TASTE PERCEPTION IN INDIVIDUALS WITH

DIABETES MELLITUS TYPE II

NEERAJA SUNIL

18SLP021

A Dissertation Submitted in Part Fulfilment of

Degree of Master of Science (Speech-Language Pathology)

University of Mysore, Mysuru

ALL INDIA INSTITUTE OF SPEECH AND HEARING,
MANASAGANGOTHRI,
MYSURU - 570006
JULY 2020

CERTIFICATE

This is to certify that this dissertation entitled **"*Taste perception in individuals with Type II Diabetes Mellitus*"** is a bonafide work submitted in part fulfilment for degree of Master of Science (Speech-Language Pathology) of the student Registration Number: 18SLP021. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru,
July 2020

Director
Dr. M Pushpavathi
All India Institute of Speech and Hearing
Manasagangothri,
Mysuru-570006

CERTIFICATE

This is to certify that this dissertation entitled **"*Taste perception in individuals with Type II Diabetes Mellitus*"** is a bonafide work submitted in part fulfilment for degree of Master of Science (Speech-Language Pathology) of the student Registration Number: 18SLP021. This has been carried out under my supervision and guidance. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru,
July 2020

Guide
Dr. Swapna N
Associate Professor of Speech Pathology
Dept. of Speech-Language Pathology
All India Institute of Speech and Hearing
Manasagangothri,
Mysuru-570006

DECLARATION

This is to certify that this dissertation entitled **"*Taste perception in individuals with Type II Diabetes Mellitus*** "is the result of my own study under the guidance of Dr. Swapna N, Associate Professor of Speech-Language Pathology, Department of Speech-Language Pathology, All India Institute of Speech and Hearing, Mysuru, and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru, **Registration No.**

July, 2020 18SLP021

Acknowledgement

The completion of this dissertation could not have been possible without the participation, assistance and prayers of so many people whose names may not all be enumerated. Their contributions are sincerely enumerated and gratefully acknowledged. However, I would like to express my sincere appreciation and indebtedness, particularly to a few people.

First and foremost, I would like to express my sincerest thanks to my guide Dr Swapna N, thanks a lot for your constant support and guidance. Ma'am, you taught me how to gain in-depth knowledge patiently. Your constant motivation and support helped me to complete my dissertation smoothly. Thank you, Dr M Pushpavathi, Director, AIISH, for providing an opportunity for undertaking this study. I want to thank Srinivas Sir and Vasanthalakshmi Ma'am, for helping me do the statistical analysis. A special thanks to Srinivas sir again for clearing all the confusions repeatedly without any hesitance, Thank you.

I want to thank the officials, doctors, nurses, Asha workers and the patients of Public Health Centre, Poothadi panchayath, Wayanad for permitting me to collect data and also for all the cooperation and support.

On the very outset of this dissertation, I would like to extend my Love and thanks to my family (Achan, Amma, Ninju, Appupan, both Ammumas, Sudha aunty, Ammu and Sudhir Maman) for supporting me throughout and inspiring me to complete this venture patiently. I am grateful to Almighty for giving me a beautiful family.

I also acknowledge with a deep sense of reverence my gratitude towards all the teachers at AIISH for being the right motivation. Thanks to my teachers at Nitte, Mangaluru for helping me build a strong foundation.

I want to thank all my seniors, juniors, and my batch mates (Brainiacs 2020) for every kind and honest help and Love.

Most of all, I would like to bend down and thank the Almighty God for the endless showers of blessing, knowledge, courage and patience. Thank you, God, for helping me choose the best of all and giving me the strength to face all the ODDS in my life, and I am thankful for who I am today.

TABLE OF CONTENTS

LIST OF TABLES

Chapter I

Introduction

Diabetes mellitus (DM), as per American Diabetes Association (2010) is defined as a cluster of metabolic syndrome, portrayed with hyperglycemia causing subsequent shortcomings in the secretion of insulin. Any defect of the insulin cycle can result in long-standing impairment of numerous systems of the body, especially the ophthalmic system, renal system, nervous system and the cardiac system (Begic, Arnautovic, & Masic, 2016) and various other organs. The risk factors include age, genetic predisposal, Body Mass Index (BMI), alcohol consumption, smoking, drugs consumed for various chronic and acute conditions, surgical management (Begic et al., 2016), and steady urban migration and lifestyle changes (Kaveeshwar, 2014).

As per the study by Wild, Roglic, Green, Sicree, and King (2004), there can be a doubling of the prevalence of Diabetes worldwide. This is logged to reach 366 million in 2030, whereas in 2000 the value was 171 million. They also report that the maximum increase can happen in India. According to the International Diabetes Federation (IDF), 435 million individuals in the world had Diabetes, in 2017, it is also reported that in India, the prevalence of adult diabetes mellitus is 8.8%, that is, 72,946,400 out of 829,491,000 adult population in India.

This vast population with diabetes fall under two key types: Type one diabetes or immune-mediated and Type two diabetes. As per the American Diabetes Association, the major variance is that Type I mostly occurs in young children and a few adults due to the destruction of beta cells causing insulin insufficiency, and Type II is due defect in pancreas thus, causing insulin deficiency. According to American Diabetes Association (2010), the onset of Diabetes can vary from person to person, as

the symptoms exhibited can be evident (including the urge to urinate frequently, feeling thirsty and hungry even after proper hydration and intake of food) or it can be so mild that it may get unnoticed. Diabetes Type I is inclusive of about 5-10% of the total individuals with Diabetes, whereas, Type II Diabetes Mellitus (T2DM) accounts for approximately 90-95%. Renal disease, retinal problems, neuropathy, peripheral vascular diseases, coronary heart disease, xerostomia or decreased salivary production, diabetic neuropathy and difficulty perceiving taste are the various complications associated with T2DM (Hillson, 2014; Begic et al., 2016). These complications are due to the pathological and functional changes in these tissues(Kahn, 1997)

One of those initial symptoms of Diabetes Mellitus is taste disturbance (Keny, Nevrekar, Bhandare, & Bhandare, 2014). Taste is one of the most vivid and complex pieces of human lifestyle, which, when affected can impair the quality of life of a person. The basic and the inexorable process of eating not only involves chewing and swallowing; it is also determined based on taste. Bitter, sweetness, sourness, saltiness, and umami are the five basic tastes that could be appreciated by humans and most other animals (Mohan, Venkatraman, & Pradeepa, 2010).

Tongue and soft palate have numerous taste receptor cells which can detect the five primary tastes. Diverse types of taste buds; circumvallate and foliate papillae densely packs posteriorly and the fungiform papillae are scattered anteriorly (Bartoshuk & Pangborn, 1993), (Liman, Zhang, & Montell, 2014). These taste buds convert taste stimuli into electrical stimuli (Liman et al., 2014) and the chorda tympani (anterior part of tongue) and glossopharyngeal nerve (posteriorly) transmit evidence to gustatory cortex through the nucleus of the solitary tract (Ambaldhage, Puttabuddi, Nunsavath, & Tummuru, 2014; Liman et al., 2014). A taste is perceived when the level of the tastant touches the threshold leading to the activation of the gustatory nerves, in turn, activates

the gustatory cortex, resulting in taste perception (Ashi, Campus, Klingberg, Forslund, & Lingström, 2019).

As reported by Keny et al. (2014), altered taste perception is seen in individuals with Diabetes due to dysfunction of taste nerve tracts and taste buds/receptors consequent to neuropathy and microangiopathy respectively. Other factors can also affect the perception of taste and its threshold. These can be endorsed as poor fetal and early postnatal nutrition (Hales & Barker, 2013) causing ineffectual early growth of islets of Langerhans and the Beta cells (Kahn, 1997), genetic makeup, BMI, alcohol consumption, smoking, corporal needs, assorted drugs for chronic and acute diseases and surgical management (De Carli, Gambino, Lubrano, Rosato, Bongiovanni, & Lanfranco, et al., 2017) and decreased or altered production of saliva (Saleh, Figueiredo, Cherubini, & Salum, 2014).

A study conducted by Gondivkar, Indurkar, Degwekar, and Bhowate (2009) aimed at evaluating the taste perception function in T2DM and also the taste perception differences in right and left parts of tongue. The study included 40 age and gender-matched participants within two groups, i.e., forty controlled and forty uncontrolled T2DM participants within the age range of 25-55years. The whole-mouth above-threshold test was used to assess the gustatory function and spatial taste test to test perception differences on both sides of tongue, using quinine hydrochloride, sodium chloride (NaCl), citric acid, and sucrose. The results revealed a reduced reaction for sweetness, shadowed by sourness and saltiness. The localized test showed that for salt perception in right and left side of tongue were not affected but, posterior tongue was affected and for bitter, left posterior tongue area was significantly affected. Research by Lawson, Zeidler, and Rubenstein (1979), using a similar procedure reported that only sweet taste was affected in T2DM.

De Carli, Gambino, Lubrano, Rosato, Bongiovanni and Lanfranco et al., (2017) also compared the taste perception thresholds between individuals with T2DM and normoglycemic controls. Gender, age, and BMI were matched to individuals with T2DM within age range of 18-65 years. Ascending-concentration method was employed for four tastes: sucrose, NaCl, citric acid, and quinine hydrochloride. The results revealed that the taste perception threshold was higher for all four tastes.

A similar study was carried out by Khera and Saigal (2018) to identify the taste perception threshold (TPT) differences between normal healthy individuals, controlled T2DM and uncontrolled T2DM of 24-73 years. They used the whole mouth above threshold and localized test using the same four tastes. They reported an altered taste perception for all the four tastes and more for sweet.

Xerostomia is one of the most commonly reported conditions that co-occurs with Diabetes Mellitus. This can be manifested as dryness in the oral cavity and lips, urge to drink more water. Xerostomia is the perception of dryness of mouth, whereas the objective measure of the same is Hyposalivation (decreased saliva flow), as reported by López-Pintor, Casañas, González-Serrano, Serrano, Ramírez, Arriba, and Hernández, (2016). Saliva acts as a medium which transmits the tastants or the taste molecule to the taste buds so that the sensation can be detected for processing (Dietsch, Pelletier, & Solomon, 2018). In the case of T2DM, the production of saliva is decreased. According to Saleh et al. (2014), the reduction in salivary flow in individuals with diabetes could be due to the dysfunction of gland parenchyma, or due to the disturbances in the microcirculation to the salivary glands, dehydration or the imbalance in the glycaemic level.

