cause abnormal functioning of the digestive system to degenerate. Delayed gastric emptying and gastroparesis are usually found in diabetics with prolonged HG. (Lofty M et al; 2017)

Macrovascular complications : Despite the known increased risk of CVD in individuals with diabetes, the pathophysiology linking the two conditions is poorly understood. Depending on the cardiovascular event or disease (eg, coronary artery disease (CAD), myocardial infarction, heart failure, or stroke) and the diabetes subtype, people with diabetes have a two to tenfold increased risk of a cardiovascular event compared to people without diabetes. Additional risk factors include the presence of other microvascular complications, as

well as gender, age, BMI, glucose control and HbA1c levels, blood pressure, and smoking status. (Cole B.J; 2020)

The mortality burden from cardiometabolic risk factors has shifted from high-income to low- and middle-income countries. Many developing countries, particularly China and India, are experiencing rapid increases in cardiovascular disease. The leading causes of the increase in cardiometabolic disease in South Asians include unhealthy diet, high blood pressure and diabetes.

Diabetic foot: Diabetic foot ulcers are the most problematic and resource-intensive complication of diabetes in the developing world. Although diabetic foot ulcers may not be as prevalent in some ethnic groups (e.g., Asian Indians), associated complications (infection, osteomyelitis, or gangrene) are difficult to treat and may pose a risk of amputation and early mortality. Diabetic Foot ulcers can be triggered by the habit of walking barefoot, improper footwear, unsanitary conditions, and rodent bites. (Misra A et al; 2018)

Diabetic Coronary Artery Disease: Coronary artery disease (CAD), stroke, and peripheral artery disease (PAD) are common in DM, leading to a high mortality rate in diabetics. DM-induced cardiomyopathy is mainly associated with dyslipidemia and increased blood pressure. The development of extensive cardiac fibrosis associated with cardiomyopathy is further aggravated by the overproduction of oxidative free radicals that disrupt myocardial cells, resulting in dysregulation of cellular calcium homeostasis, contractile dysfunction, myocardial remodeling, and subsequent cardiomyocyte death. (Lofty M et al; 2017)

Symptoms:

The most common symptoms of diabetes are polyuria, polydipsia, polyphagia, sudden weight loss (usually type 1), weakness, obesity (usually type 2), irritability, genital thrush, partial paresis, muscle stiffness, alopecia, etc. (Islam F.M.M ;2020)

Symptoms may develop quickly (within weeks or months) in type 1 diabetes, while they usually develop much more slowly (years or decades) and may be absent or mild in type 2 diabetes. Some other symptoms of diabetes are fatigue and weight loss. Several other signs and symptoms mark the onset of diabetes, although they are not specific to diabetes. In addition to the known signs and symptoms above, they also include blurred vision, slow wound healing, itchy skin, headaches, and fatigue. Persistently high blood sugar can cause

glucose absorption in the lens of the eye, leading to changes in its shape and thus changes in vision. Long-term vision loss can also be caused by diabetic retinopathy. Numerous skin rashes that occur with diabetes are collectively referred to as diabetic dermadromes. (Awuchi C *et al*; 2020)

Dietary management:

The ultimate objective of diabetes management is the daily control of hyperglycaemia and prevention of acute and long-term complications of diabetes, including macro- and microvascular disease and other long-term diabetes-related disabilities.

Although there are many medications for the efficient management of diabetes with modest benefits, the majority of patients will eventually need insulin for the control of their diabetes, which will worsen their obesity and subsequently their diabetes. Therefore, all patients with diabetes require prompt implementation of effective non-pharmacological therapy. Medical dietary therapies, and lifestyle modifications, are some of these measures. When combined with insulin therapy, non-pharmacological measures are also helpful for the efficient management of even type 1 diabetes mellitus, especially in obese patients.

Absolute insulin insufficiency causes T1DM, thus insulin control is the mainstay of treatment. To achieve the best results, T1DM treatment should also take into account dietary changes and physical activity. A fraction of T1DM patients are obese, which raises their insulin needs and negatively impacts metabolic regulation. Therefore, even in cases of T1DM, lifestyle changes are crucial. For individuals with T2DM to achieve the best glycaemic control, nutritional treatments are crucial. The majority of T2DM patients are overweight or obese, hence weight loss by dietary energy restriction aids in the management of diabetes and obesity.

Numerous studies have demonstrated the advantages of a low-GI diet on the treatment of T2DM and its associated issues. Several studies have indicated that reduced GL diets are helpful in treating T2DM and lowering complications.

Consuming fewer calories and non-nutritive sweeteners may also aid in managing diabetes. Increasing dietary fibre consumption helps with glycemic control. Except in cases of deficits regular supplementation with vitamins, antioxidants, and trace minerals is not

advised. Diets that are hypocaloric and minimal in carbohydrates aid in T2DM controlling weight and regulation of metabolism.

According to a meta-analysis of 16 studies with follow-up periods ranging from six months to four years, MNT with diets high in protein, low in carbohydrates, and with a low GI score significantly improved glycemic control in T2DM patients. The MD was connected to the biggest drops in HbA1c (-0.47%) and overweight (-1.84 kg on average) among various kinds of MNT.

The MD is essentially a diet composed of plants, which is widely recognised for its many health advantages, particularly with regard to cancer and cardiovascular disorders. People with diabetes benefit from the MD as well. The MD includes a lot of vegetables, legumes, whole grains, fruits, and nuts, a moderate quantity of poultry and fish, a small amount of whole-fat dairy products, a moderate amount of red meat, and a low to moderate amount of wine. The MD is proven to be protective not only in healthy people but also in people with cardiovascular disease and women who have a history of gestational diabetes.

In T2DM patients, MD has been shown to help with glycaemic control, lowering insulin resistance and cardiovascular risk factors (BMI, blood pressure, cholesterol, inflammatory markers and adhesion molecules), as well as increasing liver function. (Raveendran A *et al*; 2018)

Experimental and cross-sectional research has demonstrated the advantages of eating meals sooner rather than in the late hours with regard to postprandial glycemia. It has been proven to be an easy way for improving postprandial glycaemia by altering the macronutrient content of night meals by including more protein and fat. Consuming low glycaemic index (GI) items in the morning has a stronger positive impact on glycaemic response than doing so at night. When consumed alongside carbohydrates like bread and rice, fat and protein (including amino acids) can lessen the glycemic response.

Eating the vegetables in the beginning of the meal, then followed by meat, and finally grains offers the most chances of lowering postprandial blood sugar. In order to improve glycaemic control rather than concentrating solely on a meal's nutritional content, these useful suggestions could be viewed as to help diabetics better control their blood sugar levels. (Henry CJ et al; 2020)

One of the pillars of nutrition therapy for people with type 1 diabetes is healthy eating habits. Except for those with renal impairment, there is no specific reason to adjust the protein intake. When it comes to carbs, it is best to choose high-quality sources such as whole grains, fruits, vegetables, and pulses. The total amount of carbohydrates consumed may also be in accordance with recommendations for people in general.

It is crucial to count carbohydrates since it allows for proper adjustment of insulin medication Similarly, when determining how much carbohydrates to consume, physical activity should be considered. Because sugar-containing goods may have long-term impacts on body weight management as well as glucose regulation, they should be used sparingly (sugar less than 10%).

The quantity and quality of fat consumed by diabetic patients, regardless of the type of diabetes, are in accordance with the standard guidelines. The dietary recommendations for nutritional therapy for diabetes place an emphasis on the use of unsaturated fatty acids rather than saturated (7-10 E%) and trans-unsaturated fatty acids, which should be used as little as possible because both of the main types of diabetes increase the risk of atherosclerotic vascular diseases. (Uusitupa M; 2020)

No specific food regimen is advised for type 1 diabetes. Personal preferences, socioeconomic level, cultural origins, and coexisting conditions should all be taken into account while developing a dietary strategy. The insulin-to-carbohydrate ratio can be a valuable strategy to adjust mealtime insulin dosing for ideal glycaemic results. Although low-carbohydrate and very-low-carbohydrate eating patterns have grown in popularity and can temporarily lower HbA1c levels, it's still vital to combine them with healthy dietary principles.

The elevated fat and/or protein content in the food could result in late hyperglycemia, necessitating a change in insulin dosage. Because this varies greatly among people, the first dose alterations may require post-meal glucose examinations for up to 3 hours or longer. Depending on the travel destination, it may be advisable to research the estimated carbohydrate content of local foods to support better insulin adaptation. Excessive alcohol consumption hinders cognitive function and symptom awareness, leading to decreased ability to self-control diabetes. (Holt R *et al*; 2021)

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The goals of nutrition therapy are to promote and encourage good eating patterns, meet specific nutrition needs, retain the satisfaction of food, and give individuals with the necessary knowledge for adopting appropriate eating patterns, nutrition therapy is essential to the management of diabetes. Every individual having type 2 diabetes requires a different balance of carbohydrates, proteins, and fats in their diet. As a result, individualised diets that prioritise meals with established health advantages, reduce foods with established negative effects, and take into account personal preferences are advised in order to find dietary practises that are both practical and long-lasting.

Low carbohydrate, low glycemic index, high protein diets and the Dietary Approaches to Stop Hypertension (DASH) diet all improve glycemic control, yet the impact of the Mediterranean diet appears to gives off an impression of being the best. Vegetarian eating habits have been shown to lower HbA1c but not fasting blood sugar compared to non-vegetarian eating habits. (Davies M *et al*; 2019)

Getting blood sugar levels under control as closely as feasible to its normal level is the main objective of diabetes care. Individuals living with diabetes as well as individuals who are at risk should decrease their intake of meals with sugar additions that have the potential to replace more healthy, more nutritious meal options as a way to regulate their blood sugar levels, manage their body weight, and minimise their chance for coronary artery disease and liver damage.

Initially it was thought that the solubility of fibre determined its physiological impact, recent research indicates that the viscosity or fermentability of fibre may actually be more significant. Dietary fibre consumption is linked to a reduction in diabetes-related death from all causes. A meal high in fibre is digested gradually, which encourages fullness. additionally the calories might be less that may contribute to manage obesity and reduce the chance of coronary artery disease, and type 2 diabetes.

Diabetes patients need to eat no less than half of the grains as whole grains, just as the rest of the population. Legumes, whole grain breads and cereals, whole fruits and vegetables, and other types of carbohydrates with a high fibre content (>5 g/serving) must be consumed regularly. It is noted that around 10% of people with type 1 diabetes also have celiac disease, which is significantly more common than the general population.

According to the ADA, a person with T1D can follow a gluten-free diet, but it can present additional challenges. Some common CHO-containing foods that don't contain gluten are white and sweet potatoes, brown and wild rice, corn, buckwheat, soy, quinoa, sorghum, and legumes. These foods can be used in place of other CHO-containing grains.

The objective of fat consumption (amount and type) for PWD is comparable to people with CVD but those without diabetes due to the elevated risk of CVD diabetes. Recent study data has shown that reducing saturated and trans fatty acids, the main dietary fatty acids that are associated with an increase in LDL cholesterol, lowers the likelihood of CVD.

The American Diabetes Association's 2019 Lifestyle Management: Standards of Medical Care for Diabetes recommends a diet that emphasizes elements of a Mediterranean diet high in monounsaturated and polyunsaturated fats may possibly improve glucose metabolism and reduce CVD risk and consuming foods rich in long-chain n-3 fatty acids, such as oily fish (EPA and DHA) and nuts and seeds (ALA), is recommended to prevent or treat CVD.

A recent study comparing diets higher in MUFA with CHO or PUFA showed that diets high in MUFA can improve metabolic parameters in people with T2D. Monounsaturated fats (MUFA) are typically found in vegetable oils such as olive, peanut, avocado and canola oil and remain liquid at low temperatures. Foods high in MUFA include avocado, some fatty fish, nuts, and nut butter whereas PUFA had more advantageous benefits than CHO or MUFA. Improvements in blood sugar levels, insulin sensitivity, and insulin production capability were associated with PUFA substitution.

Saturated fats are generally not recommended since they raise cholesterol levels. The risk of cardiovascular disease has been linked to diets that contain high amount of saturated fats. Unsaturated fats, should be replaced with saturated fats as they are gradually reduced in the diet. PWD should make an effort to keep their consumption of saturated fats to less than 10% of total calories.

A multivitamin-mineral supplement may be beneficial for some populations, including elderly persons, women who are pregnant or nursing, strict vegetarians or vegans, and people following very low calorie or very low carbohydrate diets. Taking some vitamin or mineral supplements in excess. (Gray A; 2019)

B12 and folic acid supplements are especially important for metformin therapy patients since metformin use for an extended period of time reduces the uptake of these vitamins. Data from clinical research has demonstrated the advantages of supplementing with chromium, vitamin D3, magnesium, and zinc in patients with type 2 diabetes to improve their lipid profiles, sensitivity to insulin, glucose metabolism, and overall metabolic management.

There are minimal information on safety and effectiveness regarding the daily consumption of vitamins and other micronutrients in the treatment of T2DM, and there are no firm guidelines for the dosage and duration of these therapies. To guarantee optimal micronutrient consumption for keeping up of a healthy lifestyle, individuals with diabetes must be informed about the need of eating nutrient-dense foods like fruits and vegetables and a well-balanced diet.

Reduced consumption of refined carbs and processed meals is indicated to have a positive effect on obesity, type 2 diabetes, and related metabolic abnormalities. Other healthy changes to culinary practise include avoiding reheating of oils, steaming instead of frying and limiting the use of processed foods altogether. (Viswanathan V *et al*; 2019)

Diet and diabetes:

Energy: It has been observed that, on average, people with diabetes consume about the same proportions of macronutrients as the general population 45% of their calories from carbohydrates, 36-40% of their calories from fat, and the remainder (16-18%) from protein. The total energy intake should be adequate to achieve weight management goals. (Evert A *et al*;2019)

Because an estimated 80% to 90% of people with type 2 diabetes are overweight or obese, strategies that include energy restriction to achieve weight loss are a primary consideration. Moderate weight loss of 5% to 10% of initial body weight can significantly improve insulin sensitivity, glycemic control, hypertension, and dyslipidemia in people with type 2 diabetes and those at risk for type 2 diabetes. Total calories should reflect weight management goals (i.e., prevent further weight gain, achieve and maintain a healthy or lower body weight over the long term, or prevent weight gain) for people with diabetes and overweight or obesity. (Sievenpiper JL *et al*; 2018)

Caloric needs should be individualized based on several factors such as age, activity level, pre-pregnancy weight, stage of pregnancy, and regular blood glucose measurements. No supplemental caloric intake is recommended during the first trimester, and approximately 300-340 kcal/day above baseline (second and third trimesters only) is considered sufficient. Although these caloric requirements are not standardized and need to be individualized, a daily caloric intake of 1500-2800 calories, not exceeding 1800 kcal/day in obese women with GDM, has been correlated with successful pregnancy outcomes.