Ambaldhage et al., (2014) reported that disruptions in taste could be due to several factors, including systemic diseases such as Diabetes mellitus and salivary dysfunctions such as Xerostomia. López-Pintor et al. in 2016, reviewed articles related to dryness, impaired salivary flow in diabetes population. They reported that most of the studies found a higher prevalence of xerostomia and reduced salivary flow rate in individuals with diabetes.

The process of eating is also determined by palatability. Palatability, as reported, can increase the saliva production (Dietsch et al., 2018) and this, in turn, can be used to improve taste perception (Ambaldhage et al., 2014). For a taste to be palatable, the individual should be sensitive to taste (Ambaldhage et al., 2014). As all these aspects, i.e., taste perception, saliva production and palatability are interrelated, it is essential to assess the relationship between these.

Need for the study

A review of the related studies portrayed a discrepancy between the findings. Some studies reported the presence of altered taste perception for all the four tastes (sour, salty, bitter and sweet) in T2DM, while others reported only sweet taste getting affected. Thus, there exists a controversy between the tastes that are affected in T2DM. All these studies were conducted using a similar procedure, but the results vary. Further, there exists a debate about the effect of gender on taste perception. Thus, studies assessing the effect of gender on taste are also indispensable.

Moreover, most of these studies are carried out by the Dental practitioners to assess the gustatory function in this population. Therefore, there exist a need to investigate the taste perception in T2DM to identify the hierarchy in which tastes are affected. Findings can contribute to the dietary management of these individuals, in the

event of dysphagia. Understanding this will help to provide better insight regarding the taste perception in the diabetic population. This information can probably guide the speech-language pathologists in the assessment of taste perception while assessing the adult population with neurological disorders associated with diabetes, since the age of occurrence of Diabetes Mellitus is 40-50 years (Khera & Saigal, 2018), which almost merges with the age range in which the risk of the neurological disorders such as cerebrovascular disorders, dementia, movement disorders, degenerative neurological diseases leading to dysarthria and dysphagia is high (Nguyen, Xu, Chen, Srinivasan, Berenson, 2012).

Taste perception in Diabetes is the least studied area by speech-language pathologists, and literature is scarce regarding the presence of altered taste perception in these individuals. Moreover, its association with xerostomia and palatability is also less researched. Keesman, Aarts, Vermeent, Häfner, and Papies (2016) reported that there would be an increase in salivation for palatable food. Thus, identifying the most palatable taste can be used for stimulating salivation, in individuals with T2DM who have dysphagia. The literature also suggests that sweetness and sourness can initiate the infrahyoid and submental muscle activation earlier, as compared to the situation when no taste was provided (Pelletier & Lawless, 2003). The results of this study can be helpful to make decisions regarding the most appropriate taste that can be used during taste stimulation therapy, in turn improving the quality of life of the affected individuals, which is a significant factor in management. As reported in the literature, a notable increment in the spontaneous dry swallows was observed after the taste stimulation which can be due to the increase in stimulation of the gustatory and trigeminal conduction to brainstem enhancing neural plasticity (Dietsch et al., 2018).

Further, most of the studies are done in the western context. Of the Indian studies, most of them are done in the Northern part of India. Since India is a diverse country with different culture, tradition, cuisines, there exist a need to study the taste perception in individuals with T2DM, particularly from the southern part of the country. Keeping all these aspects in view, the present study was designed to investigate the taste perception in individuals with T2DM.

Aim of the study

This research aims to examine the taste perception in individuals with Diabetes Mellitus Type II.

Objectives of the study

- To detect taste perception threshold (TPT) in individuals with T2DM and to compare the same with neurotypical and normoglycemic healthy adults for three taste stimuli (sour, salt and sweet).
- To investigate the relationship between xerostomia and TPT in T2DM.
- To compare the TPT and palatability across three taste conditions and xerostomia across gender.
- To explore the influence of palatability of tastant in the perception of the three tastes in both the groups of individuals.

Chapter II

Review of Literature

Virginia Woolf, an English writer, quoted in her famous book 'A room of one's own' that "*One cannot think well, love well, sleep well if one has not dined well*." This statement implies that food consumption is an imperative aspect of life, which determines the performance of other vital activities. The process of feeding and eating is enjoyable and satisfying and it involves an interaction of multiple sense organs. According to Neff, Whittaker, and Karl (2017), eating comprises of all the five senses, namely, vision, odour, touch, audition and taste, of which taste is a primary and essential sense.

Taste can be considered as a sensation upon the taste organ due to a substance that a person has enjoyed (Brillat-Savarin, 2019). It involves the perception of tastant that stimulates the receptors present inside the taste buds. According to Lindemann, (2001), the taste is the sense by which the chemical qualities of food in the mouth are distinguished by the brain, based on information provided by the taste buds. Lindemann also explained it as a sensory system solely dedicated to inspect the quality of food to be ingested. Even though this process is assisted by olfactory and visual systems, the final acceptance is made based on the decision making the process of in-mouth chemoreceptor activities.

Taste assists in assessing the bolus for its harmfulness and its nutritional value. Thus, taste plays an important role in the choice of nutrition and the nutrient consumption, thereby acting as a protective mechanism. It is one among the regulatory processes, which is useful for deciding whether to accept or reject the food, thus

preventing the entry of harmful substances to the body (Gondivkar et al., 2009). It is also considered as a nutrient-sensing system, which can detect macronutrients.

These functions also help to breakdown bolus once they have been swallowed. If the food ingested is familiar, the metabolic consequences can be anticipated. Physiological outcomes of swallowing can be improved using the sensory cues. If the resultant taste is rewarding, it will be signalled as appealing. However, the taste has more meaning than its sensory palatability or rewarding ability. Literature suggests that the duration for which bolus remains in the oral cavity is inversely related to the eating rate; and the eating rate is dependent on the sensory exposure of the oral cavity to taste and its texture, openly associated to amount of chewing and mastication movements (Boesveldt & Graaf, 2017).

Taste also plays a significant role during food intake, in terms of saliva production in anticipation of the bolus, followed by the events in oral preparatory and propulsive phases of swallowing. Sense of taste can increase the pre-swallow sensory input to the higher centres such as brainstem and cortex. It is also said to reduce the swallowing threshold response, which in turn reduces the oral transit time and also increases the pharyngeal response time, thus minimizing the risk of laryngeal aspiration or penetration. Gatto, Cola, Gonçalves, Spadotto, Carvalho, and Gatto (2013) reported that sour tastant helps in oral preparatory stage by increasing the submentalis muscle contraction, (making the hyoid stay at a higher position and reducing the risk of aspiration) and decreasing the oral preparation time and transit time (attributed to a more excellent perception of the stimulus). They also recommended the use of sour stimuli for rehabilitation, especially in patients after stroke with swallowing difficulties. They also observed a decrease in the consumed volume per second and volume per swallow, with sour stimuli. Gatto et al. (2013) explained that the sour stimuli could

induce a state of mild harmful stimulus, making the bolus perception more conscious, facilitating greater oral control and faster motor response.

Taste sensation

Tastants are typically released when the bolus is formed, using saliva. Oral enzymes, like as proteases, lipase, and amylase also helps in breaking down process (Pedersen, Bardow, Jensen, & Nauntofte, 2002), which are sensed by different taste sensors. More than thousands taste combinations exists, some of which include acidic (tea and berry), pungent (ginger and pepper), fatty, metallic, other chemical sensations. Also, mixtures of different tastants can evoke completely novel output. However, five tastes among these that humans perceive have been globally accepted. They are sweet, salty, sour, bitter, and Umami (Savoury) (Breslin & Spector, 2008; Mohan et al., 2010; Loret, 2015; Melis & Barbarossa, 2017).

Simple carbohydrates are experienced as sweet. As per Chang and Ou (2000), sweetness specifies the existence of carbohydrate, which is a huge source of energy. The presence of glucose mixed in the saliva is identified as sweetness. Chandrashekar, Hoon, Ryba, and Zuker (2006) described that sweet is one of the tastes with a positive hedonic value; it is also one of the fundamental sources of energy to the body. The sweet taste can evoke pleasure to the person consuming it. Still, this pleasure is dependent on the physical properties of the sucrose.T1R1, T1R2, and T1R3 are the three G-protein-coupled receptors responsible for sweetness (Chandrashekar et. al., 2006).

Salt taste indicates that sodium and different salts are present in the saliva. These ions are essential in maintaining water balance and blood circulation in the body (Chang

& Ou, 2000). The molecular mechanisms of the reception of salt taste are poorly understood relative to the other tastes.

Acids are experienced as sour. Chang and Ou (2000) stated that sour taste could indicate the presence of dietary acids. The sour taste is a reaction to the H^+ concentration freed from acidic ingredients (less pH). A type of TRP (transient receptor potential) channel activation is evoked by sourness.

Bitter taste is stimulated by the presence of a large number of molecules (alkaloids). Alkaloids contain basic (in the sense of pH) nitrogen atoms within their structures. Most alkaloids originate from plant sources, for example, tea, coffee, aspirin, and similar molecules. When enough alkaloids are contained in a substance, it can stimulate a gag reflex. This is a protective mechanism because plants often produce alkaloids as a toxin to detect infectious microorganisms and plant-eating animals.

Umami is often mentioned as savoury. Umami is the most recent taste sensation labelled which gained recognition in the 1980s. Amino acids such as glutamate, aspartate and ribonucleic acids are responsible for the perception of umami. Umami is identified as the taste of proteins and is most associated with meat containing dishes. It is based on the activation of G-protein coupled receptors by amino acids, particularly glutamine.

Structures that help in taste identification and perception

Tongue

The tongue sits in the mouth at a physical transition between the skin and the gastrointestinal system and is the first organ to confront different types of food. The tongue has a stratified squamous epithelium, which is seated on an underlying basal lamina over the lingual connective tissue, or lamina propria, and muscle. Similar to the gut, the tongue has a mucosa that is moist and includes specialized cells of simple epithelial (Potten, Saffhill, & Maibach, 1987; Barker, Bartfeld, & Clevers, 2010).

Tongue is an essential oral structure for speech and swallowing, which is innervated by the hypoglossal nerve. It can sense general sensory stimulation like temperature, texture, and discomfort. This general sensory innervation is by the lingual nerve (CN V) and glossopharyngeal nerve (CN IX), to anterior two-thirds of the tongue and posterior one-third of respectively.

Tongue is the primary organ in gustatory system and is an integral part of the gastrointestinal part. The superficial area of tongue generally is bumpy and has several papillae. These structures contain taste buds which has receptors inside. The tongue has special sensory innervations for taste. The special visceral afferent fibres carry the senses of taste and olfaction (smell) in cranial nerves. The sense of taste from the anterior two-thirds of the tongue is mediated by the facial (CN VII) nerve and from the posterior one-third is mediated by the glossopharyngeal (CN IX) nerve.

Taste papillae

The papillae are projections of a connective tissue core covered with squamous epithelium (Snow,2003; Finger, Danilova, Barrows, Bartel, Vigers, Stone, Kinnamon, 2005). They are composed of neural and vascular tissues and specific taste bud cells,

adapted to detect chemical, tactile, and temperature stimuli. The taste papillae of the tongue are named as the magnifying effect. The wart-like projections under the mucosal membrane increases the surface area, multiplying the capacity to perceive molecules more powerfully. These papillae contain several taste buds. Majorly there are three kinds of papillae, namely; fungiform papillae, foliate papillae and circumvallate papillae.

Fungiform papillae are shaped like mushrooms. Three to five taste buds constitute each fungiform papillae. They are all over the dorsal surface, but more populated at the tip and margins of the tongue. The fungiform papillae are more numerous than the circumvallate type. The abundant blood supply gives them a bright-red colour. They are sensitive to taste, temperature and touch.

The circumvallate papillae are the largest, cylindrically shaped and are present at the back of the tongue. They project slightly over the tongue surface. They vary in number from 8-12 and are situated in front of and parallel to the sulcus terminalis of the tongue and form the shape of an inverted V. The middle papilla in the centre of the V is the largest. These are named 'circumvallate' because they are surrounded by dugout like structures, which houses several glands that help in transporting taste molecules to the sensory receptors. Each of these papillae contains more than a thousand taste buds. According to Auger (2020), the circumvallate papillae can identify bitter or bad taste as they are located at the back of the tongue. It is also reported that circumvallate papillae contribute to gag reflex.

The foliate papillae are peg-like and are surrounded by trenches. Each individual has around twenty foliate papillae, and each of these papillae houses more than hundreds of taste buds. They form ridges on the lateral and posterior surface of the

tongue. It is associated with von Ebener salivary gland. When taste stimuli stimulate the taste buds in foliate papillae, the signals are sent to the brainstem, which in turn stimulates the salivation (Cohen, Haesler, Vong, Lowell, & Uchida, 2012).

Taste buds

The principal organ of taste perception is the taste buds (Carterette & Friedman, 1978), which are present in the taste papillae of the tongue. The taste buds are the sensory end organs for gustation. The taste buds contain the gustatory receptors cells, which allows detection of taste. There are almost 10,000 taste buds all over the tongue, and it measures around 50-70μm (Maheswaran, Abikshyeet, Sitra, Gokulanathan, Vaithiyanadane, & Jeelani 2014). Taste buds are found on tongue and also in epiglottis, larynx, pharynx and soft palate

Taste buds appear as round bodies. They extend through the thickness of the epithelium and are covered by stratified squamous epithelium in the lingual papillae. Each bud consists of about 50-100 spindle-shaped, modified, epithelial cells that extend from the basement membrane to the epithelial surface and a small number of proliferative basal cells. Each bud is flask-shaped, with a broad base and a short neck opening on the epithelial surface called the taste pore. The taste pore interacts with the contents of mouth forming a window, thereby identifying the chemicals in food. The apical taste pore is bounded by numerous microvilli which are liable for taste perception. The action potentials generated from this compound-receptor leads to taste sensation. Meanwhile, the inferior pole of the bud synapses send signal to the central nervous system.

The buds on the anterior two-thirds of the tongue and the soft palate are innervated by the facial nerve. The posterior one-third of the tongue (including all

vallate papillae) and the pharynx are innervated by the glossopharyngeal nerve. Taste buds in the soft palate are innervated by the greater petrosal nerve of the face. The vagus nerve (superior laryngeal branch) innervates larynx and epiglottis.

In case of disconnection between axon and taste bud, the bud will disappear in a few days as reported by Carterette and Friedman (1978). Still, these will be continuously replaced (Conger & Wells, 1969). Conger and Wells (1969) reported that the life span of taste cells ranges from a few days to a month, and the average lifespan is around ten days (Beidler & Smallman, 1965). This is a compensatory mechanism against the toxin, mechanical or thermal induced damage to the epithelium of the gustatory system. Taste buds are one of the few organs in the human, with the capability of total regeneration (Breslin, 2013). Breslin (2013) also reported that the gustatory system is highly resistant to ageing and related damage.

Taste buds has mainly three type of cells. The most frequently encountered taste bud cells (approximately 60% of the total cell population) are the Type I cells. They are long and narrow, extending from the base of the taste bud to the taste pore (Chaudhari & Roper, 2010). These electron-dense cells (sometimes called dark cells) are characterized by large, dense-core vesicles in the apical cytoplasm as well as indented, irregularly shaped nuclei. Type II cells (often referred to as light cells) also extend from the basement membrane to the taste pore. Still, they are characterized by electron-lucent cytoplasm and massive, round or oval nuclei. Type III cells also have an apical specialization that extends into the taste pore and is similar in morphology to Type II cells. However, these cells are infrequently encountered in the taste bud and contain numerous dense-cored vesicles concentrated in the basal portion of the cell. Each of the three taste bud cells that extend into the taste pore has a different apical structure. Type

I cells have long, finger-like microvilli that arise from a short neck. Type II cells have shorter microvilli, and Type III cells end in a blunt, club-shaped structure. Basal cells are also present within each taste bud. However, they are immature as it does not possess the capacity to process taste.

Taste receptors

A taste receptor, found within the taste buds facilitates the sensation of taste. The chemically sensitive part of a taste receptor cell is its apical end, which is a small membrane region near the surface of the tongue. The apical ends have thin extensions that project into the taste pore (microvilli). Receptors can depolarize and synapse with the endings of the afferent axons at the bottom of taste buds. Receptors have excitable cell membranes. When an appropriate chemical activates a receptor, the membrane potential changes (depolarising or hyperpolarising) causing a voltage shift (receptor potential). Depolarisation causes opening of voltage-gated calcium channels; Ca2+ enters the cytoplasm and release neurotransmitters causing excitation of adjacent neurons. The cranial nerves then convey this information toward the brain. Taste receptor cells synapses onto some of the basal cells; which in turn synapse onto the sensory axons, forming a simple information-processing circuit within each taste bud.

Around 90% of receptor cells respond to more than two basic tastes. However, taste cells and their gustatory axon differ by their preferences (Kinnamon & Margolskee, 2008). These responses depend on the particular transduction mechanisms present in each cell.

Mechanism of taste perception

As the bolus enters the oral cavity and is masticated, the taste buds are stimulated. Stimulation of taste buds activates a cephalic phase response with the help

of sight, smell and taste, which will help in the release of salivary amylase, protease, lipase, which helps in perception. This will also help in initiating peristalsis, increasing mesenteric flow, all of which are important for the preparation of the gut for absorption. Also, the processes such as the release of insulin, the activation of the sympathetic pathway in the brown adipose tissue and increase in heart rate are triggered, which are essential for making metabolic adjustments in the body (Chang & Ou, 2000).

The receptors within the taste buds can identify and discriminate between the chemical components in the food presented to the oral cavity. Taste perception is due to the communication of taste molecules with the taste receptor cell's microvilli, which have ion channels. Many ways are there in which the cells in the taste bud communicates. Chemical interaction through serotonin, glutamate, Adenosine triphosphate (ATP) for intercellular communication and synaptic transmission or electrical coupling through junctions between the cells are two ways of how communication happens.

The tongue surface consists of a plasma membrane that has moderately tight protein and phospholipid layers. This membrane has several charged ions around it. When a tastant is introduced, the binding between the taste molecules that also have charged ions (e.g. salt) with that of the ions in the membrane takes place. Thus, the net membrane potential will change, resulting in some ion exchange. Likewise, in the case of non-charged taste molecules such as that of sugar, there will be the formation of weak hydrogen bonds to which the sugar binds. This exact location at which the interaction between membrane and taste molecule of the stimulus interact is called a receptor site of that particular collaboration (Carterette & Friedman, 1978). Taste is perceived when tastant reaches the threshold leading to the activation of the gustatory

nerves, which in turn, activates the gustatory cortex resulting in taste perception (Ashi et al., 2019).

Taste transduction

The transduction of taste includes several processes, and each taste employs one or more of these mechanisms. Tastants, may (1) directly pass through ion channels (saltiness and sourness), (2) bind and block ion channels (sourness and bitterness), (3) bind and open ion channels (sweet amino acids), or (4) bind to membrane receptors activating second messenger systems, that in turn open or close ion channels (sweet and bitter) (Mojet, 2004).

Saltiness: The salty taste is initiated by the cations Na+ that enters the cell through the sodium channel. When salt is tasted, the sodium concentration raises outside the receptor cell. Then gradient across the membrane is made sharper. These ions then diffuses down in its concentration level causing inflow to the cell resulting in inward current which leads to membrane depolarization.

Sourness: Acids dissolve in water to generate H+ protons. The protons causes acidity and sourness. They influence taste receptors in two ways. First, it can permeate the amiloride-sensitive sodium channel, leading to inward H+ current, in turn depolarizing the cell. Second, protons block K+-selective channels. Depolarization happens when the K+ permeability of a membrane is decreased.

Sweetness: It is perceived when the molecules bind to specific receptor sites activating a cascade, which results in a second messenger. Sweet receptors are G-protein-coupled membrane receptors. They trigger the formation of cAMP (the second messenger) within the cytoplasm. It also activates protein kinase (PKA), which phosphorylates a K+-selective channel (apparently a different one from that involved in sourness). All

these processes block depolarization of the receptor cell. There may also be a second transduction mechanism for the sweetness without involving a second messenger, in which a set of cations channels may be gated directly by the sugars.

Bitterness: These receptors are also called as poison detectors. There are different mechanisms for bitter taste transduction. Some bitter compounds (quinine), can bind directly to K+-selective channels, blocking them. There are specific membrane receptor proteins, which activate G-protein-coupled second messenger cascades. One type of bitter receptor increases the production of intracellular messenger Inositol Triphosphate (IP3).

Umami: It is mediated by the metabotropic Glutamate Receptor (mGluR4). When they attach to the receptor it stimulates a G-protein, uplifting intracellular Ca2+ (Chaudhari, Yang, Lamp, Delay, Cartford, Than, & Roper 1996; Kurihara & Kashiwayanagi, 1998). There are ionotropic glutamate receptors (linked to ion channels), i.e. the NMDA-receptor, on the tongue. When stimulated, non-selective cation channels will get exposed, depolarising the cell. All these mechanisms result in amplified firing in the primary afferent nerve.