Carbohydrate: The Research Society for the Study of Diabetes in India (RSSDI) recommends a diet high in carbohydrates (up to 45-65%), mostly low GI sources, low in fat and adequate in protein (up to 15%). The preferred carbohydrate sources are legumes, whole fruits and vegetables, which contain unrefined carbohydrates and are high in fiber. The diet plan recommends replacing saturated fats and trans fats with monounsaturated fats (MUFA) in patients with impaired glucose tolerance (IGT), diabetes and obesity. A low-carb ketogenic diet is also suggested and is preferred over a low-calorie diet. The Indian staple (dal, roti, rice and curry) is considered a mixed yet balanced diet of carbohydrates of varying GI, proteins and fats that provide satiety and adequate calories. (Viswanathan V *et al*; 2019)

Epidemiological studies have shown that the timing of carbohydrate-rich meal consumption, when earlier in the day, has protective benefits against the development of diabetes. Acute studies have reported that late-night carbohydrate consumption in particular, increased dietary carbohydrate intake resulted in a higher postmeal glucose profile the next morning. (Henry C *et al*; 2020)

Clinical trials lasting up to two years have shown that low-carbohydrate diets (where carbohydrates are replaced with total fat and saturated fat) have beneficial effects on obesity, lipids (including high-density lipoprotein (HDL) cholesterol, and triglycerides, but not had low-density lipoprotein (HDL) lipoprotein LDL cholesterol) and glucose metabolism. (Kelly T *et al*; 2020)

The Institute of Medicine (IOM) recommends 46-65 percent energy (E%) from carbohydrates and a minimum of 175 grams of carbohydrates daily to ensure adequate fetal growth and cerebral development and function. The (IOM) has not established a daily intake of added sugars that individuals should aim for, but recommends that added sugar intake be limited to no more than 25% of total energy during pregnancy. (Rasmussen L *et al* 2020)

Protein: Protein intake goals should be individualized based on current eating habits. Some research has found successful management of type 2 diabetes with diets slightly higher in protein (20-30%), which may contribute to increased feelings of fullness. Sources of lean protein with each meal (8-12 oz/day) should be included. Protein should be a supplement to vegetables, fruits, and whole grains in one meal, not the entire meal. (Gray A; 2019)

NNR recommends a protein intake of 10-20 E% for non-pregnant adult women, which equates to approximately 0.8-1.5 g protein/kg/day, based on a (Physical activity level) PAL of 1.6 at an intake of 10E% and a PAL of 1.4, at an intake of about 20 E% and in addition, There is an increased need for protein during pregnancy due to its role in the synthesis of maternal (blood, uterus and breast), fetal and placental tissues. The recommended amount of protein in the dietary management of GDM is similar to the general dietary recommendations for normal pregnancy. The IOM recommends 10-35E% protein during pregnancy and an estimated average requirement of 0.88 g/kg/day with a recommended minimum daily intake of 71 g protein. NNR recommends supplementing safe protein intake during pregnancy for healthy women who gain 13.8 kg of 0.7, 9.6, and 31.2 g/day in the first, second, and third trimesters, respectively.

Fat: The recommended amount of fat in the dietary management of GDM is similar to the general dietary recommendation for NGTP. The IOM recommends 20-35E% from fat, while NNR's recommendation is the same as for non-pregnancy; 25-40E%. High intake of fat should be avoided as it has been associated with childhood obesity, increased maternal inflammation and oxidative stress, and impaired glucose uptake into muscles. Also, a high-fat diet can cause placental dysfunction. (Rasmussen L *et al* 2020)

Because of the high risk of CVD (cardiovascular disease) in individuals diagnosed with diabetes, the dietary fat intake target (amount and type) for PWD is similar to that of people with CVD but without diabetes. Recent studies have found that reducing the amount of saturated fat and trans fat, the key dietary fatty acids associated with elevation in LDL cholesterol, reduces the risk of cardiovascular disease. The American Heart Association and the American College of Cardiology currently recommend limiting the intake of saturated and trans fats in the diet. Institute of Medicine and Academy of Nutrition and Dietetics recommendations for healthy individuals are that 20% to 35% of total calories should come from fat.

Fibre: Patients with DM should consume 20 to 35 g of fibre from raw vegetables and unprocessed grains (or about 14 g of fibre per 1,000 kcal consumed) per day (the same as the general population). Dietary fibre is defined as carbohydrates and lignin in plants that are not digested by the stomach or absorbed in the gastrointestinal tract. A high-fibre meal is processed more slowly, which promotes satiety, may contain fewer calories, and contain less added sugar, which may help fight obesity and also prevent the risk of heart disease, type 2 diabetes, and colon cancer. The FDA recommends consuming 25 g of fibre for every 2,000 calories consumed. The goal of 25g or more daily fiber intake can be difficult for some people to achieve, as large amounts of fiber can cause negative GI effects such as gas and bloating. If the person is not used to having larger amounts of fibre in their diet, it should be added slowly. (Gray A; 2019)

The American Diabetes Association recommends a minimum of 28 g of fibre to women with GDM, which is similar to IOM recommendations for normoglycemic women during pregnancy. These recommendations can be met by consuming 600g of fruit and vegetables daily with at least 300g of vegetables, with an emphasis on coarse and fibrous vegetables, and by choosing whole grain breads, pasta and rice. (Rasmussen L *et al* 2020)

Fibre may also promote insulin sensitivity through effects on the gut microbiome, short-chain fatty acid production, and other effects. (Lennerz B *et al*; 2021)

Antioxidant

Antioxidant therapy could be useful in treating DM because oxidative stress plays a role in its etiology. The effect of antioxidant therapy on the prevention or treatment of diabetes complications has been the subject of numerous studies in diabetic people and animal models of the disease.

Also, it has been demonstrated that a marked increase in endogenous prooxidant activity and a decline in antioxidants contribute to oxidative stress in diabetes. (Nasri H et al; 2015)

Vitamin E: Vitamin E is thought to play a key role in controlling hyperglycemia, and combined therapy with antioxidants is also being considered for the control and prevention of diabetic complications. Dietary vitamin and administration of vitamin E are positively associated with glucose concentration. The antioxidant property of vitamin E is associated with the prevention of hyperglycemia and minimizes the macrovascular and microvascular complications in individuals with diabetes.

Vitamin C: It is a powerful antioxidant that scavenges free radicals in water. Eriksson and Kohvakka studied the effect of vitamin C supplementation (2 g/day for 90 days) in 56 diabetics; The result has shown that the high-dose dietary supplement lowers fasting blood sugar and HbA1c levels and improves glycemic control. A population-based study found that frequent intake of vitamin C from the diet reduced the risk of type 2 diabetes. The mechanism behind the treatment of diabetes is not clear. However, it reduces microalbuminuria, erythrocyte sorbitol levels and plays a major role in improving insulin resistance in diabetics due to its antioxidant function.

Alpha-lipoic acid: A powerful antioxidant, it is also known as 1,2-dithiolane-3-pentanoic acid or thioctic acid. Alpha Lipoic Acid fights cell damage triggered by free radicals, those unstable, highly reactive molecules that are derivatives of both normal and scratched cell activity. It can restore endogenous antioxidants such as glutathione, vitamin E and vitamin C.

It is effective in many pathological conditions such as cardiovascular diseases, diabetes mellitus and liver diseases. Alpha-lipoic acid has been reported to advance glucose metabolism in patients with type 2 diabetes mellitus by directly activating lipid, tyrosine, and serine/threonine kinases in target cells due to these mechanisms, which stimulate glucose uptake and glycogenesis.

Selenium: Low-dose selenium supplementation has beneficial effects on glucose metabolism, which mimics insulin-like effects in animal models. However, while the mechanism behind insulin mimicking is not clear, the previous report showed that Se activates the key protein responsible for the insulin signaling cascade. (Rajendiran D *et al* ; 2018)

Zinc: By acting as a cofactor of the superoxide dismutase enzyme, controlling glutathione metabolism and metallothionein expression, competing with iron and copper in the cell membrane, and inhibiting the nicotinamide adenine dinucleotide phosphate-oxidase enzyme, zinc plays a significant role in antioxidant defence in type 2 diabetic patients. By lowering persistent hyperglycemia, zinc helps these individuals' oxidative stress as well. By improving the transport of glucose into cells, it does in fact stimulate the phosphorylation of insulin receptors. (Cruz KJ et al; 2015)

Carnitine: The process of converting FFA into usable energy involves L-carnitine. It moves FFA into the mitochondrial matrix where they are processed by the citric acid cycle to produce energy. Red meat, fish, dairy products, soy, nuts, and seeds all contain it. It has been intensively researched for its potential advantages in type 2 diabetes and may reduce oxidative stress.

Resveratrol: Resveratrol is a polyphenolic substance that can be found in the roots of Japanese knotweed, the skin of red grapes, pomegranates, berries, and acai (Polygonum cuspidatum). This antioxidant is also abundant in red wine. It has been demonstrated to improve cardiovascular function, and diabetes benefits may also result from its use.

Procyanidins and Cinnamon: Foods high in procyanidins include peanuts, apples, cranberries, avocados, red beans, almonds, and cinnamon. Due to its tannin concentration, cinnamon has also been suggested in Ayurvedic and Asian medicine in addition to being used as a flavouring agent in food. Several research have demonstrated the value of C.cassia for

treating diabetes. (Abdali D et al; 2015)

Functional dietary foods for diabetes:

Fundamental food sources and snacks are required by diabetics to control blood glucose levels. The food elements for diabetics ought to be high in fiber content and low in glycemic load. Snacks should be planned between two primary feast times. It aims to provide sufficient calorie consumption furthermore, dietary necessities, forestall hypoglycemia that generally happens at night, accomplish or keep up with normal weight, and control blood glucose to prevent the risk of complexities in diabetics.

Chronic illnesses, such as diabetes, cancer, and heart disease, are of great societal concern. An eating regimen that is characterised as being disproportionately heavy in fat, refined sugar, salt, and cholesterol is frequently the root cause for these chronic disorders. As the global population continues to get older, chronic disease risk is rising in older people, which is turning into a major issue.

The constant rise in life expectancy and quality, combined with the serious adverse effects brought on by medications and medicines, as well as an ageing population and an increase in the occurrence of chronic diseases, have spurred the need for producing meals that are safe and loaded with enough nutrients. Eating foods fortified with beneficial components (such as vitamins, probiotics, minerals, fibre, and antioxidants) may lower the chance of developing chronic diseases and enhance one's physical and mental health.

Over the years, functional foods have attracted a lot of research attention, particularly in the fields of nutritional health and technology. The Functional Food Centre described Functional foods as "natural or processed foods that contain biologically active compounds; which, in defined, effective, and non-toxic amounts, provide a clinically proven and documented health benefit utilising specific biomarkers for the prevention, management, or treatment of chronic disease or its symptoms," (Baker MT et al; 2022)

Functional foods are a significant area for invention since they are made to do more than just satiate appetite and supply nourishment but they also aim at preventing diseases linked to poor nutrition, improve physical and mental health, and boost the well-being of consumers. (Dantas TL et al; 2021)

Functional foods are created with one goal in mind: to offer consumers a beneficial advantage to consuming them, which can be gained through the inclusion of bioactive components. a number of the most pertinent techniques utilised to generate this class of food products include decreasing or substituting fat and salt, adding an element that lowers cholesterol, and manufacturing foods with a probiotic bacteria (Granato et al., 2020).

Consuming foods with high amylose content (>25%) and low glycemic index (GI) (55) can improve insulin sensitivity in those with diabetes mellitus, slow down the pace of glucose absorption, and regulate blood glucose, all of which lower the risk of problems. The amount of amylose starch in a sweet potato ranges from 30 to 40 percent. In vitro starch digestion may be slowed down by foods with excessive amounts of amylose. The latter will determine glycemic activity since it generates less glucose and, as a result, requires fewer amounts of insulin to turn glucose into energy. (Mappiratu K et al; 2022)

A randomized study with ten testing days among seven non diabetic subjects by Kweman NT et al; 2021 reported that after consumption of bread made from sweet potato flour and composite flour showed the lowest blood glucose response due to the high anthocyanin content. The purple sweet potato loaves were identified as low glycemic index foods that were high in fibre, included anthocyanin as the native antioxidant, and were beneficial for regulating blood sugar levels.

Another study with three to four days of interval among ten healthy subjects showed that the sweet potato that was processed into noodles lowered the GI category. he noodles also had higher potential to be a functional food because of their high total phenolic and anthocyanin content after the flour was partially gelatinized and retrograded. (Nurdjanah S et al; 2022)

A study administrating ipomoea batatas L. (white skinned sweet potato, WSSP) over a long time stated that it helped to control hyperglycemia in animal models of diabetes produced by streptozotocin or alloxan in previous research. The results of the current investigation showed that WSSP improved insulin sensitivity in skeletal muscles of normal rats, and this effect was related to components with a molecular weight of <10 kDa. Additionally, the liver's gluconeogenesis was suppressed by WSSP treatment, which was caused by components with a molecular weight of >50 kDa. So, using a variety of mechanisms, WSSP can quickly regulate blood glucose homeostasis. The beginning of

T2DM and associated consequences can be avoided by reducing postprandial hyperglycemia. This study showed the potential use of WSSP as a functional dietary material to prevent T2DM. (Kinoshita A et al; 2023)

In a randomized study twenty male rats were treated with purple sweet potato jelly and it was found that type 2 diabetic mellitus rat model could dramatically lower MDA and FBS levels when purple sweet potato jelly was fed for 14 days. As a result, purple sweet potatoes can be described as an alternate herbal remedy for the treatment of type 2 diabetes mellitus in literature. (Noviati TD et al; 219)

METHODOLOGY

III. METHODOLOGY

The methodology of the study entitled, **"Development and acceptability of antioxidant rich diabetic food products"** is discussed under the following headings:

A. Selection of Ingredients

B. Processing of flour base

C. Nutrient Analysis

D. Formulation and standardization of recipes

E. Sensory evaluation

Due ethical clearance was obtained from Institutional Human Ethics Committee, with the approval number AUW/IHEC/FSMD-22-23/XMT-11.