Central taste pathways

The information on taste travels from the taste buds to the primary gustatory axons, into the brainstem and to the cerebral cortex via thalamus. The taste buds convert taste stimuli into electrical stimuli (Liman et al., 2014), which are transmitted by the cranial sensory nerves to the gustatory cortex through the nucleus of the solitary tract (Ambaldhage et al., 2014; Liman et al., 2014).

The special visceral afferent fibres of the facial nerve (CN VII) and the lingual nerve receive the information from the taste buds on the anterior two-thirds of the tongue and soft palate. These special visceral afferent fibres emerge from the facial nerve and form the chorda tympani. The chorda tympani then relays sensory input to the otic and geniculate ganglia, from which the postganglionic fibres emerge and project to the brainstem. They then synapse within the rostral part of the nucleus of the solitary tract in the posteroinferior part of the medulla oblongata.

The taste information from the posterior one-third of the tongue and pharynx is carried by the special visceral afferent fibres from both the superior laryngeal nerve (branch of the vagus nerve and the glossopharyngeal nerve), which synapse with the inferior ganglion of the vagus nerve and the inferior ganglion of the glossopharyngeal nerve. From the inferior ganglion, the postganglionic fibres exit and course towards the nucleus of solitary tract after entering the brainstem at the rostral medulla oblongata. The fibres end within the rostral segment of the ventral part of the solitary nucleus, where the neurons encode the acceptability of a taste as well as its quality. For example, dangerous sour and bitter substances are encoded as lousy tasting, which are rejected, while sweet and salty substances are encoded as good tasting and are swallowed.

From this gustatory nucleus, taste pathways diverge. The neurons send fibres that intersects with ipsilateral central tegmental tract terminate at the parvocellular division of the ventral posteromedial nucleus of the thalamus. The posterior limb of the internal capsule houses the fibres from thalamus. These fibres terminate in cortical taste centre of cerebral cortex, which mediates the conscious experience of taste. The primary gustatory cortex is in the inferior part of the parietal lobe adjacent to the somatosensory area of the tongue and face. This area extends into the lateral fissure and

on to the insula. The neurons of the primary gustatory cortex project to the secondary gustatory cortex. The secondary gustatory cortex is located within the orbitofrontal cortex (caudolateral region deep within the lateral fissure).

The gustatory nucleus scheme its cells to a variety of brainstem regions, mainly in the medulla (involved in swallow, salivation, gag reflex, vomiting, and essential physiological functions, like digestion and respiration). Likewise, gustatory data is disseminated to the hypothalamus and associated parts of the basal telencephalon. These structures of the limbic system are responsible for palatability and motivate us to ingest.

Mascioli, Berlucchi, Pierpaoli, Salvolini, Barbaresi, Fabri, and Polonara (2015) published a study on cortical activations from unilateral tactile-taste stimulations of the tongue. They concluded that the representation of the tongue in the cerebral hemispheres in both the touch and the taste modalities is bilateral. This bilateralism was attributed to the partial crossing of the afferent pathways, perhaps with a predominance of the crossed pathway in the touch modality and the uncrossed pathway in the taste modality. The corpus callosum is also crucial for this bilateral representation and can contribute to it by inter-hemispheric transfer of information (Breslin, 2013).

Taste perception in humans

The taste system converts facts about the quantity as well as the character of stimuli. In general, the greater the stimulus concentration, the greater will be the perceived intensity of taste. Taste perception threshold (TPT) for almost all ingested tastants are somewhat high. For example, the TPT for citric acid is 2 m*M;* salt (NaCl), 10 m*M*; and for sucrose, 20 m*M.* Since the body requires considerable levels of salts and carbohydrates, receptors respond only to relatively high concentrations of these

essential substances. This is to encourage satisfactory consumption. It is beneficial to detect poisons (e.g., bitter-tasting plant compounds) at much lower concentrations. Thus, the threshold concentration for quinine is 0.008 m*M*, and for strychnine 0.0001 m*M*.

Humans differ both in their sensitivity to the taste qualities and in their taste preferences. Children, with their highly sensitive sense of taste, are often intolerant of spicy foods. Taste buds are lost with advancing age, and therefore taste thresholds increase or the gustatory sensitivity declines with age. Adults have a tendency to increase salt and spices intake in food compared to younger population. There are also differences in taste preference across adults of similar age. Some find particular tastes unpleasant, while others do not.

There is a common misconception about taste sensitivity that tip of the tongue detects sweetness, salt is identified by posterior-lateral edges, sour at the mediolateral edges, and bitter on the posterior part. This was originally explained in 1901 by Hanig. He measured TPT for NaCl, sucrose, quinine, and hydrochloric acid (HCl) (Purves, Augustine, Fitzpatrick, Katz, LaMantia, McNamara, & Williams, 2001). Hanig never specified that other parts of the tongue were unresponsive to these chemicals. He only reported about the highly sensitive areas on the tongue for different tastes. Individuals with absent anterior part of their tongue can still taste sweetness and saltiness. All tastants can be identified by all regions of tongue, but these regions have different thresholds. The tip of the tongue is most approachable to sweet, as these compounds produce pleasurable sensations. The signal from this area stimulates eating patterns (mouth movements, salivary secretion, insulin release, and swallowing). Whereas reactions to bitter composites are most excellent at the posterior part of tongue.

Activation of this region provokes tongue protrusion and other shielding feedbacks that prevent consumption. Sourness can result in grimaces, puckering responses, and salivary secretion to dilute the tastant.

Palatability

The process of eating is also determined by palatability. Palatability is the hedonic reward (i.e., pleasure) provided by foods or fluids that are agreeable to the "palate", which often varies relative to the homeostatic satisfaction of nutritional, water, or energy needs (Friedman & Stricker, 1976). Palatability, as reported, can increase saliva production (Dietsch et al., 2018) and this, in turn, can be used to improve taste sensation (Ambaldhage et al., 2014). For a taste to be palatable, the individual should be sensitive to taste (Ambaldhage et al., 2014). As all these aspects, i.e., taste perception, saliva production, and palatability are interrelated, it is vital to assess the relationship between these.

As per Carterette and Friedman (1978), the degree of unpleasantness or pleasantness can be referred to as the hedonic tone. Thus, the overall verdict of the pleasantness of a particular food item not only depends on its taste but also its odour, colour, texture weight and temperature of the bolus. Other factors including genetics (i.e. the number of taste buds), age, gender, race and culture (Drewnowski, 1997) can also influence the pleasantness or the hedonic tone.

The most popular method of measuring the degree of pleasantness is through the use of rating scales. These scales provide an efficient approach for the assessment of the magnitude of perceived intensity and hedonic liking for various taste qualities (Lim, Wood, & Green, 2009; Lawless, Sinopoli, & Chapman, 2010). The most widely used rating technique is the hedonic rating. One among the rating scales is the Words only

version of 9 points Hedonic rating scale. This scale is used to measure the palatability of the tastant (Peryam & Pilgrim, 1957). This will be used after the presentation of each tastant. The participants will be asked to assess the taste and score on this scale of liking. It consists of numbers from 1 to 9, where the numbers are labelled as 1-dislike extremely, 2- dislike very much, 3-dislike moderately, 4- dislike slightly, 5-neither like nor dislike, 6-like slightly, 7- like moderately, 8- like very much, 9- like extremely. Another version of hedonic rating technique is the Numbers only version. In this, there are numbers from 1 to 9, and there will be labelled in the beginning and end sometimes at the mid-point as well, such as 1 like the least or dislike the most as1 and neither like nor dislike as 5 and like the most as 9. However, researchers argue that the numbers in this scale are not equally spaced and creates confusion to the user and analyser, so its usage is limited as compared to that of words only version (Wichchukit & O'Mahony, 2015). For the present study, the words only version was chosen as it has the description of each number, thus avoiding confusions while rating.

Taste assessment

There are five most commonly used measurement methods for characterizing the taste function in human beings (Webb, Bolhuis, Cicerale, Hayes, & Keast, 2015).

1. Detection threshold (DT)
2. Recognition threshold (RT)
3. Suprathreshold intensity ratings of prototypical tastants
4. Propylthiouracil (PROP) bitterness intensity
5. Fungiform papillae number (FP Number)

Detection threshold (DT) is obtained when a person is asked to discriminate between a taste solution and a pure solvent. For obtaining DT, the procedure begins from a very low concentration and is gradually increased. Once DT is obtained, the concentration is increased to assess the level at which a person can discriminate between different tastes and can correctly recognize and label the solution. That level of concentration is considered as the Recognition Threshold (RT). For this, the method used is a forced-choice task. According to Webb et al. (2015), if a person has a lower DT and RT, then that person has higher sensitivity towards that taste molecule than a person with higher DT and RT.

Modified Harris-Kalmus Method can be used to identify the Recognition Threshold, which is the least level at which a person can describe a taste correctly. For this, a series of twenty cups containing the same solution in different concentrations are kept in ascending order. Once the taste is identified correctly, the sorting test is carried out. It consists of six cups containing the solution in the concentration at which the taste was identified correctly and three cups with distilled water. The task is to identify the cups with the taste solution. This is done to make sure that the RT identified is correct (Galindo-Cuspinera, Waeber, Antille, Hartmann, Stead, & Martin, 2009).

Another method is the suprathreshold intensity method. It is also similar to the DT and RT procedure, as it involves the gradual increase in the concentration of the tastant. Suprathreshold intensity is defined as the perceived magnitude or intensity of a substance at a concentration above the RT. Webb et al. (2015) explained that if TPT is high, the perceived magnitude will be higher and as the concentration continues to increase, highest threshold is reached for the stimulus and quality. The name

suprathreshold intensity ratings of prototypical tastants indicate that during this method quantification of taste function is made.

The fourth method is propylthiouracil (PROP) bitterness intensity. Propylthiouracil is considered as an oral marker for taste preferences. The PROP is extremely bitter for some people, and for some others, it is less bitter, or some perceive no bitterness (Bartoshuk, Gent, Catalanotto, & Goodspeed, 1983). It is assumed that people who perceive PROP as more bitter are considered as supertasters and people who cannot perceive PROP or can detect only at higher concentration level is considered as non-tasters. Melis and Barbarossa (2017) proposed that this assumption can be generalized to other tastes as well. They said that supertasters would be more responsive to tastes such as bitter, sweet, sour and fats as compared to non-tasters. Because of this quality, PROP was initially used to identify supertasters and persons with heightened taste responses.

The following method is the fungiform papillae number (FP Number). Fungiform papillae contain taste buds, the density of which varies from person to person. As the FP number increases, the intensity of the signal picked up and sent to central structures also increases, in turn, resulting in the perception of more intense taste. Thus this method involves the identification of the intensity of taste and the subsequent correlation with the number of FP (Webb et al., 2015).