RESEARCH DESIGN

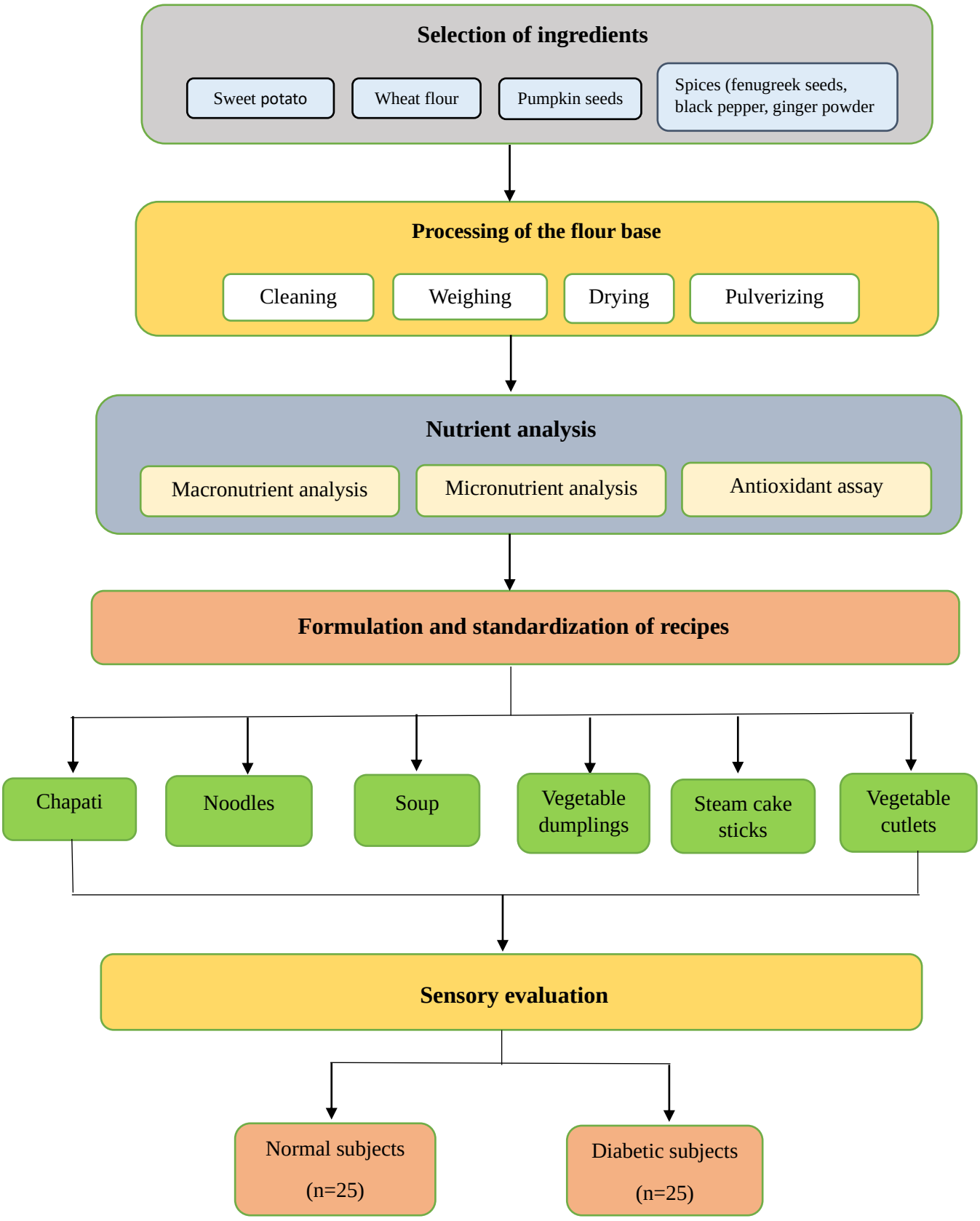


Figure I

A. SELECTION OF INGREDIENTS

Diet management is the cornerstone of diabetes and the control of blood sugar is based on the type of foods consumed during every meal time. In diabetes diet management healthy food options are crucial to keep blood sugar levels in control.

Antioxidants from food play a significant role in the management and prevention of diseases. Antioxidant therapy protects the beta-cell from oxidative stress-induced apoptosis and maintains the beta-cells functionality. According to studies, antioxidants improve insulin sensitivity. (Rajendiran D et al; 2018)

Diabetic food products using ingredients that have antioxidant activity may serve as a wholesome substitute for the management of blood sugar.

For the development of diabetic food products, a flour base was developed containing ingredients like sweet potato, wheat flour, pumpkin seeds, and spices like fenugreek seeds, black pepper and ginger powder. A short description of the ingredients used is given below.

SWEET POTATO (*Ipomoea batatas*)

Ipomoea batatas (I. batatas), commonly known as the sweet potato, is a plant belonging to the Convolvulaceae family. The sweet potato is a perennial herbaceous vine that produces edible leaves and storage roots and can grow well in marginal areas. I. batatas extract has proven to be a potent antioxidant and the presence of bioactive compounds such as flavonoids, quercetin, and polyphenols helps to suppress fat accumulation via the downregulation of the lipogenic pathway. (Naomi R *et al*; 2021)

Sweet potatoes have a lower glycaemic index therefore they tend to raise blood sugar levels relatively slow. (Chen CM *et al*; 2019)

Sweet potato flour has emerged as a crucial tool for the creation of new goods. Its essential nutrient content is important for supporting the development of major food products and can be utilized as a component in a variety of meal preparations. It has been discovered to have a significant amount of beta-carotene (Dereje B et al; 2020) Therefore sweet potato was selected as the main ingredient for the development of antioxidant rich diabetic food products.

WHEAT (*Triticum aestivum*)

Wheat flour is used as a basic ingredient in a variety of food and bakery products.

Recent evidence shows that increased intake of whole grains, such as wheat flour products that contain bran, helps reduce the incidence of type 2 diabetes, chronic diseases, cardiovascular diseases, and intestinal diseases. (Adams et al., 2020; Hu et al., 2020; Reynolds et al., 2020)

In addition, whole grain wheat can have a positive effect on blood parameters such as blood sugar and fat levels in patients with diabetes. (Nazari J et al; 2021)

Hence wheat flour was selected as an ingredient because of its nutritional properties.

PUMPKIN SEEDS (*Cucurbita maxima*)

The seeds have a high potassium content, a low sodium content, and are abundant in calcium, manganese, phosphorus, and magnesium. In addition, pumpkin seeds are a good source of trace metals like zinc, iron, and copper. Minerals with antioxidant potential, such as Zn, Cu, Mn, and Fe, operate as cofactors for essential biocatalysts that depend on antioxidants. (Dotto JM; 2020)

Since pumpkin seeds contain ingredients that lower blood sugar levels. (Syed QA et al; 2019) it was selected as an ingredient.

FENUGREEK SEEDS (*Trigonella foenum-graecum*)

An ancient herb, fenugreek is known for its culinary and therapeutic value in the Indian subcontinent. In addition, it is also rich in vitamins, minerals, and antioxidants that help protect the body's cells from damage which is caused due to unstable molecules called free radicals. (Sharma S; 2020)

Fenugreek seeds are used worldwide to treat diabetes mellitus. They are high in soluble fibers, saponins, trigonelline, diosgenin, and 4-hydroxy isoleucine. Soluble fibers such as

galactomannan found in fenugreek seeds help lower blood sugar by slowing the digestion and absorption of carbohydrates. (Ahmad U et al; 2021)
Since fenugreek seeds have a hypoglycemic effect it was selected as an ingredient.

BLACK PEPPER (*Piper nigrum*)

Black pepper (Piper nigrum) is a perennial plant that produces berry-like, pungent fruit and is a member of the Piperaceae family. Black pepper is known for its phytochemical activity as well as immune-stimulating, anti-tumorigenic, carminative, and anticholesterolemic properties. Many compounds, such as vitamins, curcumin, and other nutrients, are better absorbed when piperine is consumed. (Muhammad et al., 2017)

Black pepper contains a bioactive compound named piperine, which is the most abundant and active alkaloid in pepper and is used as a therapeutic agent because of its many health benefits. (Lee JG et al; 2020)

The extract of black pepper shows anti-diabetic activity by improving insulin levels, indicating its use in the treatment of diabetes. (Sarfraz et al., 2017) hence black pepper was selected as an ingredient.

GINGER (*Zingiber officinale*)

Ginger is the rhizome of the plant Zingiber officinale. Research has revealed that ginger possesses anti-inflammatory, antidiabetic, and anti-clotting properties. (Daily JW et al; 2015)

Ginger enhances cell survival, lowers intracellular reactive oxygen species (ROS), and promotes insulin production in pancreatic cells. Ginger inhibits the activity of nuclear factor kappa B (NF-B) and the expression of inflammatory proteins such as tumor necrosis factor (TNF-) and interleukin 6 (IL-6) in the liver. (Shidfar F et al; 2015)

Ginger shows an improvement in the HbA1c level which shows an impact on glucose control over a long period of time. (Huang FY et al; 2019) Hence ginger powder was selected for the study.

B. PROCESSING OF THE FLOUR BASE

The selected dry ingredients like wheat flour, pumpkin seeds and spices were obtained from the local market, whereas the sweet potato was obtained fresh from the vegetable market in Coimbatore, Tamil Nadu.

Cleaning

Sweet potato was cleaned thoroughly with water to remove the dust and unwanted dirt. Then it was left for air drying on the counter.

Weighing

The ingredients were weighed according to the required quantity. 570g of raw sweet potato, 100g of pumpkin seeds, and 10g each of spices such as fenugreek seeds, black pepper were weighed.

Drying

Drying is done in order to remove moisture from the materials. Drying makes the food products less likely to spoil by inhibiting microbial development and thereby extending the shelf life. The sweet potatoes were cleaned and peeled using a peeler. Then it was shredded finely and placed in the oven tray for drying. The shredded sweet potatoes were dried using an oven in the laboratory.

Pulverizing

Pulverizing is done by applying an external force to solid substances to reduce the hard and bigger materials into fine pieces. The ingredients such as sweet potato, pumpkin seeds, fenugreek seeds and black pepper were made into a fine powder by using a food processor and sieved using a 60mm mesh sieve. The powdered flours were stored in a High Density Polyethylene (HDPE) bags for further analysis and development of recipes.

C. NUTRIENT ANALYSIS

The flour base was subjected to analysis of macro and micro nutrients using standard procedures, the details of which are given in Table I.

TABLE I

METHODS FOR MACRONUTRIENTS ANALYSIS

Parameter Analysed	Method	Reference
Energy	DGHS method	FSSAI, Manual methods of Analysis,2022
Carbohydrate	High performance liquid chromatography	Bureau of Indian Standards, IS 1656:2006
Protein	Kjeldalh method	FSSAI, Manual methods of Analysis,2022
Fat	Soxhlet method	FSSAI, Manual methods of Analysis,2022
Fibre	Fibra plus method	FSSAI, Manual methods of Analysis,2022

TABLE II

METHODS OF MICRONUTRIENTS ANALYSIS

Parameter Analysed	Method	Reference
Calcium	FSSAI	Manual methods of Analysis of foods, 2022
Iron	AOAC	Official methods of Analysis – 21st edn;2019
Sodium	AOAC	Official methods of Analysis – 21st edn;2019

Potassium	AOAC	Official methods of Analysis – 21st edn;2019
Magnesium	AOAC	Official methods of Analysis – 21st edn;2019
Phosphorous (mg) Zinc (mg) B-carotene (mcg) Magnesium (mg) Vitamin A (mcg) Selenium (mcg) Copper (mg) Vitamin C (mg)	Indian Food Composition Tables	T. Longvah, R. Ananthan, K. Bhaskarachary and K. Venkaiah; 2017

ANTIOXIDANT ASSAY

Antioxidant Assay was done as sweet potatoes are rich in many antioxidant properties such as ascorbic acid, carotenoids, flavonoids, polyphenols, phenolic compounds, and vitamin E. Pumpkins' natural phenolic compounds have the potential as antioxidants such as carotenoids, polyphenols, and tocopherols which can help to avoid oxidative stress. (Tasya Z et al; 2022)

The antioxidant assay was done using two methods namely the Ferric Reducing Antioxidant Power Assay (FRAP) test and 2,2-Diphenyl-1-picrylhydrazyl (DPPH) test. The chemical 2, 2-diphenly-1-picrylhydrazl (DPPH) has been frequently utilized to assess the radical scavenging capacity of various bioactive (Nagarajaiah et al; 2021). The flour base and the developed product chapati were subjected to analysis using standard procedures which are given in the table below.

Table III

METHODS FOR ANTIOXIDANT ASSAY

Parameter Analysed	Method	Reference
Total antioxidant activity	DPPH method	Munteanu, I. G., & Apetrei, C. (2021). Analytical methods used in determining antioxidant activity: A review. International Journal of Molecular Sciences, 22(7), 3380.
Total antioxidant activity	FRAP method	Munteanu, I. G., & Apetrei, C. (2021). Analytical methods used in determining antioxidant activity: A review. International Journal of Molecular Sciences, 22(7), 3380.

D. FORMULATION AND STANDARDIZATION OF RECIPES

Six food products such as chapati, noodles, soup, vegetable dumplings, steamed cake sticks, and vegetable cutlets were developed using the ingredients such as sweet potato flour, wheat flour, pumpkin seeds flour and spices like fenugreek seeds powder, black pepper powder and ginger powder. Chapati which is a common food item and which can be consumed during meal times were developed. Noodles which is an easily prepared food item was developed. Soup is one of the most comfort foods for any individual.

Developed food products such as chapati is a regular food item. Hence, chapati was planned. Noodles were planned as it provides a hearty meal. Soup is one of the most comfort foods for any individual and it was developed using flour base. The other recipes formulated were snacks such as vegetable dumplings, steamed cake sticks, and vegetable cutlets.

The snacking pattern should serve the purpose of healthy snacking. But due to the unavailability of cost-effective and limited healthy snacking options, diabetic patients end up snacking on deep-fried items that are available. Therefore, taking everything into consideration, antioxidant rich diabetic snacks were propounded to be developed.

The term Standardization is defined as one which has been tested a number of times and has been found consistently satisfactory in quantity, quality and yield. (Hussain 2017)

A written description was followed for each recipe. Each ingredient was weighed using a weighing scale before and after preparation. The duration of preparation and the portion size were all noted down. These formulated recipes were standardized by test and trial method three times in order to get the correct consistency and yield.

E. SENSORY EVALUATION

Sensory evaluation is a scientific method to evoke, measure, analyse, and interpret responses to products as perceived through the senses of sight, smell, touch, taste, and hearing'(Kemp and Hort 2015)

Sensory evaluation was carried out to evaluate the overall acceptability, detect the presence of off-quality, and to know the consumer preference.

The most commonly used scale for evaluating the food products is called the 9-point hedonic scale which ranges from "like extremely" to "dislike extremely". (Fiorentini M *et al*; 2020)

The standardized recipes such as chapati, noodles, vegetable dumplings, soup, steam cake sticks and vegetable cutlet were given for analysis to the panelists for the acceptibilty test. The formulated product samples were given to 25 normal female subjects in the age group of 21-30 years and 25 diabetic panel members (21 females and 4 males) in the age group of 25-60 years. Purposive sampling method was used in order to select the participants. The participants were considered for the purpose of evaluation of the food products. The subjects were selected without any critical illness and complications. They were asked to give an honest independent response according to their opinions. The evaluations was carried out at both the sensory evaluation laboratory for non-diabetics and at home for diabetics.

Samples were coded with different symbols and the sample order was randomized. The attributes included appearance, colour, texture/consistency, flavour and taste. The selected subjects were given a scorecard and asked to score the product according to the attributes based on their preference. The subjects were instructed to rinse their mouth before and after the evaluation of samples. The method used for scoring the product was 9-point hedonic scale. (Raihing C & Mageshwari, SU; 2018)

Based on the scores and the overall acceptability of the product, a comparison was done for all the prepared products which were compiled, and the data were consolidated.

Plate I: Sensory evaluation

Normal subject

Diabetic subject

RESULT AND DISCUSSION

IV. RESULT AND DISCUSSION

The results of the study **"Development and acceptability of antioxidant rich diabetic food products"** is discussed under the following headings:

A. Details on the formulation of flour base

B. Standardization details of the formulated products

C. Result of the nutrient analysis

D. Details of sensory evaluation

A. DETAILS ON THE FORMULATION OF FLOUR BASE

The ingredients used for the formulation of flour base were sweet potato flour, wheat flour, pumpkin seeds, fenugreek seeds, black pepper and ginger powder.

Table IV

Type of Processing

INGREDIENTS	PROCESSING	RAW QUANTITY (in gms)	FLOUR WEIGHT (in gms)
Sweet potato	Flour	570	500
Pumpkin seeds	Flour	100	100
Fenugreek seeds	Powder	10	10
Black pepper	Powder	10	10

SWEET POTATO FLOUR

Processing information

The sweet potatoes were obtained from the market and washed thoroughly with water to remove the dirt and peel was removed manually using a peeler. The sweet potatoes were weighed and sliced at 4mm thickness. The slices were dehydrated at a low temperature

(50°C) using a laboratory scale hot air electrical oven until the slices became brittle and pulverized by using a food processor.

WHEAT

Wheat in the form of wheat flour was obtained from the market.
The wheat flour was stored in an air tight pouch until further analysis.

PUMPKIN SEEDS FLOUR

Processing information

The pumpkin seeds were obtained from the local market. The seeds were weighed and put in the mechanical grinder and pulverised for about 15-30 seconds until the seeds turned into fine flour. When the pumpkin seeds were fully powdered with a slight texture the pumpkin flour was done. The flour was sieved using a 60-size mesh to get uniform sized particles.

FENUGREEK POWDER

Processing information

Fenugreek seeds were obtained from the local market. The seeds were weighed and grounded using a mechanical grinder until the seeds were fully powdered. Using a 60-size mesh the powder was sieved well to obtain uniform size particles.

GINGER POWDER

Ginger powder was obtained from the local market and stored at room temperature until further analysis.

BLACK PEPPER POWDER

Processing information

Black pepper was obtained in the form of seeds from the local market. The seeds were weighed and grounded using a mechanical grinder until the seeds were fully powdered. Using a 60 size mesh the powder was sieved thoroughly to obtain uniform sized particles.

Processing of Sweet potato

Washing and peeling of sweet potato

Weighing

Grated (4mm thick)

Dehydrated in an oven at 50°C

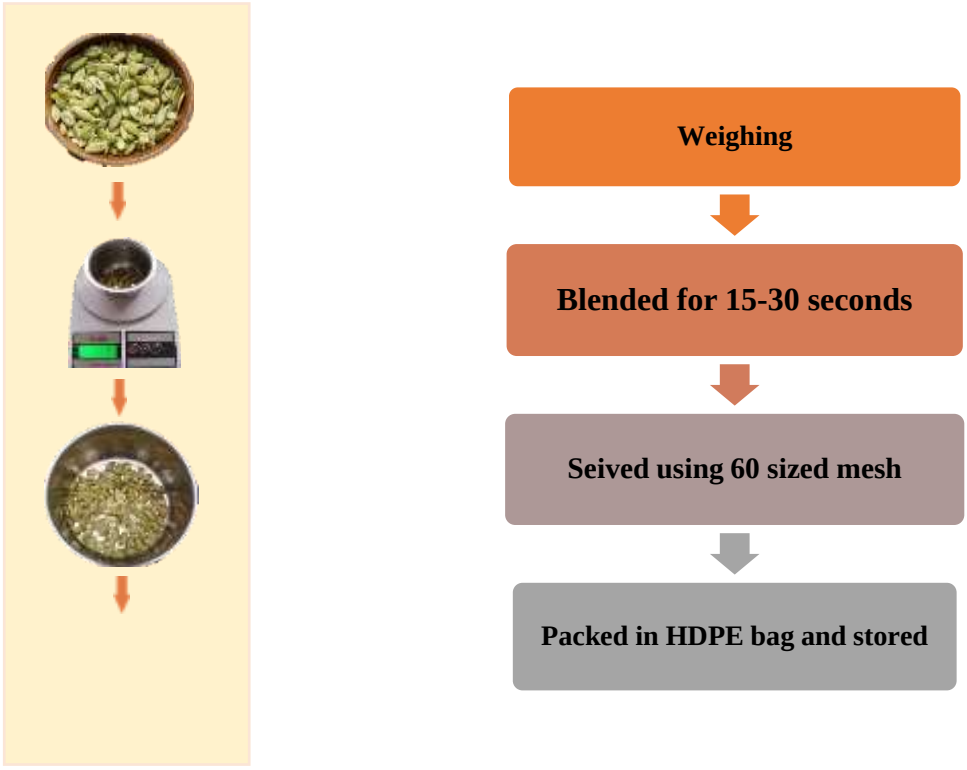
Cooling

Crushed in a food processor

Seived (60 mesh)

Flowchart of sweet potato flour formulation

Figure II



Flowchart of Pumpkin seeds flour formulation

Figure III

PROCESSING OF FENUGREEK SEEDS

Cleaning of fenugreek seeds with water

↓

Weighing

↓

Blended for 15-30 seconds

↓

Seived using 60 sized mesh

↓

Packed in HDPE bag and stored

Flowchart of Fenugreek seeds powder formulation

Figure IV

PROCESSING OF BLACK PEPPER

Cleaning of fenugreek seeds with water

↓

Weighing

↓

Blended for 15-30 seconds

↓

Seived using 60 sized mesh

Flowchart of Black pepper powder formulation

Figure V

a. Weight of flour base

The weights of the flour base are shown in the table below.

Table V

Weight of flour base

INGREDIENTS	WEIGHT OF RAW INGREDIENTS (gms)	EDIBLE PORTION (gms)	FLOUR WEIGHT	PERCENT (%)
Sweet potato	570	535	500	44
Wheat flour	-	-	500	44
Pumpkin seeds	100	100	100	9
Ginger powder	10	-	10	1
Fenugreek seeds	10	10	10	1
Black pepper	10	10	10	1

Table V shows the total weight of the flour base of each ingredient starting from the raw weight till the final obtained weight. Forty four per cent of sweet potato flour and wheat flour were used and the remaining 12 per cent was made from the other ingredients. Nine per cent was pumpkin seeds flour and the rest 3 per cent were spices such as fenugreek seeds powder, black pepper powder and ginger powder.

B. STANDARDIZATION DETAILS OF THE FORMULATED PRODUCTS

Table VI
FORMULATED PRODUCTS

The products formulated are given in table below.

Sl no.	Formulated products
1	Chapati
2	Noodles
3	Soup
4	Vegetable dumplings
5	Steamed cake sticks
6	Vegetable cutlets

The products formulated were main dish items such as chapati, noodles, soup and snacks item like vegetable dumplings, steamed cake sticks and vegetable cutlets. The products were made with antioxidant rich ingredients like sweet potato flour, wheat flour, fenugreek seeds powder, black pepper powder and ginger powder. The products were developed to provide healthy food options for diabetics that will help to keep the blood sugar levels in control.

CHAPATI

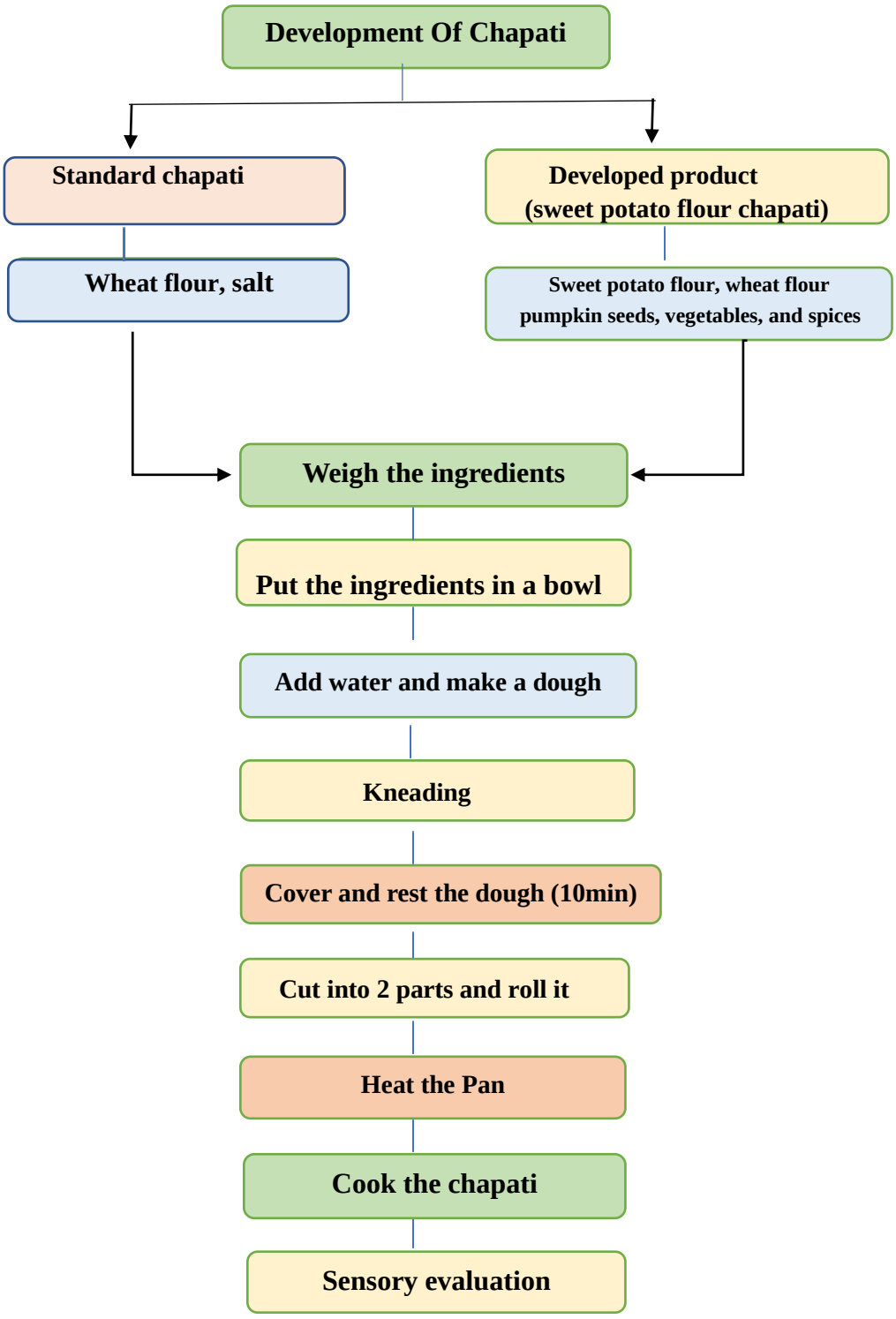
The chapati was incorporated and formulated with sweet potato flour and a standard was also formulated.

Table VII

FORMULATION OF CHAPATI

Ingredients	Quantity (in gm)	
	Standard	**Developed product**
Wheat flour	50	-
Salt	1	1
Flour base	-	58
Total	51	59
	Yield = 70g Portion per serving = 35g Total number of servings = 2	Yield = 80g Portion per serving = 40g Total number of servings = 2

The quantity of the ingredients used to make the standard and developed products is shown in Table VII. The yield for each product is listed at the bottom with the overall and per-serving quantities. A flowchart of the process used to formulate the product is located below the table.



Flow chart of chapati

Figure VI

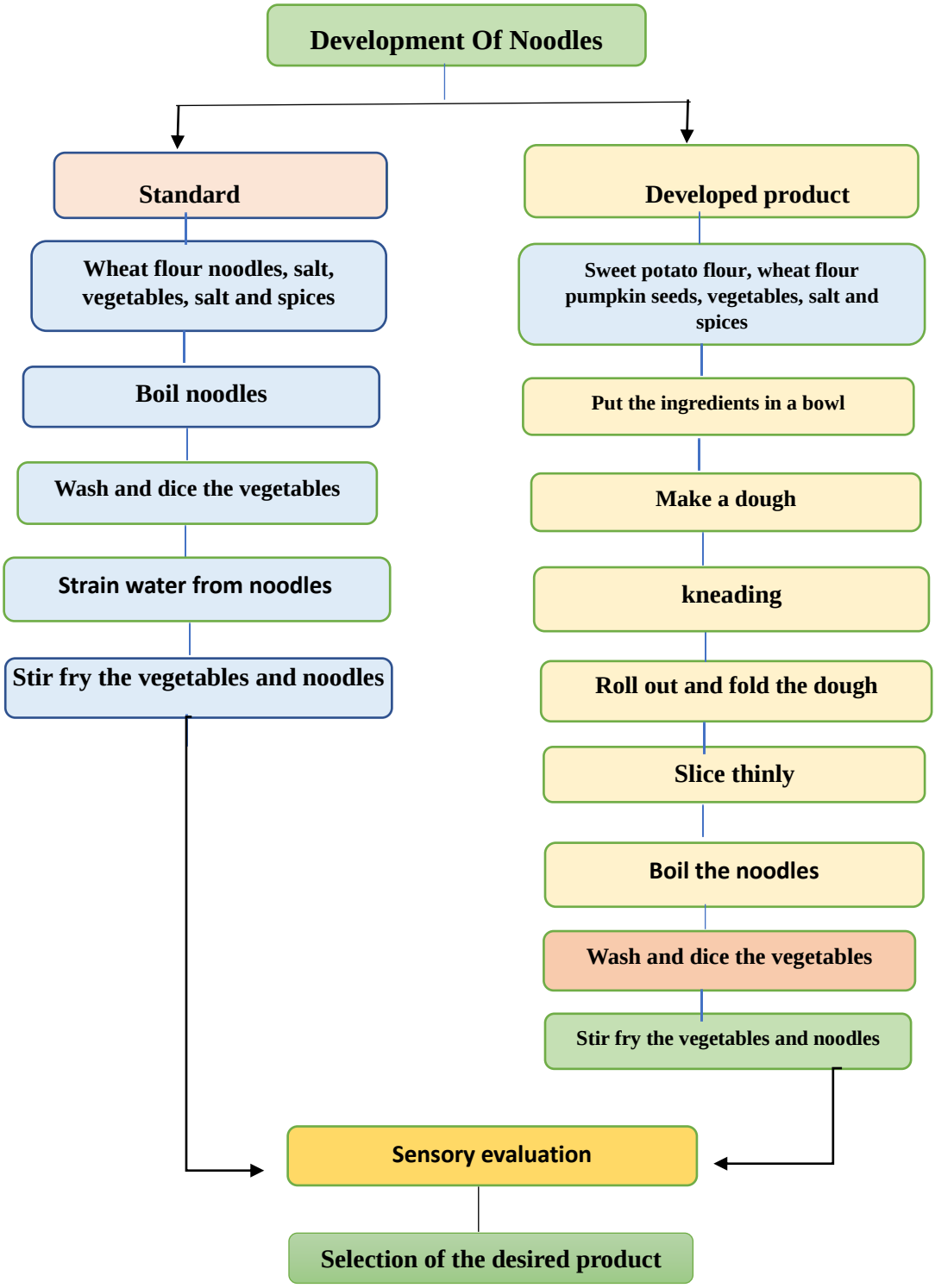
NOODLES

Table VIII

FORMULATION OF NOODLES

Ingredients	Quantity (in gm)	
	Standard	**Developed product**
Wheat flour	50	-
Salt	5	5
Oil	5	5
Flour base	-	53
Carrot	10	10
Cabbage	10	10
Capsicum	10	10
Beans	10	10
Onion	10	10
Curry leaves	5	5
Coriander leaves	5	5
Chilli powder	2	2
Total	122g	125g
	Yield = 140 g Portion per serving = 70g Total number of portions = 2	Yield = 150 g Portion per serving = 75g Total number of portions = 2

The quantity used to prepare the standard and developed products is shown in Table VIII. The yield for the products is listed at the bottom with the total quantity and serving size. A flowchart of the process used to formulate the product is located below the table.