Nagai, Kubota, Katayama, and Kojima (2012) assessed taste perception by using Filter Paper Discs (FPD) of different tastes which are available in different concentrations. The participant is instructed to rinse the mouth with water and a 5mm disc paper is placed in a specific area of the tongue, which is innervated by chorda tympani. Different concentrations can be used for each taste, from lowest to highest.

The least level where a taste is predicted appropriately is considered as the recognition threshold. Filter paper disc test also has an advantage of assessing the taste function of soft palate. FPD method is used to measure the ability of a person to recognize the tastants. Circular FPDs with a diameter of 5mm is soaked in the tastant solutions. The solutions will be of six different concentrations. The FPD will be placed on the tongue surface. Initially, the lowest concentration will be used, and gradually the concentration will be increased until the person correctly indicates the true taste. The concentrations or the threshold of detection will be labelled from 1 to 6, where 1 is the lowest threshold (if the taste is identified at the lowest concentration) and six is the highest, if the taste is identified at the highest concentration (Berling, Knutsson, Rosenblad, & Von Unge, 2011).

Electrogustometer is another clinical tool used for the assessment of taste acuity at various loci, in which a mild anodal electric current is presented with the help of a reloadable probe. The probe is made of stainless steel and is flat, circular with 5mm diameter. The stimuli can be of predetermined duration (0.5, 1, 1.5 or 2 seconds). A feedback stimulus is also generated that ensures low errors. Electroguestometry has a disadvantage that it is limited only to test bitter taste. The threshold index method is the method used to test using electroguestometry. In this method, three samples are provided to the client, wherein one is the solution with tastant, and the other two will be distilled water. The task will be to identify if any of the samples has any taste. The same procedure will be repeated with increasing concentration. The threshold level at which the participant correctly differentiate and identify the taste is termed as threshold index (Berling et al., 2011).

Pavlidis, Gouveris, Gorgulla, Hast, and Maurer (2015) suggested the following method of administration for Electroguestometry. The participants should not drink or eat for an hour before testing. First, a 30dB stimulus will be presented to check if the participant can detect the electroguestometric stimuli. The testing begins with the lowest stimulus amplitude, 6dB. The amplitude is increased gradually until the participant can recognize the stimulus. This electric threshold will be measured at six locations (2cm away from the tongue paramedially on both sides innervated by chorda tympani, the area innervated by the glossopharyngeal nerve that is the vallate papillae of both sides and the area innervated by the major petrosal nerve which is the soft palate, bilaterally). To avoid bias, the order of the areas tested can be randomized. To avoid stimulus adaptation stimulus interval of 3-4 minutes can be used. The participant will be asked to discriminate between the sour/ metallic taste perception (at the gustatory function threshold) and the perception of an electrical sensation (due to trigeminal nerve stimulation). A two-alternative forced-choice method (yes if taste perceived and no if no taste perceived) with single staircase detection method (1 up and 2 down) can be employed. This method is advantageous even in cases where the participant has only a slight issue in detecting taste.

Pavlidis et al. (2015) reported that Electroguestometry is useful, especially in disorders such as Oropharyngeal cancers, diabetes, head and neck cancers, Bell's palsy, trigeminal neuralgia, trigeminal sensory neuropathy. However, Electroguestometry cannot be used in cases of spontaneous dysgeusia, dissociated taste disorder and heterogeusia. Pre-post-surgical or treatment taste alterations can be assessed using this tool. There are several advantages for this method; the range of measured value always remains constant and is quantitative (in dB), it has a short testing period. It is a quick,

portable and secure method of gustatory assessment. It also has outstanding test-retest reliability.

A study done by Berling et al. (2011) studied the correlation between two methods of taste assessment; electroguestometry and filter paper disc method. They reported that both methods are highly reliable and have good reproducibility. The only disadvantage reported was for electroguestometry, as it involves the application of anaesthesia and ingestion of a bitter tastant.

The literature suggests two psychophysical assessments of taste characteristics in humans. First, the method is the absolute sensitivity measurement, which is nothing but the identification of stimulus concentration dissolved in water, and the second method is the Differential threshold measurement, which is the measurement of an individual's ability to detect the minimal change in intensity of taste (Breslin & Spector, 2008). The current study focuses on the Absolute sensitivity measurement to identify the taste perception threshold.

Factors affecting taste perception

Many factors affect taste perception and its threshold, including colour/vision impairments, hormonal influences, genetic variations, and plugged noses. The perception of taste is also affected by other external and internal factors such as poor fetal and early postnatal nutrition (Hales & Barker, 2013), causing ineffectual early development of islets of Langerhans and Beta cells in the body (Report of the Expert Committee on the Diagnosis and Classification of Diabetes Mellitus, 1998), genetic makeup, BMI, alcohol consumption, smoking, corporal needs, consumption of assorted drugs for chronic and acute diseases and surgical management (De Carli, Gambino, Lubrano, Rosato, Bongiovanni, & Lanfranco, et al., 2017), decreased or altered

production of saliva, use of dentures, loss of teeth, dental problems and its treatments and ageing (Saleh et al., 2014). Other causes include the common cold and upper respiratory tract infection (Boyce & Shone, 2006).

Hunger itself affects the taste, as hunger makes individuals more sensitive to sweet and salt. Bitter perception however, is not exaggerated by appetite. Sensitivity also reduces amid 1 and 4 hours after a mealtime, based on what the meal is. Spicy food has a more significant effect than a bland meal.

Smoking also affects taste perception. While smoking the taste buds gets exposed to chemical that significantly reduces the taste buds to sense taste. People with cancer and anorexia have low TPT due to their physical condition. Obese individuals have impaired taste buds. Pregnancy can also alter taste perception. It is reported in almost two-thirds of them. They tends to have a low TPT salt, causing increased salt consumption.

There are no uniform reports of how temperature affects taste, as both low and high temperature can affect taste buds. High temperature increases TPT sweet and lowers TPT salt and bitter. Low temperature increases the sensitivity to bitter and decrease TPT sour.

Food culture also influences taste sensation. Trachootham Satoh-Kuriwada, Lam-ubol, Promkam, Chotechuang, Sasano, and Shoji (2018) compared taste thresholds between populations with different food culture, i.e. Thai and Japanese. A matched case-control study was conducted in 168 adults (84 for each; aged between 50 and 90 years). RTs of sweet, salty, sour, bitter, and umami were measured using the filter paper disc. DTs were measured using electroguestometry. Calibrated

questionnaires measured spicy preference. Higher RTs of all tastes and higher DTs were found in Thai as compared to those of Japanese. Separate analyses of healthy and unhealthy persons confirmed the significant differences between the two countries. The average thresholds for sweet, salty, sour, and bitter in Thai and Japanese were 4 and 2, respectively. The average threshold for umami in Thai and Japanese was 5 and 3, respectively.

Moreover, the Thai population had a stronger preference for spicy food with 70% mild- or moderate and 10% strong lovers, compared to over 90% non- or mild-spicy lovers in Japanese. Besides, 70% of Thai consumed spicy food weekly, while 80% of Japanese consumed it monthly. The findings suggested that population with more definite spicy preference such as Thai had much more inferior taste sensitivity and perception than that with milder preference like Japanese.

Certain medications such as terbinafine, baclofen, phenylbutazone, carbamazepine, dapsone, and levodopa can influence taste perception. Olokoba, Obateru, and Olokoba (2012) reported that chemotherapy using drugs, especially vinblastine and radiotherapy, can also cause gustatory system dysfunction. Schiffman (2018) reported that the drugs used to treat Diabetes which include Metformin and Insulin, also could induce altered taste perception. This can be due to the direct influence of these drug components on taste channels and receptors. However, Metformin induced taste disturbances can be attributed only to 1 in 10 to 1 in 100, as reported by Hillson (2014).

Gender can also influence taste perception, however this is an area of debate. There exist several discrepancies between the existing studies in this matter. (Fikentscher, Roseburg, Spinar, And Bruchmüller, (1977) reported that normotypical

females were more to sensitive all tastes, which was particularly significant after the age of 40 years. Hyde and Feller (1981) reported that the taste perception threshold of caffeine and citric acid (sour) were higher for young normotypical women as compared to men, though no significant difference was reported. However, some other studies reported that the taste perception threshold for bitterness was higher for women as compared to men (Mojet, 2004). Fischer, Cruickshanks, Schubert, Pinto, Klein, Pankratz, and Huang (2013) found among 2374 adults with a mean age of 48.8 years, that females tended to rate their perceived intensity of sweetness stronger than males.

Taste discrimination reduce with age. This could be consequent to the degeneration of the taste buds with increasing age. Sour taste is least affected than the other tastants. The taste thresholds for sweet, salt and bitter are 2.5 times higher in adults. Boyce and Shone (2006) reported that elderly persons need almost two to three-fold more concentration of salt to identify its presence in tomato soup.

Taste perception in healthy elderly individuals

Change in taste or gustatory function is a common event in the process of ageing. According to Boyce and Shone (2006), elderly participants had a higher prevalence of taste loss. However, the self-awareness of this is very less, as their concern focusses more on life-threatening conditions. Most of the time, taste disturbance is due to the defect in olfaction. One theory of ageing and taste disruption assumes that loss of taste function is due to the changes that happen at the cellular and receptor level, including ion channels. This theory does not account for the loss of taste buds or papillae (Boyce & Shone, 2006).

There are several studies related to the quantification of disruption of taste with age. Most studies done in the 1980s found no change in perception for sweet taste with

age (Enns, Van Itallie, & Grinker, 1979; Dye & Koziatek, 1981; Hyde & Feller, 1981; Weiffenbach, Cowart, & Baum, 1986; Cowart, 1989; Murphy & Gilmore, 1989). Hyde and Feller (1981) and Cowart in 1989 found a significant decrease in perception for salty, sour and bitter tastes, Murphy and Gilmore (1989) also found a significant decrease in perception for sour and bitter tastes.

Mojet, Heidema, and Christ-Hazelhof (2003) conducted a study on young adults (19 to 33 years) and elderly persons in the age range of 60 to 75 years. Both the groups had 21 participants each. They reported that intensity discrimination of taste was highly resistant to ageing. They concluded this because both young and elderly group yielded similar results and interestingly during specific trials; the elderly subjects were more accurate than young. For the study, they considered five tastants: sour, salty, sweet, and bitter and umami. Two sets of stimuli were prepared for each taste; one in distilled water and other in natural products such as chocolate drink, ice tea, tomato soup, mayonnaise and bouillon in five concentration levels.

Ng, Woo, Kwan, Sea, Wang and Henry (2004) tried to investigate the effect of age on Umami taste thresholds using the ascending forced-choice method. They considered three age groups: 69 to 94, 36 to 61 and 21 to 34 years. They used pork and beef flavours which were commercially available. They reported that the taste threshold increased with age. They concluded that taste function was abnormal in a healthy elderly population.

A meta-analysis was carried out by Methven, Allen, Withers, and Gosney (2012) who categorized the studies based on the tastant used. In the following paragraphs, the studies considered for this meta-analysis study have been discussed.

Salty taste: The studies that considered NaCl for salt taste reported that the threshold increased with age, especially for males. Accurately speaking, there is a 57-fold increase in the threshold with an increase in age (Bales, Steinman, Freeland-Graves, Stone, & Young, 1986; Schiffman, Crumbliss, Warwick, & Graham, 1990; Mojet, Christ-Hazelhof, & Heidema, 2005; Wardwell, Chapman-Novakofski, & Brewer, 2009).

Sour taste: The studies considered acetic acid, tartaric acid or citric acid for sour taste. One out of the studies which used citric acid reported higher thresholds for younger females compared to older males and females (Mojet et al., 2005). The rest of the other studies reported an increase in threshold with age (Chauhan, 1989; Murphy, Quiñonez, & Nordin, 1995). One of the studies which used hydrochloric acid, reported an increase in threshold as there is an increase in age (Spitzer, 1988). From these studies, it was concluded that there was a 1.5 fold increase in threshold with an increase in age (Methven et al., 2012).

Bitter taste: There were around thirteen different compounds which were used for studies. The most commonly used compound was quinine derivatives and caffeine. Nine different studies were considered, among which only one study (Wardwell et al., 2009) described a hike in TPT with age. From these studies, Methven et al. (2012) stated that the upsurge in TPT was 1.5 to 7.4 fold, for quinine derivatives and caffeine, it was 1.1 to 1.6 fold. Methven et al. (2012) also reported that there was a genetic link in the ability to detect bitter taste.

Sweet taste: In almost ten studies, sweet detection was measured. In all the studies, sucrose was used as tastant. Four studies (Enns et al., 1979; Easterby-Smith, Besford, & Heath, 1994; De Jong, De Graaf, & Van Staveren, 1996; Mojet et al., 2005) found

no age effect on sucrose detection. In the rest of seven studies (Hyde & Feller, 1981; Bales et al., 1986; Spitzer, 1988; Kaneda, Maeshma & Goto. 2000; Fukunaga, Uematsu, & Sugimoto, 2005; Kennedy, Law, Methven, Mottram, & Gosney, 2010), there was a 1.2 to 2.6 fold increase in detection threshold with age.

A few studies investigated the effect of sweeteners on age, like saccharin and aspartame. Two studies (Schiffman et al., 1981; Smith, 1994) which used saccharin found four-times more threshold geriatrics as linked to the young population. A 4.1 fold increase with age was found for studies which used aspartame, but two studies (Schiffman et al., 1981; Mojet et al., 2005) found no age effect.

From this meta-analysis study, it was concluded that there was a decrease in sensitivity of taste perception with an increase in age. However, this decline depended on tastant used and the mode of presentation (such as using taste strips, ascending taste method).

According to Kennedy et al. (2010), older adults had a significantly higher detection and recognition threshold than young adults, with no significant difference between gender groups, suggesting a reduced sensitivity towards sweetness among older adults.

In the Indian population, Krishnaa and Jayaraj (2017) analysed taste perception in twenty participants in the age group of 18-25, 26-40, 40-50, 50 years and above. They who were blindfolded and given different substances to taste and were asked to score the substance based on the intensity of taste. The result revealed sweet was perceived to a better degree, irrespective of age in comparison to the other tastes. There was a change in the perception of taste with age, although the results were not found to

be statistically significant. The decrease in the taste intensities was attributed to the decrease in the number of taste buds and its shrinkage.

Taste Disruption

The sense of taste is a vital part of one's life as it is an enjoyable source of nutrition. In most individuals, the taste is unaltered throughout life; however, in a few, the taste is disrupted due to several factors. This disturbed taste sensation can affect the total physiological and psychological well-being of the individual, in turn affecting the quality of life (Kumbargere Nagraj, George, Shetty, Levenson, Ferraiolo, & Shrestha 2017).

There are several kinds of taste disturbances, namely Hypogeusia, Ageusia and Dysgeusia. Hypogeusia is the reduction of the gustatory function, whereas Ageusia is the loss of gustatory function. Hypogeusia is diagnosed when the patient shows diminished response towards some or all of the tastes, whereas, Ageusia is diagnosed when the individual has a total loss of gustatory sensation even at the highest concentrations of the taste stimuli (Cecchini, Cardobi, Sbarbati, Monaco, Tinazzi, & Tamburin 2018). Dysgeusia is defined as the qualitative taste changes, distorting taste disturbance. All these taste disorders can be associated with central or peripheral cases.

According to Maheswaran et al. (2014), there are three kinds of disruptions of the central nervous system leading to taste disruption; i) Transport problem, which is characterized by the inability of the stimulus to reach the receptor cells, as in salivary dysfunction, ii) Sensory problem, which is characterized by trauma to the peripheral sensory organ, as in trauma to tongue, and iii) Neuronal problem, which is caused by conditions such as neoplasm, where the damage happens to the peripheral nerve or central nervous system due to tumours, injury, infections.

A condition that can cause taste disruption is Diabetes Mellitus. Keny et al. (2014) reported altered taste perception in individuals with Diabetes, due to dysfunction of taste nerve tracts and taste buds/receptors due to neuropathy and microangiopathy, respectively.

Diabetes mellitus

Diabetes mellitus is recorded as one of the age-old diseases known to manhood as per Olokoba et al. (2012). Diabetes is a metabolic disorder characterized by high blood glucose levels as a result of inadequate insulin production or ineffective use of insulin by the body. Diabetes mellitus (DM), according to the ADA (2004) can be a cluster of metabolic illnesses regarded by hyperglycemia, which brings about in subsequent shortcomings in insulin emission and its action. Piero in 2015 described DM as a devastating metabolic disorder.

Every cell in the body needs energy to function, and glucose is one of the primary energy sources. The glucose level in the body is regulated by the pancreatic hormone Insulin (Piero, 2015). Insulin binds to the receptor sites in the cell's membrane and will allow glucose into the cells and tissues through the channels. If glucagon level is high, then glucose will not enter the cell. Instead, it will remain in the blood, leading to hyperglycemia. It causes water to ooze out from the cells into the blood. Also, the sugar is eliminated through urine. The dehydration or excess thirst, and polyuria was seen in diabetic individuals can be attributed to this event. All these finally lay the way to glycosuria. As this condition persists in the body, the cells will lack glucose due to lack of insulin. This condition will force the cell to find an alternative energy source which is the fatty acids stored in the adipose tissue. These fatty acids do not have mitochondria which help in the beta-oxidation pathway. Thus brain, kidney cells and red blood cells will not be able to use this alternative source of energy.

Moreover, the blood-brain barrier resists the entry of fatty acids. Hence, these fatty acids undergo keto-genesis to produce acetyl-CoA, which in turn produce ketone bodies. The brain, kidney cells and red blood cells will utilize this as an alternative energy source. However, the ketone bodies are excreted through urine, causing one of the characteristic features of diabetes, Ketonuria. The presence of these ketone bodies will produce ketosis. Also, it is acidic causing lowering of pH, and this condition is called acidosis. An intermingling of acidosis and ketosis will lead to a condition called Ketoacidosis. If this condition is untreated, it can lead to coma and death (Piero, 2015).

The vast population with DM fall under 2 main groups: Type I Diabetes mellitus or immune-mediated and T2DM. The significant difference between Type I and Type II is that Type I mostly occurs in young children and a few adults because of the impaired beta cells of the pancreas leading to insulin deficiency (an autoimmune disease). Type II (adult-onset metabolic disorder) occurs due to the failure to produce insulin due to loss of beta cells ADA (American Diabetes Association), 2019).

Diabetes Type I is inclusive of about 5-10% of the total individuals with Diabetes, whereas, T2DM holds for around 90-95%. Relative insulin deficiency, insulin opposition, and high blood sugar level are the chief characteristic featured by T2DM. T2DM can result in various complications, both short term and long term (Olokoba et al., 2012).

A third category, "other specific types of diabetes," has been identified which consist of diabetes caused by a precise and recognised fundamental fault (genetic defects or diseases of the exocrine pancreas) (IDF, 2019). According to Cho, Shaw, Karuranga, Huang, da Rocha Fernandes, Ohlrogge, and Malanda (2018), the three

common varieties are type 1 (insulin-dependent), type 2 (non-insulin-dependent), and gestational diabetes.

A more recent classification given by Classification and Diagnosis of Diabetes, Standards of medical care in diabetes (2019) categorizes DM into a few general categories. They are as follows:

1. Type I Diabetes, leading to insulin deficiency and is due to destruction of autoimmune beta cells.
2. Type II Diabetes, leading to insulin resistance due to the inability of beta cells to produce insulin.
3. Gestational diabetes mellitus called as GDM, which is usually diagnosed in the third or second trimester of pregnancy.
4. Specific types of diabetes due to other causes such as syndromes including monogenic diabetic syndrome, neonatal diabetes, chemical induced diabetes or due to organ transplantation or exocrine pancreas diseases or MODY (Maturity Onset Diabetes of the young).

The diagnosis of T2DM can be made in various ways, which has to be repeated twice before confirmation of the diagnosis if the classic symptoms of T2DM are not present (Pop-Busui, 2010). The different tests widely used are:

1. A1C Test: It is the average blood sugar level of 2 to 3 months, i.e., the blood sugar level is tracked every month for 2-3 months, and an average is made. The diagnosis of diabetes is made if A1C value is ≥6.5% and a diagnosis of Pre-diabetic condition is made if A1C value is between 5.7-6.4%. An A1C value <5.7 % is considered as usual.

2. Fasting Plasma Glucose (FPG) – The values are obtained by measuring the blood sugar level. The measurement should be made in empty stomach (last meals should be at least 8 hours before testing). FPG< 100mg/dl is measured as typical, 100-125mg/dl is pre-diabetes and ≥ 126mg/dl is reflected as diabetic condition. According to American Diabetes Association, (2010), the FPG ≤ 70mg/dl is considered as hypoglycaemic, FPG of 100mg/dl is considered as normal, and FPG ≥ 126 mg/dl or higher is considered as hyperglycaemic.
3. Oral Glucose Tolerance Test (OGTT): This test takes nearly 2 hours because the sugar level is measured after drinking a sweet solution 2 hours pre-test. It tells how the body processes the sugar taken orally. OGTT < 140mg/dl is considered as normal, 140- 199 mg/dl is pre-diabetes and OGTT ≥200 mg/dl is considered as diabetic.
4. Random / Casual plasma Glucose Test: This test is done at any point in time when the severity of diabetic symptom is at peak. The diagnosis of DM is made if the blood sugar level is ≥ 200mg/dl.