Flow chart of noodles

Figure VII

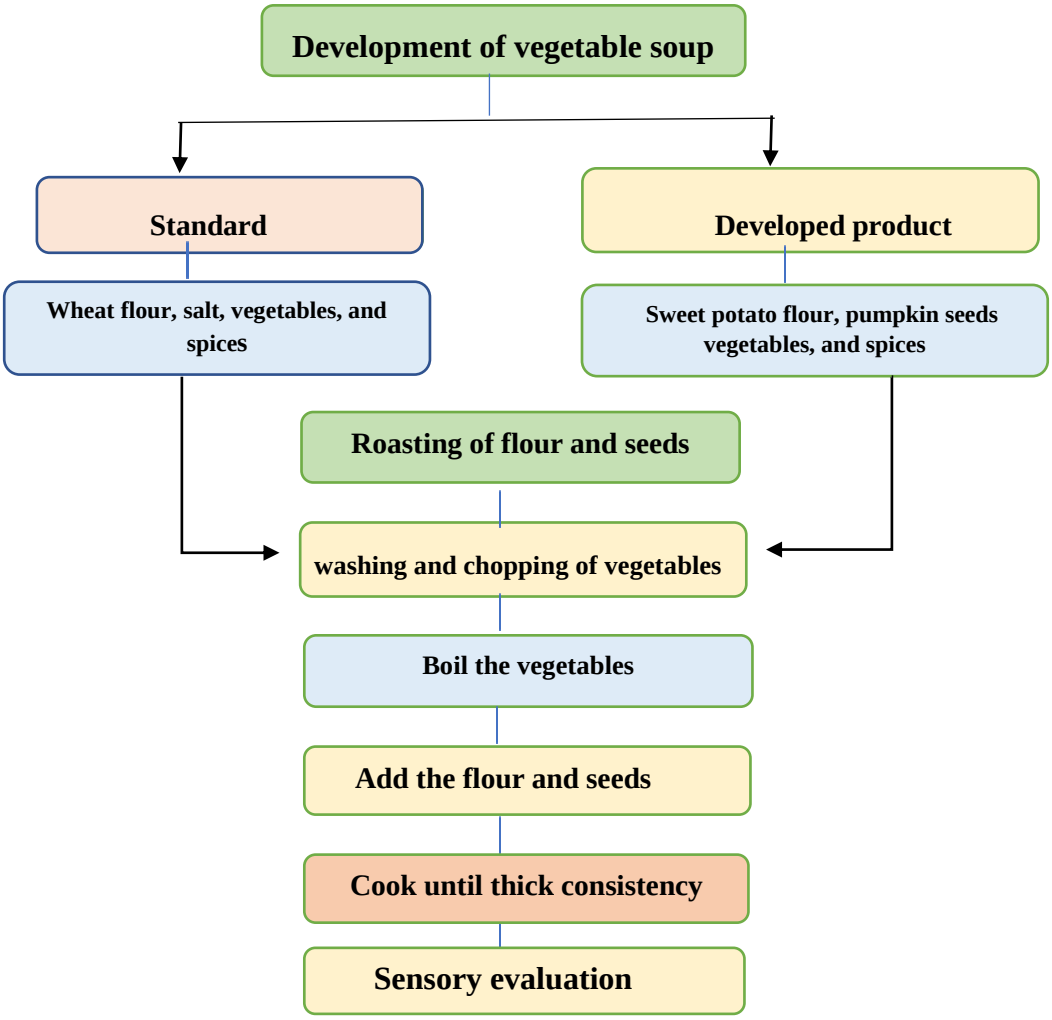
VEGETABLE SOUP

Table IX

FORMULATION OF VEGETABLE SOUP

Ingredients	**Quantity (in gm)**	
	Standard	**Developed product**
Wheat flour	25	-
salt	5	5
Flour base	-	32
Carrot	10	10
Beans	10	10
Curry leaves	3	3
Total	53	60
	Yield = 70 g Portion per serving = 35 g Total number of portions =2	Yield = 80g Portion per serving = 40g Total number of portions = 2

The quantity of the ingredients used to make the standard and developed products is shown in Table IX. The yield for each product is listed at the bottom with the overall and per-serving quantities. A flowchart of the process used to formulate the product is located below the table.



Flow chart of soup

Figure VIII

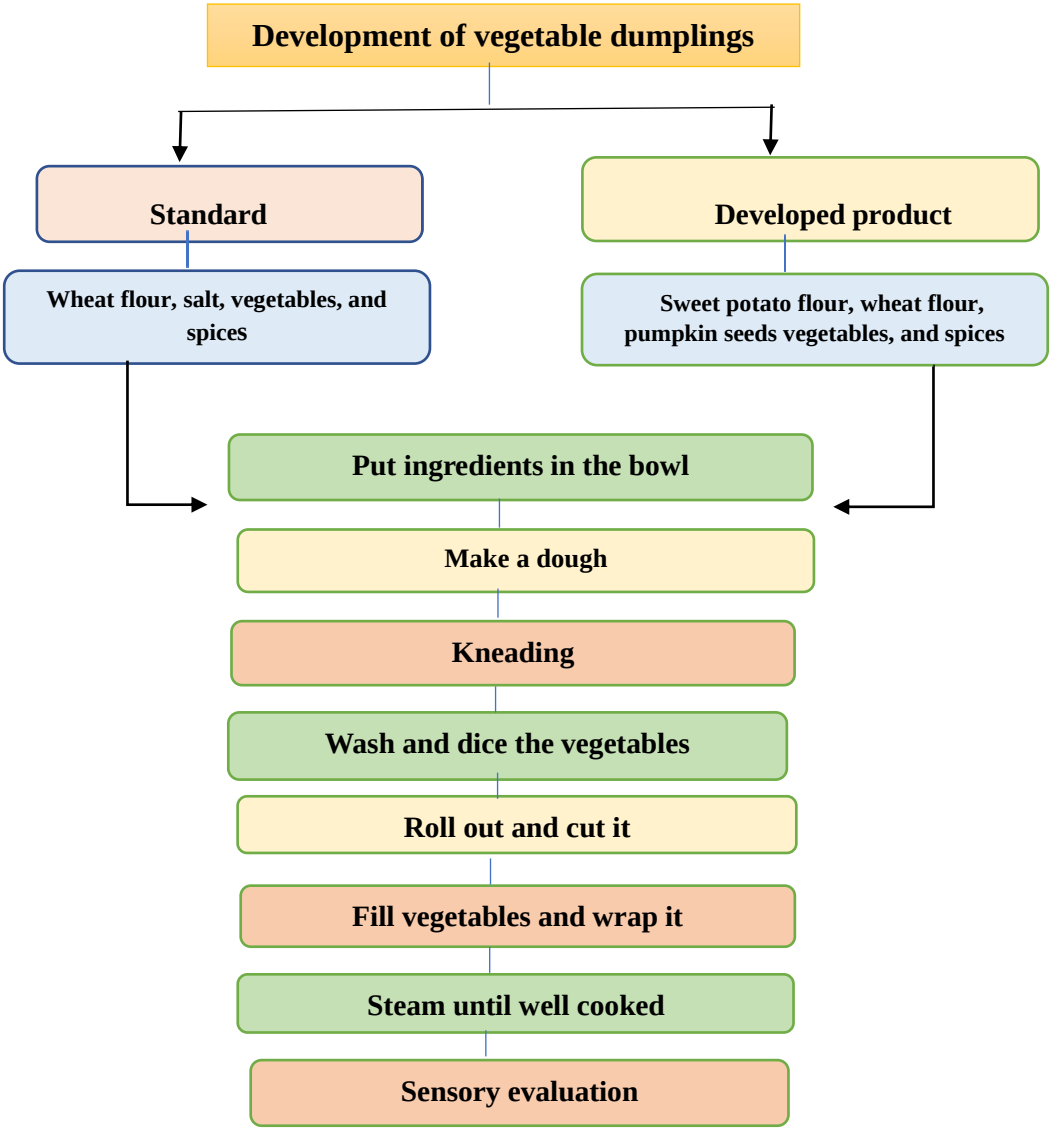
VEGETABLE DUMPLINGS

Table X

FORMULATION OF VEGETABLE DUMPLINGS

Ingredients	**Quantity (in gm)**	
	Standard	**Developed product**
Wheat flour	50	-
Salt	5	5
Oil	2	2
Flour base	-	58
Carrot	10	10
Cabbage	10	10
Beans	10	10
Onion	10	10
Total	97 g	105g
	Yield = 120g Portion per serving = 60g Total number of portions = 2	Yield = 140g Portion per serving = 70g Total number of portions =2

The quantity of the ingredients used to make the standard and developed products is shown in Table X. The yield for each product is listed at the bottom with the overall and per-serving quantities. A flowchart of the process used to formulate the product is located below the table.



Flowchart vegetable dumplings

Figure IX

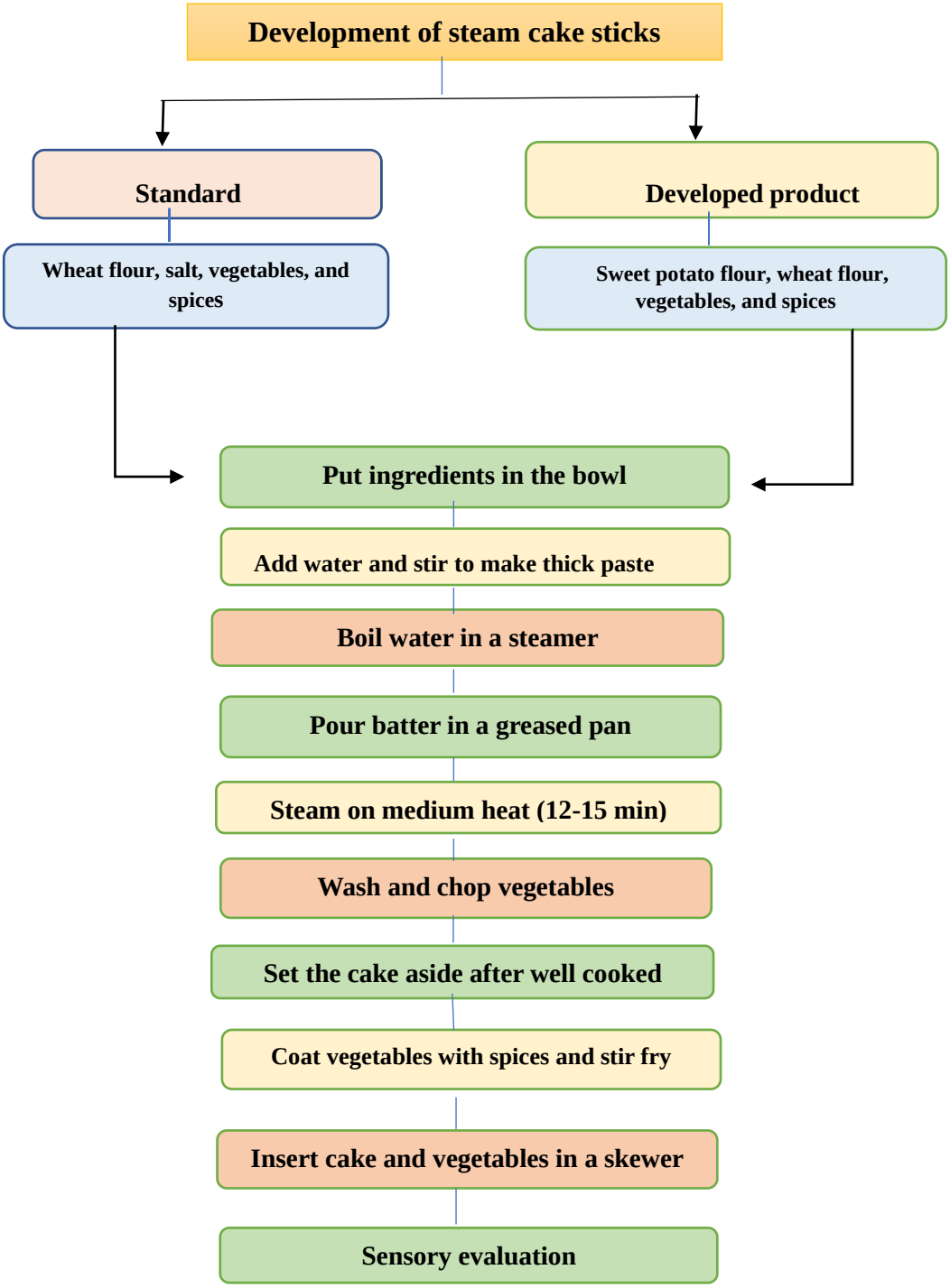
STEAM CAKE STICKS

Table XI

FORMULATION OF STEAM CAKE STICKS

Ingredients	Quantity (in gm)	
	Standard	**Developed product**
Wheat flour	50	-
Salt	5	5
Oil	5	5
Flour base	-	53
Capsicum	10	10
Tomato	10	10
Onion	10	10
Curry leaves	5	5
Green chilli	5	5
Garam masala	5	5
Turmeric powder	2	2
Lemon juice	2	2
Baking soda	1	1
Asefoidata	2	2
Total	112	115g
	Yield = 135g Portion per serving = 45g Total number of portions = 3	Yield = 140g Portion per serving = 47 g Total number of portions = 3

The quantity of the ingredients used to make the standard and developed products is shown in Table XI. The yield for each product is listed at the bottom with the overall and per-serving quantities. A flowchart of the process used to formulate the product is located below the table.



Flowchart of steam cake sticks
Figure X

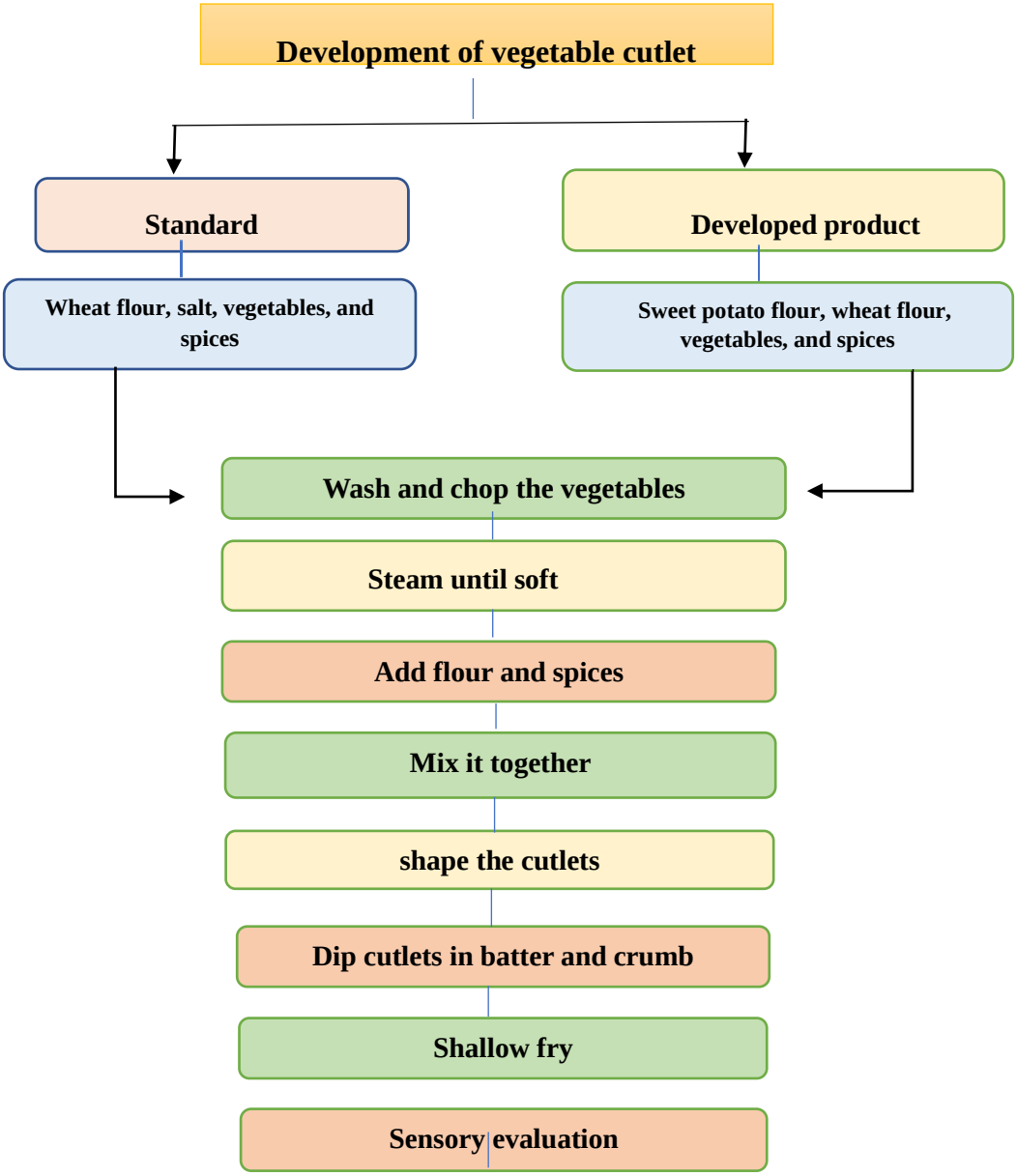
VEGETABLE CUTLET

Table XII

FORMULATION OF VEGETABLE CUTLET

Ingredients	Quantity (in gm)	
	Standard	**Developed product**
Wheat flour	50	-
salt	5	5
Oil	10	10
Flour base	-	53
Red Flat rice(poha)	5	5
Carrot	10	10
Capsicum	10	10
French beans	10	10
Cauliflower	10	10
Onion	5	5
Green chilli	2	2
Curry leaves	5	5
Cumin seeds	1	1
Mustard seeds	1	1
Fennel seeds	1	1
Total	125g	128g
	Yield = 140g Portion per serving = 35g Total number of portions = 4	Yield = 145g Portion per serving = 35g Total number of portions = 4