A combination of pharmacological and lifestyle modification is recommended to achieve reasonable metabolic regulator in DM (Marín-Peñalver, Martín-Timón, Sevillano-Collantes, & Cañizo-Gómez, 2016) along with other associated conditions. Usually, to control body weight, lipid profile, blood sugar and blood pressure, dietary modifications are suggested. Mostly in case of T2DM, a combination of metformin and dietary modifications are suggested in the initial stage. If the disease progresses, a different line of approach is considered, in which other oral and injectable drugs are provided, which is also called as *third-line pharmacological agents*. This third line pharmacological agent includes drugs such as insulin, sulfonylureas, and meglitinides

and alpha-glucosidase inhibitors. Insulin, to date, is the most effective anti-hyperglycemic component, especially for T2DM. It is said to improve many of the associated metabolic problems. It mainly works by reducing glucose production by beta cells by increasing its secretory function, increasing the glucose utilization by increasing the sensitivity of cells to insulin. Thus, abnormal lipoprotein composition will improve (Wu, Ding, Tanaka, & Zhang, 2014). However, the first and foremost option is Metformin which is the *first-line of treatment*. The *second-line of treatment* is considered depending on the degree of blood sugar, the presence of comorbid conditions, and also the accessibility to the treatment. Most of the time, it is an individualized treatment plan considering the risk of Hypoglycaemia (Marín-Peñalver et al., 2016).

Causes of Diabetes Mellitus

According to the National Diabetes Statistics Report, (2020), the cause of Type I diabetes is immune system dysfunction, which destroys the beta cells in the pancreas that produce insulin. They also reported that the risk factors that trigger T1DM are environmental causes, certain viruses and genes. Thus, T1DM can be considered as an autoimmune reaction, which must have started long before the expression of the disease. It is also said that diet and lifestyle cannot cause type 1 diabetes.

The principal causes of T2DM can be endorsed as genetic overlay and lifestyle. As per Begic et al. (2016), T2DM is a multifactorial disease. It is caused due to a variety of interrelated environmental and genetic factors. The risk factors include age, genetic predisposal, Body Mass Index (BMI), alcohol consumption, smoking, and variety of drugs for various chronic and acute conditions, surgical management (REDCDM, 1998; Begic et al., 2016), steady urban migration and lifestyle changes (Kaveeshwar, 2014). Obesity, sedentary lifestyle and physical inactivity are the additional menace issues for

the early occurrence of Diabetes in childhood also in adolescents. The presence of environmental toxins can also has a noteworthy part in the upsurge of rate of the happening of T2DM as reported by Olokoba et al. (2012). The risk factors can also include cardiovascular diseases and abnormal lipid profiles.

Prevalence and Incidence of Diabetes Mellitus

Statistics from IDF (2015) showed that diabetes prevalence increased from 8.3% (382 million) in 2013 to 8.8% (415 million) in 2015 among the world's adults aged 20 to 79 years. Additionally, the top three countries with the most significant number of adults with diabetes in 2015 were China, India, and the US (Ogurtsova, Rocha Fernandes, Huang, Linnenkamp, Guariguata, Cho, & Makaroff, 2017). As per the reports in 2017, India, which is a developing country, is second in housing highest number of diabetic patients, first being China (Tripathy, Thakur, Jeet, Chawla, Jain, Pal, & Saran, 2017). Tripathy et al. (2017) also reported that Indians tend to have innate insulin resistance and a higher genetic predisposition, thus making Indians more prone to develop diabetes. From this study, it was reported that 8.3% was the prevalence of diabetes and 6.3% was the prevalence of prediabetes. The age group considered was 45 to 69 years.

The National Urban Diabetes Survey (2017) reported based on a statewide study that the prevalence of DM was 5.9% and 2.7 % respectively for urban and rural India. This was also reported by The Prevalence Of Diabetes in India Study (PODIS). Two cities in Chandigarh had the highest prevalence, of 13.6%. The Chandigarh Urban Diabetes Survey (CUDS) also reported 11.1 and 13.2%, respectively as the prevalence for DM and Pre-diabetes in Chandigarh (Tripathy et al., 2017).

A huge cross-sectional research was conducted in the rural part of West Bengal in the year 2016, and they considered participants above 18 years of age. They found that 2.95% was the prevalence of DM and 3.34% was the prevalence of pre-diabetic condition (Barik, Mazumdar, Chowdhury, & Rai, 2016). Another study carried out by (Little, Humphries, Patel, & Dewey, 2016) established that in India the highest prevalence for T2DM was in rural south India, who considered the population above 19 years of age.

In 2011, a study was carried out in 3 states and 1 union territory belonging to India, Tamilnadu, Maharashtra, Jharkhand and Chandigarh respectively. They used a stratified multistage sampling design and considered participants above 20 years of age. Prevalence of DM stayed 10.4% (Tamilnadu), 8.4% (Maharashtra), 5.3% (Jharkhand), and 13.6% (Chandigarh) and the prevalence of pre-diabetes was 8.3%, 12.8%, 8.1% and 14.6% correspondingly for Tamilnadu, Maharashtra, Jharkhand and Chandigarh. They conveyed that the risk factors remained family income, obesity, hypertension and family history (Anjana, Pradeepa, Deepa, Datta, Sudha, Unnikrishnan, & Mohan, 2011).

Magliano, Islam, Barr, Gregg, Pavkov, Harding, and Shaw (2019) conducted a systematic review to identify the trends in the incidence of type 2 Diabetes. They considered all the studies from 1980 to 2017. They reported that in most of the countries, the incidence of diagnosed diabetes was rising from the 1990s to 2000s, after which it showed a falling trend. They attributed this achievement to the awareness campaigns and public awareness programmes.

The American Diabetic Federation in 2019 reported that in developing countries, the most commonly affected age group was 40 to 60 years (working-age

group). In developed countries, the incidence was above the age of 60 years (Classification and diagnosis of diabetes; Standards of medical care in diabetes, 2019).

The prevalence of DM across gender has also been reported. A study was carried out in Sweden in 705 males and 688 females of 70 years of age. They found that the prevalence of T2DM was 9.1% in females and 14.6 % in males. The authors explained that this difference was because of the higher body mass index and adiposity in males than in females, which makes males more prone towards developing T2DM (Nordström, Hadrévi, Olsson, Franks, & Nordström, 2016). In the Indian scenario, studies report conflicting results. Gutch, Razi, Kumar and Gupta (2014) reported a higher prevalence in females than males in North India. In contrast, another study (Ramachandran, 2014) reports that in South India, males have a higher prevalence than females.

Symptoms of Diabetes Mellitus

Maximum of the indications are alike in in cooperation types of DM, but they vary in their degree and time of commencement (Ship, 2003). T1DM has a rapid onset, while the symptoms of T2DM develop gradually. The classic triadic symptoms of DM including polyphagia (excessive eating or appetite), polydipsia (abnormal increase in the urge to drink water), and polyuria (production of an excessive amount of diluted urine) may be present. Besides, weight loss, fatigue, constipation, candidiasis and blurred vision are few of the most common symptoms (Bearse, Han, Schneck, Jacobsen, & Adams 2004). The other associated symptoms include irritability, drowsiness, and fatigue.

Bearse et al. (2004) also reported that if the disease is longstanding, then certain microvascular and macrovascular complications such as heart and vascular diseases can

also result. Many patients develop diabetic ketoacidosis, which occurs when cells use alternative energy-producing mechanisms, leading to high levels of by-products called ketoacids. Ketoacids acidify the blood, leading to dangerous acid-base disturbances. Diabetic ketoacidosis causes abdominal pain, nausea/vomiting, and drowsiness and is a potentially life-threatening condition.

According to Cho et al. (2018), there is a long asymptomatic time period throughout which the disorder can go undetected. Thus, when diagnosed, a substantial proportion of people have various microvascular complications related to diabetes. Olokoba et al. (2012) reported that more than twenty-five per cent of patients at the time of diagnosis of T2DM had microvascular complications. These adults with poorly controlled long-standing diabetes may advance micro-vascular and macro-vascular situations that can produce permanent injury to the retinal system (retinopathy, cataracts), renal system (nephropathy), neurons (neuropathy and paraesthesia), and cardiac system (speeded atherosclerosis). It can cause repeated infections and decreased wound healing. Weak body, increased sweat, mental muddle, in-coordination, and quaking occurs when an individual serum glucose level falls under 50 to 70mg per decilitre, these indications become more (damaged of consciousness and seizures) when intensities fall underneath 40 mg/dL. Acute (e.g., diabetic ketoacidosis, hypoglycaemia) and chronic (e.g., CVDs, diabetic nephropathy) complications of diabetes cause disability and death worldwide (Cho et al., 2017).

The microangiopathy can lead to dysfunction in the taste buds/receptors due and the dysfunction in the nerve tracts due to neuropathy can alter the taste perception in individuals with DM (Keny et al., 2014).

Taste perception and palatability in Diabetes mellitus

Ship (2003) described that further one-third of adults with DM had Hypogeusia. Sheil (2020) defines hypogeusia as the reduced ability of a person to perceive taste stimuli. Hypogeusia occurs due to peripheral neuropathy and microangiopathy involving taste receptor cells is responsible for the altered taste perception (Khera & Saigal, 2018).

Taste disturbance in DM is a known fact, but the underlying cause is unclear. Several authors tried to explain this mechanism through different schools of thoughts. One school of thought is that the taste disturbance can be due to the neuropathy and associated degeneration of the taste nerves. As the level of glucose in intercellular space increase, it hints to the creation of Advanced Glycosylation End products (AGEs), which binds to the receptor sites. These AGEs have cross-linking proteins such as collagen and extracellular matrix proteins. All these will alter the extracellular matrix structure and composition and will induce endothelial dysfunction. The continued presence of hyperglycemia can activate protein kinase C (PKC). This PKCs will alter the transcription of extracellular proteins in the endothelial cells and neurons, causing retinopathy, neuropathy and renal complications (Puranik, 2017).