The quantity of the ingredients used to make the standard and developed products is shown in Table XII. The yield for each product is listed at the bottom with the overall and per-serving quantities. A flowchart of the process used to formulate the product is located below the table.



Flowchart of vegetable cutlet

Figure XI

DEVELOPMENT OF CHAPATI

The plates for development of chapati is given below.

PLATE II: STANDARD

PLATE III: DEVELOPED PRODUCT

The chapati was standardized three times each for both standard and developed product. On the plates above, the left side displays the ingredients used to develop the chapatis, and the right side displays the finished product. The standard product is shown on Plate II, while the developed product is shown on Plate III. The developed product yielded 80g for 2 servings which gave 40g per serving whereas the yield for standard product was 70g which gave 35g per serving.

DEVELOPMENT OF NOODLES

The plates for development of noodles is given below.

PLATE IV: STANDARD

PLATE V: DEVELOPED PRODUCT

For both the standard and developed products, the noodles were standardised three times each. Plate IV displays the ingredients needed for the preparation of standard noodles along with the standardised recipe. While plate V displays the ingredients used for the preparation of the noodles along with the developed product in the right, The developed noodles had a yield of 150g which gave 75g for 2 servings and the standard noodles yielded 140 g for 2 servings, which gives 70 g per serving.

DEVELOPMENT OF SOUP

The plates for development of soup is given below.

PLATE VI: STANDARD

Plate VII: DEVELOPED PRODUCT

Plate VI displays the ingredients needed for the preparation of standard noodles along with the standardised recipe. While plate VII displays the ingredients used for the preparation of the noodles along with the developed product on the right. The product was standardised three times, and each time the standard yielded 70g for 2 servings which gave 35g per serving whereas the developed product's yield was 80g for 2 serving, giving 40g per serving.

DEVELOPMENT OF VEGETABLE DUMPLINGS

The plates for development of vegetable dumplings are given below.

PLATE VIII: STANDARD

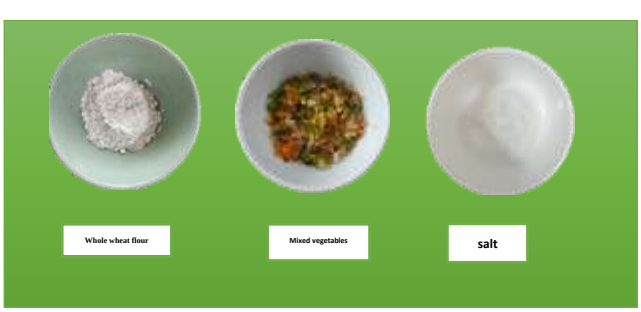


Plate IX: DEVELOPED PRODUCT

Plate VIII shows the ingredients used for preparing the standard product whereas, Plate IX shows a list of the ingredients used for preparing developed product on the left side and the finished product on the right. The product was standardised three times, and each time the standard yielded 120g for 2 servings which gives 60g per portion while the developed product's yield was 140g for 2 servings, giving 70g per serving.

DEVELOPMENT OF STEAM CAKE STICKS

The plates for development of steam cake sticks is given below**.**

PLATE X: STANDARD

PLATE XI: DEVELOPED PRODUCT

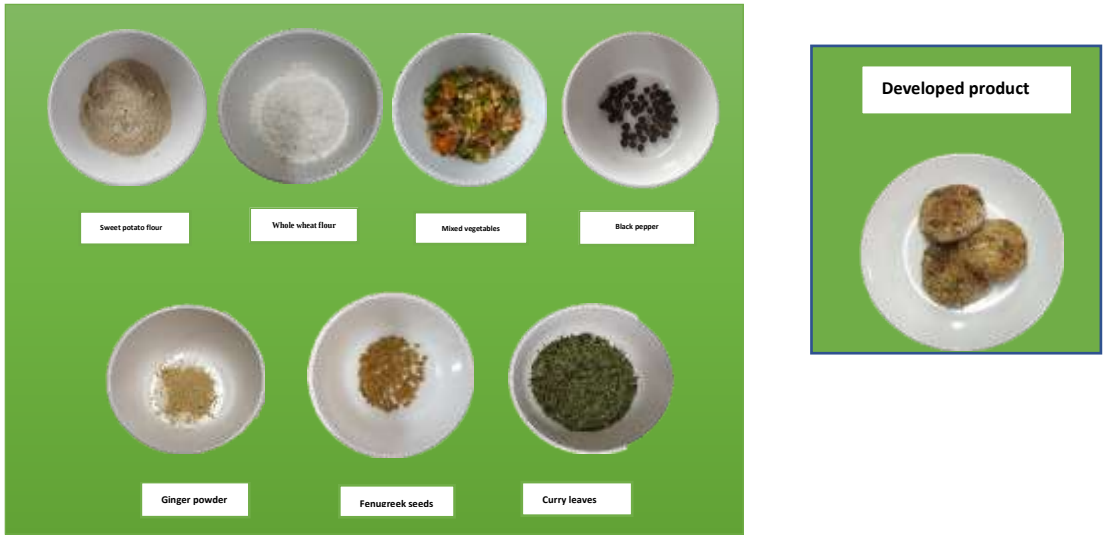
Plate X emphasises a list of the ingredients used for the standard product on the left side and the finished product on the right. Plate XI shows the ingredients required for the developed product on the left side and the finished product on the right side. The product was standardised three times; each time, the standard yielded 135g for 3 servings, that gives 45g per portion and the developed product yielded 140g which gave 47g for 3 servings.

DEVELOPMENT OF VEGETABLE CUTLETS

The plates for development of vegetable cutlets is given below.

PLATE XII: STANDARD

PLATE XIII: DEVELOPED PRODUCT



The product was standardised three times. Plate XII shows a list of the ingredients used for making standard on the left side and the created product on the right. Plate XIII shows the list of ingredients required for the developed product along with the ingredients used to prepare it. Each time, the standard product yielded 140g which gave 35g and developed product yielded 145g for 4 servings which gives 36 g per serving.

C. RESULT OF THE NUTRIENT ANALYSIS

The nutrient analysis was carried out to approximately calculate the macronutrients and minerals present in the developed food products.

Table XIII

MACRONUTRIENT OF CHAPATI

Nutrients (per 100g)	Standard product*	Developed product
Calorific value (%)	274.08	299.94
Carbohydrates (%)	55.73	58.8
Protein (%)	9.19	9.75
Fat (%)	1.60	2.86
Fibre (%)	0.79	1.42

*reference values (Sachanarula S *et al*; 2022)

Table XIII shows the macronutrient content of 100g of developed product chapati. The macronutrients analysed for the developed product namely chapati shows that except for fat and fibre the values for energy, carbohydrate and protein were quite similar for the standard and developed products.

Fat was known to the level of 2.86% in the developed product which can probably be attributed to the presence of pumpkin seeds and also sweet potato flour. But on the contrary, fibre percentage had improved in the developed product making it ideal for diabetes. The standard had 0.79% whereas the developed product chapati has 1.42%.

Table XIV

MICRONUTRIENT OF CHAPATI

Nutrients (per mg/100g)	Standard product*	Developed product
Calcium	35.0	56
Iron	7.92	0.1
Sodium	12.1	394
Potassium	244	399
Magnesium	86.2	68

*reference values (Nagarajaiah SB *et al*; 2021)

Table XIV shows the micronutrient content of 100g of developed product chapati. The micronutrients analysed for the developed product namely chapati shows that the values for calcium, sodium and potassium were quite high in developed product whereas the iron and magnesium content of the developed products decreased as compared to the standard product. The calcium and potassium content had improved in the developed product which can be probably attributed to the presence of sweet potato flour and pumpkin seeds making it ideal for diabetes.

TABLE XV

NUTRIENT COMPOSITION OF SELECTED INGREDIENTS

INGREDIENTS	QUANTITY (gms)	Phosphorous (mg)	Zinc (mg)	B-carotene (mcg)	Magnesium (mg)	Vitamin A (mcg)	Selenium (mcg)	Copper (mg)	Vitamin C (mg)
Sweet potato flour	25	9.4	-	2.78	5.26	0.46	-	-	5.55
Wheat flour	25	78.75	0.71	0.67	31.25	0.11	13.28	0.12	-
Pumpkin seeds	5	58.7	0.38	0.25	27.5	0.04	0.47	0.06	0.09
Ginger powder	1	0.44	0	0.89	0.55	0.15	-	0	0.05
Fenugreek seeds	1	4.35	0.041	1.42	1.67	0.24	0.1	0.01	-
Black pepper powder	1	1.44	0.01	7.67	1.96	1.28	0.12	0.02	-

The nutritive value of the selected ingredients such as sweet potato flour, wheat flour, pumpkin seeds, and spices like ginger powder, fenugreek seeds and black pepper powder were computed using the Indian Food Composition Table (IFCT, 2017). The nutritive value of each ingredient is given in the table above.

ANTIOXIDANT ASSAY OF THE FOOD PRODUCTS

Analysis of natural product antioxidant activity is the basis for consumer recommendations of foods with high antioxidant activity (Xu et al; 2017). The antioxidant activity of the samples was determined using 2, 2-Diphenyl-1-picrylhy drazyl (DPPH) assay and Ferric Reducing Antioxidant Power Assay (FRAP) test.

TABLE XVI

ANTIOXIDANT ACTIVITY

DPPH ASSAY OF FLOUR BASE		**DPPH ASSAY OF DEVELOPED CHAPATI**		**FRAP ASSAY OF DEVELOPED CHAPATI* (mg/g)**
Concentration (µl)	**% Inhibition**	**Concentration (µl)**	**% Inhibition**	
10	54.10	10	54.10	715.28
50	50.82	50	59.02	
150	49.18	150	63.11	
250	43.44	250	63.93	
350	36.89	350	65.57	
500	32.79	500	67.21	
750	24.59	750	67.21	

*reference values (Nagarajaiah SB *et al*; 2021)

The above tables show the DPPH percentage inhibition of the sample at a concentration of 2.01 for the flour base and 0.8mg/ml H2O for chapati. The concentration of the solution depends solely on the sample. As the concentration of the flour base increased the inhibition rate decreased whereas, when the concentration of the developed product increased the inhibition rate also increased gradually. It is clear that the developed product chapatis has a

remarkable antioxidant activity. Thus, it can be concluded that the developed product chapati has a greater antioxidant activity when compared to the flour base.

The FRAP (Ferric Reducing Antioxidant Power) Assay was done for the developed product chapati. The antioxidant content analyzed shows that the developed product had a remarkable antioxidant activity when compared to the standard reference value. The standard had 08.50 mg whereas the developed product chapati has 715.28 mg. This is likely due to the inclusion of pumpkin seeds and sweet potato flour as they possess great antioxidant potential.

D. DETAILS OF SENSORY EVALUATION

Sensory evaluation of Chapati

The organoleptic characteristics of chapati is given in tables below

Table XVII

Mean acceptability scores of standard chapati

The mean acceptability scores of standard chapati is given in table below

SENSORY CHARACTERISTICS	MEAN SCORES	
	NORMAL SUBJECTS (n=25)	DIABETIC SUBJECTS (n=25)
APPEARANCE	7.24 ± 0.72	8 ± 0.70
TEXTURE	8 ± 0.70	7.52 ± 0.82
TASTE	8.08±0.75	8 ±0.70
FLAVOUR	7.96 ± 0.78	8.24 ± 0.72
COLOUR	7.66±0.89	8.52±0.65
OVERALL ACCEPTABILITY	**7.78 ± 0.41**	**8.05 ± 0.33**
ṭ-value	**50.457**	**48.904**
p-value	**<0.0001**	**<0.0001**

*** <0.005 significant at 5% level**

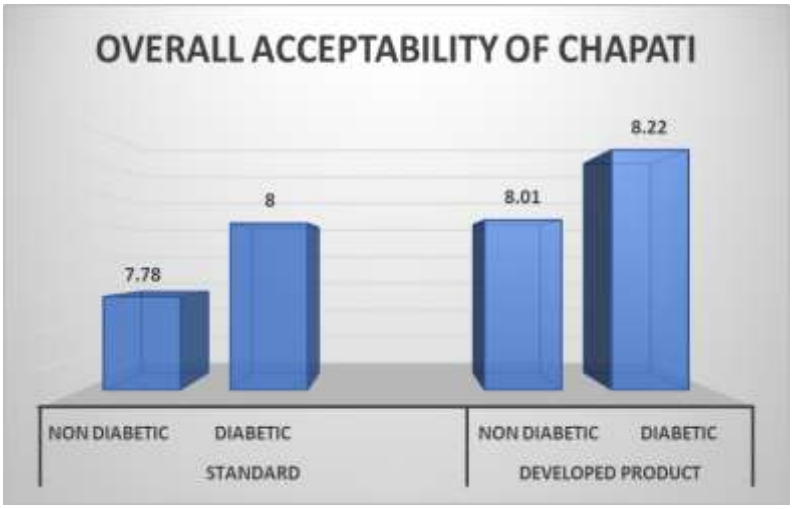
Table XVIII

Mean acceptability scores of developed chapati

The mean acceptability scores of developed chapati is given in table below

SENSORY CHARACTERISTICS	MEAN SCORES	
	NORMAL SUBJECTS (n=25)	DIABETIC SUBJECTS (n=25)
APPEARANCE	8.04 ± 0.97	8.08 ± 0.70
TEXTURE	7.88 ± 0.72	7.96 ± 0.78
TASTE	7.88 ± 0.92	8.16 ±0.74
FLAVOUR	8.12 ± 0.78	8.56 ± 0.65
COLOUR	8.16 ± 0.8	8.36±0.81
OVERALL ACCEPTABILITY	**8.01 ± 0.43**	**8.22 ± 0.48**
t-value	**136.355**	**77.379**
p-value	**<0.0001**	**<0.0001**

*** <0.005 significant at 5% level**



Overall acceptability of chapati

Figure XII

The normal subjects gave standard chapati a good taste rating (8.08), whereas the diabetic subjects gave the colour a high rating (8.52). The diabetes subjects gave the least score for texture (7.52). while the normal subjects gave the least score for appearance (7.24).

For the developed product, normal subjects and diabetic subjects gave the flavour the highest rating (8.12) and (8.56) respectively. The normal subjects gave both texture the lowest scores (7.88), whereas diabetics gave texture the lowest score (7.96).

The t-value of standard product chapati for normal subjects is 50.457 whereas for diabetic subjects is 48.904 and (p-value <0.05) which is considered to be statistically significant and that there is a difference in the acceptance levels between the two samples.

The t-value of developed product chapati for normal subjects is 136.355 whereas for diabetics subjects is 77.379 and (p-value <0.05) which is considered to be statistically significant and that there is a difference in the acceptance levels between the two samples.

Table XIX

Mean acceptability scores of standard product noodles

The mean acceptability scores of standard product noodles is given in table below

SENSORY CHARACTERISTICS	MEAN SCORES	
	NORMAL SUBJECTS (n=25)	DIABETIC SUBJECTS (n=25)
APPEARANCE	7.84 ± 0.68	7.44 ± 1.04
TEXTURE	7.92 ± 0.75	8.04 ± 0.67
TASTE	7.32 ± 1.02	7.68 ± 0.85
FLAVOUR	7.12 ± 0.97	7.2 ± 0.76
COLOUR	8 ± 0.87	8.08 ± 0.70
OVERALL ACCEPTABILITY	**7.64 ± 0.44**	**7.68 ± 0.50**
t value	**43.364**	**45.252**
P value	**< 0.0001**	**< 0.0001**

*** <0.005 significant at 5% level**

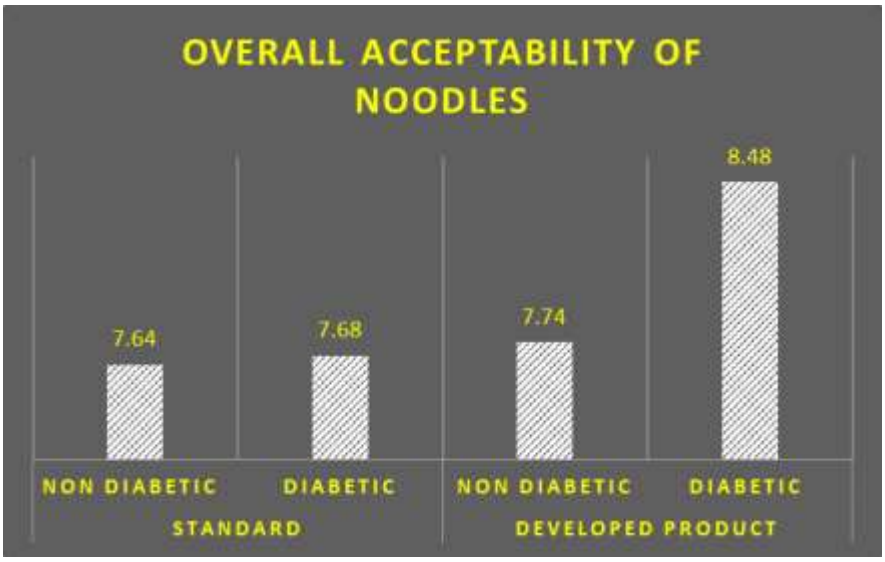
Table XX

Mean acceptability scores of developed product noodles

The mean acceptability scores of developed product noodles is given in table below

SENSORY CHARACTERISTICS	MEAN SCORES	
	NORMAL SUBJECTS (n=25)	DIABETIC SUBJECTS (n=25)
APPEARANCE	7.48 ± 0.82	8.32 ± 0.80
TEXTURE	7.88 ± 0.66	8.52 ± 0.71
TASTE	8 ± 0.57	8.68 ± 0.47
FLAVOUR	8.08 ± 0.70	8.52 ± 0.71
OVERALL ACCEPTABILITY	**7.74 ± 0.39**	**8.48 ± 0.49**
t-value	**49.888**	**107.600**
p-value	**<0.0001**	**<0.0001**

*** <0.005 significant at 5% level**



Overall acceptability of noodles

Figure XIII

The mean acceptability score of noodles are displayed in Table XIX and XX. For standard product both the normal and diabetic subjects gave colour a high score (8 and 8.08) respectively and the lowest rating was given for flavour by both normal and diabetic subjects (7.12) and (7.2) respectively.

For the developed product the normal subjects rated flavour with the highest score (8.08), while the diabetics rated taste with the highest score (8.68). Color received the lowest scores from both normal and diabetic subjects (7.28) and (8.24) respectively.

The t-value of standard product noodles for normal subjects is 43.364 whereas for diabetic subjects is 45.252 and (p-value <0.05) which is considered to be statistically significant and that there is a difference in the acceptance levels between the two samples.

The t-value of developed product noodles for normal subjects is 49.888 whereas for diabetics is 107.600 and (p-value <0.05) which is considered to be statistically significant and that there is a difference in the acceptance levels between the two samples.

Table XXIII
Mean acceptability scores of standard product Soup

The mean acceptability score of standard product soup is given in the table below

SENSORY CHARACTERISTICS	MEAN SCORES	
	NORMAL SUBJECTS (n=25)	DIABETIC SUBJECTS (n=25)
APPEARANCE	7.36 ± 0.86	7.92 ± 0.64
TEXTURE	7.56 ± 0.86	8 ± 0.64
TASTE	6.72 ± 1.02	7.36 ± 0.95
FLAVOUR	6.96 ± 0.78	7.04 ± 0.84
COLOUR	7.2 ± 0.95	7.68 ±0.74
OVERALL ACCEPTABILITY	**7.16 ± 0.59**	**7.6 ± 0.43**
t-value	**48.539**	**42.485**
p-value	**< 0.0001**	**< 0.0001**

*** <0.005 significant at 5% level**

Table XXIV

Mean acceptability scores of developed product soup

The mean acceptability score of developed product soup is given in the table below

SENSORY CHARACTERISTICS	MEAN SCORES	
	NORMAL SUBJECTS (n=25)	DIABETIC SUBJECTS (n=25)
APPEARANCE	7.2 ± 0.95	8.36 ± 0.63
TEXTURE	7.68 ± 0.74	8.4 ± 0.64
TASTE	6.76 ± 1.12	8.56 ±0.65
FLAVOUR	6.92 ± 0.86	8.6 ± 0.57
COLOUR	7.52 ±0.82	8.64±0.63
OVERALL ACCEPTABILITY	**7.21 ± 0.50**	**8.51 ± 0.38**
ţ-value	**41.540**	**152.781**
p-value	**<0.0001**	**<0.0001**

*** <0.005 significant at 5% level**

Overall acceptability of soup

Figure XV

Table XXIII and XIV shows the mean acceptability scores of soup. For standard product the normal subjects rated texture a high score (7.56) and the diabetic subjects gave the colour a high rating (7.52). The lowest rating was given for taste (6.72) by normal subjects and diabetic subjects rated the lowest score for flavour (7.04).

For the developed product the normal subjects rated texture with the highest score (7.68), while the diabetics rated colour with the highest score (8.64). Taste received the lowest scores from normal subjects (6.76) and appearance received the lowest rating from the diabetic subjects (8.36)

The t-value of standard product soup for normal subjects is 448.539 whereas for diabetics is 42.485 and (p-value <0.05) which is considered to be statistically significant and that there is a difference in the acceptance levels between the two samples.

The t-value of developed product soup for normal subjects is 41.540 whereas for diabetics is 152.781 and (p-value <0.05) which is considered to be statistically significant and that there is a difference in the acceptance levels between the two samples.

Table XXI

Mean acceptability scores of standard Vegetable dumplings

The mean acceptability scores of standard vegetable dumplings is given in table below

SENSORY CHARACTERISTICS	MEAN SCORES	
	NORMAL SUBJECTS (n=25)	DIABETIC SUBJECTS (n=25)
APPEARANCE	8.4 ± 0.5	7.2 ± 0.76
TEXTURE	8.2 ± 0.70	7.36 ± 0.95
TASTE	8.12 ± 0.78	7.28 ± 0.93
FLAVOUR	8.08 ± 0.75	7.16 ± 0.89
COLOUR	8.2 ± 0.70	7.52 ± 0.82
OVERALL ACCEPTABILITY	**8.2 ± 0.38**	**7.30 ± 0.40**
t-value	**182.147**	**114.125**
p-value	**< 0.0001**	**< 0.0001**

*** <0.005 significant at 5% level**

Table XXII

Mean acceptability scores of developed Vegetable dumplings

The mean acceptability scores of developed Vegetable dumpling is given in table below

SENSORY CHARACTERISTICS	MEAN SCORES	
	NORMAL SUBJECTS (n=25)	DIABETIC SUBJECTS (n=25)
APPEARANCE	7.68 ± 0.96	8.24 ± 0.72
TEXTURE	7.72 ± 0.61	8.04 ± 0.78
TASTE	7 ± 1	7.96 ± 0.84
FLAVOUR	7.88 ± 0.6	7.84 ± 0.74
COLOUR	7.16 ± 0.89	8.04 ± 0.61
OVERALL ACCEPTABILITY	**7.48 ± 0.39**	**8.02 ± 0.52**
ṭ-value	**43.594**	**122.996**
p-value	**<0.0001**	**<0.0001**

*** <0.005 significant at 5% level**

Overall acceptability of vegetable dumplings

Figure XIV

Table XXI and XXII displays the mean acceptability scores for vegetable dumplings. For standard product the normal subjects gave appearance a high score (8.4) and the diabetic subjects gave the colour a high rating (7.52). The lowest rating was given for flavour by both normal and diabetic subjects (8.08) and (7.16) respectively.

For the developed product the normal subjects rated flavour with the highest score (7.88), while the diabetics rated appearance with the highest score (8.24). Taste received the lowest scores from normal subjects (7.28) and flavour received the lowest rating from the diabetic subjects (7.88)

The t-value of standard product vegetable dumplings for normal subjects is 182.147 whereas for diabetic subjects is 114.125 and (p-value <0.05) which is considered to be statistically significant and that there is a difference in the acceptance levels between the two samples.

The t-value of developed product vegetable dumplings for normal subjects is 43.594 whereas for diabetic subjects is 122.996 and (p-value <0.05) which is considered to be statistically significant and that there is a difference in the acceptance levels between the two samples.

Table XXV
Mean acceptability of standard product steam cake sticks

The mean acceptability score of standard product steam cake sticks is given in the table below

SENSORY CHARACTERISTICS	MEAN SCORES	
	NORMAL SUBJECTS (n=25)	DIABETIC SUBJECTS (n=25)
APPEARANCE	8.16 ± 0.86	7.56 ± 0.71
TEXTURE	7.88 ± 0.86	8.16 ± 0.62
TASTE	8.12 ± 1.02	7.8 ± 0.76
FLAVOUR	7.88 ± 0.78	7.52 ± 0.65
COLOUR	8.04 ± 0.95	8.36 ± 0.7
OVERALL ACCEPTABILITY	**8.01 ± 0.59**	**7.88 ± 0.44**
t-value	**136.355**	**47.640**
P-value	**< 0.0001**	**< 0.0001**

*** <0.005 significant at 5% level**

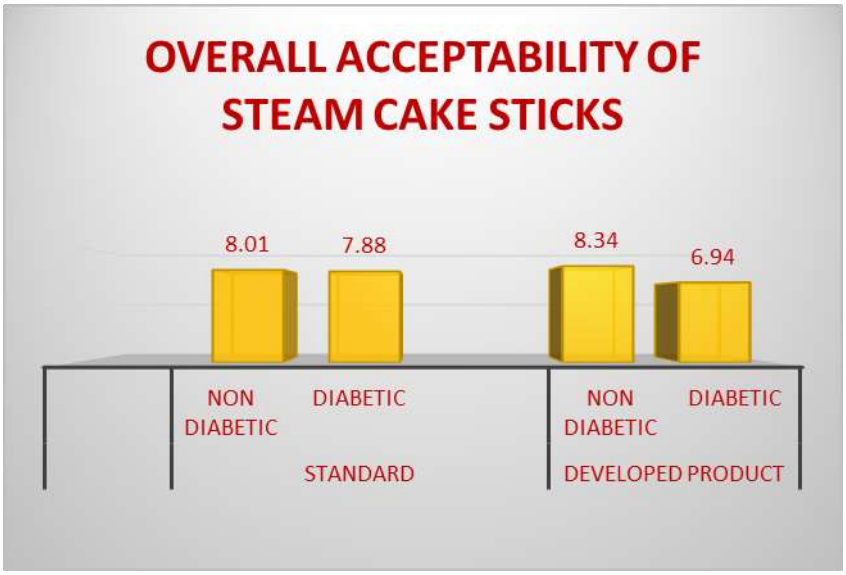
Table XXVI

Mean acceptability scores of developed product steam cake sticks

The mean acceptability score of developed product steam cake sticks is given in the table below

SENSORY CHARACTERISTICS	MEAN SCORES	
	NORMAL SUBJECTS (n=25)	DIABETIC SUBJECTS (n=25)
APPEARANCE	8.4 ± 0.95	7.08 ± 0.63
TEXTURE	8.28 ± 0.74	6.56 ± 0.64
TASTE	8.2 ± 1.12	6.4 ± 0.65
FLAVOUR	8.28 ± 0.86	7.16 ± 0.57
COLOUR	8.56 ± 0.82	7.52 ±0.63
OVERALL ACCEPTABILITY	**8.34 ± 0.50**	**6.94 ± 0.38**
ṭ-value	**132.999**	**33.877**
p-value	**<0.0001**	**<0.0001**

*** <0.005 significant at 5% level**



Overall acceptability of steam cake sticks

Figure XVI

Table XXV and XXVI displays the mean acceptability score for vegetable dumplings. For standard product the normal subjects gave appearance a high score (8.16) and the diabetic subjects gave texture a high rating (8.16). The lowest rating was given for texture and flavour by normal subjects (both 7.88) and diabetics gave the flavour the lowest score. (7.52).

For the developed product the normal and diabetic subjects rated colour with the highest score (8.56) and (7.52) respectively. flavour received the lowest scores from normal subjects and diabetic subjects (8) and (6.4) respectively.

The t-value of the steam cake sicks of standard product for normal subjects is 136.355 whereas for diabetic subjects is 47.640 and (p-value <0.05) which is considered to be statistically significant and that there is a difference in the acceptance levels between the two samples.

The t-value of the steam cake sicks of developed product for normal subjects is 132.999 whereas for diabetic subjects is 33.877 and (p-value <0.05) which is considered to be statistically significant and that there is a difference in the acceptance levels between the two samples.

Table XXVII

Mean acceptability of vegetable cutlets

The mean acceptability score of standard product vegetable cutlets is given in the table below

SENSORY CHARACTERISTICS	MEAN SCORES	
	NORMAL SUBJECTS (n=25)	DIABETIC SUBJECTS (n=25)
APPEARANCE	7.92 ± 0.70	8.24 ± 0.66
TEXTURE	7.8 ± 0.81	8.36 ± 0.63
TASTE	8.32 ± 0.74	8.6 ± 0.57
FLAVOUR	7.92 ± 0.70	8.4 ± 0.64
COLOUR	7.96 ± 0.67	8.24 ± 0.66
OVERALL ACCEPTABILITY	**7.98 ± 0.51**	**8.36 ± 0.31**
t-value	**90.540**	**126.382**
p-value	**< 0.0001**	**< 0.0001**

*** <0.005 significant at 5% level**

Table XXVIII

Mean acceptability scores of the developed product

The mean acceptability score of standard product steam cake sticks is given in the table below

SENSORY CHARACTERISTICS	MEAN SCORES	
	NORMAL SUBJECTS (n=25)	DIABETIC SUBJECTS (n=25)
APPEARANCE	8.32 ± 0.74	8.16 ± 0.62
TEXTURE	8.28 ± 0.84	8 ± 0.70
TASTE	8.2 ± 0.76	7.08 ± 0.81
FLAVOUR	8 ± 0.91	7.84 ± 0.68
COLOUR	8.12 ± 0.66	8.24 ± 0.77
OVERALL ACCEPTABILITY	**8.18 ± 0.53**	**7.86 ± 0.40**
ṭ-value	**142.552**	**37.864**
p-value	**<0.0001**	**<0.0001**

*** <0.005 significant at 5% level**

Overall acceptability of vegetable cutlets

Figure XVII

Table XXVII and XXVIII displays the mean acceptability score for vegetable cutlets. For standard product the normal subjects and diabetic subjects gave flavour a high score (8.32 and 8.6). The lowest rating was given for texture by normal subjects (7.8) and diabetics gave the texture and colour the lowest score. (both 8.24).

For the developed product the normal subjects rated highest score for appearance (8.32) and diabetic subjects rated colour with the highest score (8.24). the lowest rating was given for taste (8.2) from normal subjects and diabetic subjects rated colour with the lowest score (8.24).

The t-value of the vegetable cutlets of standard product for normal subjects is 90.540 whereas for diabetic subjects is 126.382 and (p-value <0.05) which is considered to be statistically significant and that there is a difference in the acceptance levels between the two samples.

The t-value of the vegetable cutlets of developed product for normal subjects is 42.552 whereas for diabetic subjects is 37.864 and (p-value <0.05) which is considered to be statistically significant and that there is a difference in the acceptance levels between the two samples.

Table XXIX

Overall acceptability scores of the developed products

The overalls acceptability scores of the developed products are given in the table below.

OVERALL ACCEPTABILITY				
SENSORY CHARACTERISTICS	STANDARD PRODUCT		DEVELOPED PRODUCT	
	NORMAL SUBJECTS (n=25)	DIABETIC SUBJECTS (n=25)	NORMAL SUBJECTS (n=25)	DIABETIC SUBJECTS (n=25)
CHAPATI	7.78 ± 0.41	8.05± 0.33	8.01 ± 0.43	8.22 ± 0.48
NOODLES	7.64 ± 0.44	7.68 ± 0.50	7.74 ± 0.39	8.45 ± 0.49
SOUP	7.16 ± 0.59	7.6 ± 0.43	7.21 ± 0.50	8.51 ± 0.38
VEGETABLE DUMPLINGS	8.2 ± 0.38	7.30 ± 0.40	7.48 ± 0.39	8.02 ± 0.52
STEAM CAKE STICKS	8.01 ± 0.59	7.88 ± 0.44	8.34 ± 0.50	6.94 ± 0.38
VEGETABLE CUTLETS	7.98 ± 0.51	8.36 ± 0.31	8.18 ± 0.53	7.86 ± 0.40

Table XXIX shows the mean acceptability scores of the developed products. The overall acceptability of the standard products by diabetic subjects shows that the standard product chapati and vegetable cutlets were the most acceptable product among the diabetic subjects. The other standard products such as noodles, soup and steamed cake sticks had a similar rating and vegetable cutlets were the least acceptable product.

whereas, the standard product such as the standard vegetable dumplings, steamed cake sticks and vegetable cutlets was the most acceptable among the normal subjects with a minimal score difference and standard product soup was the least acceptable among the normal subjects.

The overall acceptability of the developed product shows that the developed product chapati, noodles and soup were the most acceptable products. The other developed products such as vegetable dumplings, steam cake sticks and vegetable cutlets had less acceptability among the diabetic subjects.

The standard product chapati, steamed cake sticks, and vegetable cutlets were the most acceptable products among the normal subjects and the developed product vegetable dumplings, steam cake sticks and vegetable cutlets had the least acceptability among the normal subjects.

SUMMARY AND CONCLUSION

V. SUMMARY AND CONCLUSION

The study titled "**Development and acceptability of antioxidant rich diabetic food products**" was conducted to develop antioxidant rich diabetic food products using sweet potato flour, wheat flour, pumpkin seeds and spices such as fenugreek powder, black pepper powder and ginger powder.

Diabetes is a condition that develops when the blood glucose level is excessively high. Diabetes mellitus occurs by either a shortfall in the synthesis of insulin or resistance to the action of insulin. The complications of diabetes are the main causes of mortality.

Any type of diet that promotes or maintains health is considered healthy. The body receives the basic elements it needs from a healthy diet, including enough hydration, micronutrients, macronutrients, and calories. A balanced diet is necessary for both nutrition and health. It guards against several chronic, noncommunicable diseases, including cancer, heart disease, and diabetes. A healthy diet must include a variety of foods and include less salt, sugar, and trans fat.

Sweet potatoes and pumpkin seeds are naturally rich in nutrients including β-carotene, phenolic acids, anthocyanins, carbohydrates, fibres, thiamine, riboflavin, niacin, potassium, zinc, calcium, iron, and high-quality protein.

Sweet potatoes primarily contribute to human nutrition through the provision of antioxidants in the form of provitamin A and, to a slight extend of vitamin C. Despite being a food high in carbohydrates, sweet potatoes have a low glycaemic index (<55), suggesting that they are suitable for diabetics.

Spices contain bioactive substances like thymoquinone, curcumin, eugenol, cinamaldehyde, and allicin. Spice polyphenols mimic the effects of insulin by increasing insulin activity in the brain, spice polyphenols also mimic the effects of insulin.

Easily available and cost effective ingredients were used for the development of products. The ingredients such as sweet potato, pumpkin seeds and spices were selected as they have anti diabetic properties.

Diabetic individuals should eat healthy foods to maintain overall wellness, improve blood glucose control, and attain target blood lipid (fat) levels, to maintain a normal blood pressure,

keep the weight in a healthy range and halt the progression of diabetes problems or slow their onset.

The key findings of the study are as follows:

- The sweet potato flour obtained from 570g sweet potato was 1/3rd of the original weight. Pumpkin flour obtained from 100g of pumpkin seeds remained the same as the original weight. Spice powder obtained from 10g each of fenugreek seeds and black pepper remained the same as the original weight. Wheat flour and ginger powder were obtained directly from the market.

- The developed chapati yielded 80g for 2 servings whereas the yield for standard chapati was 70g for 2 servings. The yield of developed and standard noodles was 150g and 140g respectively for 2 servings. The developed soup yielded 80g a whereas the yield for standard soup was 70g for 2 servings. The developed vegetable dumpling yielded 140g and the standard vegetable dumpling yielded 120g for 2 servings. The developed steam cake sticks and the standard steam cake sticks yielded 140g and 135g for 2 servings. The developed vegetable cutlets and the standard cutlets yielded 145g and 140g respectively for 4 servings.

- The calorific value of standard and developed chapati was 274.08 % and 299.94% respectively. The carbohydrate content of the standard and developed chapati was 55.73% and 58.8g respectively. Protein content of the standard and developed chapati was 9.19% and 9.75%. The fat content of the standard chapati was 1.60% and the developed chapati was 2.86 %. Fibre content of the standard chapati was 0.79% and the developed chapati was 1.42%. All the nutrients were higher in the developed chapati when compared with the standard chapati.

- The calcium content of the standard chapati was 20.2 mg and 56 mg for the developed chapati. Iron content of the standard and developed chapati was 4.9 mg and 0.1 mg respectively. Sodium content of the standard and developed chapati was 12.1mg and 394mg respectively. The potassium content of the standard chapati was 244mg and the developed chapati was 399 mg. The magnesium content of the standard and the developed chapati was 86.2 mg and 68 mg respectively.

- The inhibition rate of the flour base in DDPH assay decreased as the concentration increased whereas, in developed chapati, the concentration increased as the inhibition increased. The FRAP assay was quite high in developed chapati when compared with the standard chapati.

- The standard and developed chapati had the highest overall acceptability among diabetic subjects and had a minimal statistical significance with a p-value of (<0.005).

- The developed noodles and standard noodles had the highest overall acceptability among the diabetic subjects and had a minimal statistical significance with a p-value of (<0.005).

- The standard soup had the highest overall acceptability among the normal subjects and had a minimal statistical significance with a p-value of (<0.005).

- The standard vegetable dumplings had the highest overall acceptability among the normal subjects and had a minimal statistical significance with a p-value of (<0.005).

- The developed steam cake sticks and standard steam cake sticks had the highest overall acceptability among the normal subjects and had a minimal statistical significance with a p-value of (<0.005).

Conclusion:

The information provided by the current studies on the antioxidant activity of the developed product, its nutritional value, and its antioxidant potential can help in the development of more diabetic food products. The developed products have a low glycaemic value, control the blood sugar level and provide the necessary nutrients the body needs. The availability of developed food products can provide more healthy and nutritious food options for diabetics. Also, it is crucial to promote sweet potatoes and pumpkin seeds as a natural source of antioxidants in processed food items since the bioactive compounds included in these foods have numerous therapeutic capabilities such as (anticancer, antidiabetic, and anti-inflammatory properties). The sweet potato flour and pumpkin seeds incorporated ingredients can be an ideal food product for diabetes and can

be used in daily meals. The presence of fiber can help to lower insulin resistance and stabilize the blood sugar level.

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ANNEXURES

ANNEXURE I

ETHICAL APPROVAL LETTER

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

Chairman
Dr. Sudha Ramalingam
Director – Research and Innovation
Professor- Community Medicine,
PSG Institute of Medical Sciences
& Research, Coimbatore.

Member Secretary
Dr A Thirumani Devi
Professor
Department of Food Science
and Nutrition

Members
Mr. K Arulmoli (Legal Expert)
Dr. Subashini K.Sripathi
Dr. A Saraswathy(Medical Officer)
Ms. D. Kavitha
Dr. A R Sudamani Ramasamy
Dr. G. Victoria Naomi
Dr. Judith Justin
Dr. Anitha Subash
Dr. K Sampath Rani

To
Ms. Mhalo Ngullie
Department of Food Service Management and Dietetics
Avinashilingam Institute for Home Science and
Higher Education for Women
Coimbatore- 641043

Dear Mhalo Ngullie,

Ref: Your proposal No. IHEC/22-23/FSMD-11 entitled "Development and Acceptability of Antioxidant Rich Snacks for Diabetics" 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-11 entitled "Development and Acceptability of Antioxidant Rich Snacks for Diabetics" submitted by you. The Approval number for the same is AUW/IHEC/FSMD- 22-23/XMT-11.

We wish you all the best in your research endeavours.

Regards

5.1.23

Dr. A Thirumani Devi
Member Secretary

Institutional Human Ethics Committee

ANNEXTURE II

SCORE CARD FOR SENSORY EVALUATION

HEDONIC RATING TEST

Name: **Date:**

Age: **Gender:**

Taste the samples and check how much you like or dislike each one. Use the appropriate scale to show your attitude by checking the point that best describes your feelings about the sample. Please give a reason for this attitude. Remember you are the only one who can tell what you like. An honest expression of your personal feelings will help us.

QUALITY ASPECTS	PRODUCT CODE					
	I	II	III	IV	V	VI
Appearance						
Texture						
Taste						
Flavour						
Colour						

9- POINT HEDONIC SCALE:

Like extremely - 9

Like very much- 8

Like moderately -7

Like slightly- 6

Neither like nor dislike -5

Dislike slightly - 4

Dislike moderately - 3

Dislike very much -2

Dislike extremely -1

ANNEXTURE III

LAB REPORTS

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/1345	Date	17.02.2023

Details of Customer	
Customer Name and Address	Ms. Mhalo Ngullie Avinashilingam College, Coimbatore.
Customer Reference	-

Details of Sample			
Sample Received Date	13.02.2023	Sampled by	Customer
Nature of Sample	Food	Description	Chappati
Sample Code	GLARL/F/02/23/1345	Received Condition	Packed well.
Analysis Started on	14.02.2023	Analysis Completed on	17.02.2023

Result of Analysis

S. No	Characteristic	Test Method	Unit	Results
1.	Calcium	FSSAI/AOAC/ IS	mg/100g	56
2.	Iron		mg/100g	0.1
3.	Sodium		mg/100g	394
4.	Potassium		mg/100g	399
5.	Magnesium		mg/100g	68

*** End of Report ***

CBE - 14

Authorized Signatory
Technical Manager
(M.Amsaveni)

Page 1 of 1

GREENLINK

Sample code: RCN

Concentration: 0.8mg/mL H2O

Concentration (µl)	% Inhibition
10	54.10
50	59.02
150	63.11
250	63.93
350	65.57
500	67.21
750	67.21

The results of Antioxidant Assay of samples submitted by Ms.Minola Ngullie, M.Sc.FSMD, of our Institution are given in the above Table and Photographs.

Attested by

P.Lalitha 27/4/23

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, Research and Development Cell
& Co-ordinator, Bharat Ratna Prof C.N.R Rao Research Centre

Sample Code – Sweet Potato Flour
Concentration: 2.01mg/mL H2O

Concentration (µl)	% Inhibition
10	54.10
50	50.82
150	49.18
250	43.44
350	36.89
500	32.79
750	24.59

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

The results of Phytochemical screening of samples submitted by Mhalo Ngullie, 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
Dean i/c, Research and Development Cell
& Co-ordinator, Bharat Ratna Prof C.N.R Rao Research Centre

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

Date: 06.03.2023

TEST REPORT

Name & Address of the customer:	Name of the product : Chapathi Sample ID : 2721 No. of samples : 1 Quantity received : 100g Packaging condition : Plastic cover Date of Receipt : 07.02.2023 Date of Testing : 13.02.2023 Date of Completion : 02.03.2023 Sampling : Sampling not conducted by us

M/s **Mhalo Ngullie**
Avinashilingam Institute for Home Sciece and Higher Education for Women,
Bharathi Park Road,
Saibaba Colony.

S. No	Parameters	Results	Method of Analysis
1.	Calorific value (%)	299.94	DGHS method
2.	Total Antioxidant (mg/g)	715.28	Frap method
3.	Protein (%)	9.75	Kjeldhal method
4.	Carbohydrates (%)	58.8	IS 1656:2006
5.	Fat (%)	2.86	Soxhlet method
6.	Fiber (%)	1.42	Fibra plus method

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

6/3/23

(Dr.S. Karthikeyan)
Authorized signatory