Puranik (2017) suggested that the acquired or congenital defect in taste receptors or the abnormality in the underlying mechanism for the appreciation of taste in the brain or microangiopathy can be the other causes of taste disturbances. Gondivkar et al. (2009) reported that previous studies suggest a direct correlation between the blood glucose level and taste perception ability. They attribute this effect to a generalized taste sensing defects in the taste receptors, rather than neuropathy.

A few studies have tried to assess the taste perception in persons with DM. Lawson, Zeidler, and Rubenstein (1979) reported that perception of sweet taste was affected in T2DM compared to Type I. To define if a general shortcoming in glucose appreciation occurred in DM, TPT and palatability were assessed in Adult Onset Diabetics (AOD), Juvenile Onset Diabetics (JOD), and fit first degree relations of individuals with DM (NR). Controls were age and gender matched non-diabetics deprived of first-degree diabetic relations. The AOD and NR groups displayed significantly advanced glucose starting point than their controls. In divergence, glucose threshold in JOD was not dissimilar from the controls. The AOD collection also established advanced sucrose TPT than controls. This alteration was not existing for JOD or NR groups. No alteration in salt TPT was seen in any of the groups. Palatability was measured by two choice conditions and scores of test solutions of variable concentrations. No significant alteration in glucose or sucrose preference was noted, but both the AOD and NR groups liked low salt concentrations than controls. Their results specified that there might be an extensive damage of cellular glucose recognition in AOD and their relations, while JOD had a precise beta-cell defect.

Dye and Koziatek (1981) explored the relationship of age and diabetes to the threshold and perception of the hedonic qualities of sucrose solutions. A significant increase in threshold beginning in the eighth decade was observed. Diabetic persons did not differ significantly in the threshold for sucrose from non-diabetic subjects. Younger individuals tended to judge suprathreshold solutions as sweeter than older persons. Results from pleasantness ratings were less clear but could be taken to imply that the younger, more recently diagnosed diabetic found it more challenging to stay on a restricted diet necessary for the control of diabetes than the older diabetic.

Other researchers investigated the outcome of hypoglycaemia in DM on gustatory responses to sucrose in phenylthiocarbamide (PTC) tasters and PTC non-tasters, before and after the consumption of a glucose solution (Bhatia & Sharma, 1991). After a 12-hour overnight fasting, pre-screening for PTC sensitivity was done in each. Each of them tasted, and rated, 7 concentrations of solutions for intensity and hedonic responses. Blood glucose levels were also dogged under fasting and then after a 100g glucose burden. A reduction in palatability of the glucose solutions convinced by the glucose load (negative alliaesthesia) was obvious in both groups. Tasters displayed higher hedonic ratings, as paralleled to non-tasters and this variance was more obvious after the glucose load in non-tasters.

Tepper, Hartfiel, and Schneider (1996) investigated the relationship between sweet taste function and dietary intake in 21 patients with T2DM and 16 age, weight, and gender matched controls. Participants graded the sweetness intensity and pleasantness of a series of potion samples sweetened with sucrose: 1.5–24%, fructose: 1–18%, or aspartame: 0.25–4%. They also kept 7-day food records. No group variances were found in sweet TPT, pleasantness ratings, daily energy intakes, or macronutrient alignment of the diets. Though, individuals with T2DM consumed less sugar but 3.5 times more substitute sweeteners than controls. Peak pleasantness ratings for the beverage samples positively correlated with dietary sweetness in T2DM but not the controls. These results recommend that in diabetes, hedonic ratings for a sweetened beverage were related to dietary sweetness intake rather than changes in TPT sweet.

A study was conducted for testing taste perception using the whole mouth, above threshold taste test (Mann, 2002). There were three groups. Group, I consisted of the uncontrolled diabetic group and Group II comprised of controlled T2DM

patients, and Group III consisted of normal healthy individuals. The results suggested that the Group III responded at a lower concentration level and Group I responded at higher concentration level and Group II in between for sweet, salty and sour tastes. However, the taste perception threshold for bitter was achieved at a lower concentration level for all the three groups. These results suggested that the taste perception or response in the Diabetic population was affected for sweet, salty, and sour taste, but not for bitter taste.

Navvabi, Farzad, and Alaeei (2009) evaluated the taste sensitivity between diabetic and non-diabetic individuals. They found that for sweet and salty taste, individuals with DM had less sensitivity even though their blood sugar level was under control with medication. However, for the sour and bitter taste, there was no difference between both the groups. They also reported that there was no age, duration of diabetes and gender effect. This study was a single-blind case-control study with 99 participants.

In 2009, Gondivkar et al., carried out a study to assess the gustatory function in individuals with T2DM and compare it with normals. The study consisted of a total of 120 subjects (51 females and 69 males). In the experimental group, there were 40 controlled (19 females and 21 males) and 40 uncontrolled (15 females and 25 males) diabetes patients. The whole mouth above threshold test was carried out using NaCl, Citric acid and Quinine hydrochloride solutions. They found that taste perception for all the tastes were impaired in the experimental group compared to the control group. On comparing the tastes, sweet taste was having a highly statistically significant difference followed by sour and least for salt. Hypogeusia was observed in 50 (62.5%) of the participants in the experimental group and 5 (12.5%) of the control subjects. The authors stated that this blunted taste response to sweet taste could be due to the increased consumption of sugar and pre-existing hyperglycemia. Also, ageusia was

found in six of the uncontrolled diabetic subjects. From this study, the authors concluded that individuals with T2DM have a reduced taste response for all the tastes.

Dey and Inamdar (2011) compared the tasting ability in people with diabetes and non- people with diabetes for taste parameters like sweet, sour, salty, bitter and Phenylthiocarbamide (PTC) in 65 subjects with DM and 30 control subjects. The results revealed that there was significantly lowered tasting ability of the diabetic subjects for sweet, salt, sour and bitter solutions as compared with the controls. Highly significant results were observed for sweet taste. However, no significant difference in PTC tasting ability was observed between the two groups. It was concluded that diabetes affects the tasting ability for all tastes except PTC.

Dey and Inamdar, (2012) studied 30 male and 35 female diabetic subjects for their taste perception of different tastes like sweet, sour, salty, bitter and PTC. On comparison, it was found that there was no significant difference ($p>0.05$) in tasting ability of male and female diabetics for different taste parameters.

Khobragade, Wakode, and Kale (2012) assessed the relationship between taste threshold in type 1 diabetics and non-diabetics for four basic taste modalities (i.e. sweet, salt, sour and bitter). They studied 70 cases of type 1 diabetic and 70 non-diabetics. The taste threshold was evaluated using seven different serially half diluted concentrations of glucose (2.00 M–0.031 M), NaCl (1.00 M– 0.0156 M), citric acid (0.05 M– 0.0007 M) and quinine sulphate (0.001 M–0.000015 M). A significant increase in taste threshold for all the four tastes was seen. They concluded that taste sensation was reduced in Type I diabetics.

Wasalathanthri, Hettiarachchi, and Prathapan (2014) conducted a study to measure the sweet taste sensitivity in pre-diabetics in contrast with individuals with DM and with normoglycemic controls. Forty pre-diabetics, 40 diabetics and 34 normoglycemic controls were studied. The 3 groups were matched for age, sex and BMI. The division into groups was based on their glycated haemoglobin levels. The detection and recognition thresholds were estimated by the multiple forced-choice methods using sucrose solutions prepared in ¼ log dilutions. The intensities of perceived sensations for a sequence of suprathreshold concentrations of sucrose solutions prepared in ½ log dilution were determined by rating on a visual analogue scale. The mean detection thresholds of diabetic, pre-diabetic and normoglycemic groups were 0.025, 0.018 and 0.015, respectively, with a significant upsurge in the diabetic group matched to the normoglycemic group. The mean recognition thresholds were not diverse among the three groups. When the intensity ratings for suprathreshold concentrations of sucrose were equated between the 3 groups, for all suprathreshold concentrations tested, significant differences were observed across the four concentrations and between groups in suprathreshold ratings. The diabetic group had significantly lower suprathreshold ratings than the normoglycemic group. Although all mean suprathreshold intensity ratings of the pre-diabetic group were between the normoglycemic and diabetic groups, the differences were not significant. The results of the present study did not support the hypothesis of decreased sweet taste sensitivity of pre-diabetics. However, the results established the presence of blunted taste response in people with DM.

Gaphor and Saeed (2014) assessed the relationship among TPT in type 2 diabetics and non-diabetics patients for four rudimentary taste modalities. This single-blind case-control research was executed on a 100 DM patients and a 100 healthy

individuals for detection of taste sensitivity for 4 prime tastes. TPT were perceived by the whole mouth taste method and the use of 5 concentrations for each taste. The results specified the taste threshold measured for each generated normal range for all tastes in the DM group (0.032molar for sucrose, 0.032for NaCl, 0.001molar for citric acid and 0.00001molar for quinine hydrochloride). Still, there was a substantial difference in the perception of sweet and salt taste between the two groups.

The threshold index test of sweet taste was used by Dias, Brazil, Almeida, Silva, and Milagres (2016), to evaluate the taste perception in individuals with T2DM. There were a total of 80 adults within the age range of 20-55 years. There was an equal number of participants in both experimental and control groups. The test utilized five ascending concentrations of sucrose. They found that the individuals in the experimental group were less sensitive towards sucrose. Thus they had a higher threshold index value. They concluded that this dysfunction in the detection of sucrose could lead to increased intake of carbohydrates leading to increase in the blood sugar level. They attribute this decreased taste sensitivity to xerostomia (Hyposalivation).

De Carli, Gambino, Lubrano, Rosato, Bongiovanni and Lanfranco et al. (2017) also conducted a case-control observational study to compare the taste perception thresholds between individuals with T2DM and normoglycemic controls. The participants were coordinated for gender, age, and BMI. All participants were within the age range of 18-65 years. A validated forced-choice Ascending-concentration method was employed for four tastes: sucrose (sweet), sodium chloride (salt), citric acid (sour), and quinine hydrochloride (bitter). This study used ten continuously increasing concentrated solutions in a series. $1.25 \times 10{-}3$ to $6.4 \times 10{-}1$ mol/L for sucrose, $1.25 \times 10{-}3$ to $6.4 \times 10{-}1$ mol/L for sodium chloride, $4.88 \times 10{-}5$ to $2.5 \times 10{-}2$ mol/L for citric acid, and $3.11 \times 10{-}7$ to $1.6 \times 10{-}4$ mol/L for quinine hydrochloride were the

concentration ranges. The diluted stimuli were prepared by mixing the concentrated solutions in deionized water. A number was assigned to each of the concentration levels, where 1 was the highest concentration, and 10 was assigned to the lowest concentration level. Three sets of 15ml solution were presented in each step; one was with the stimuli, and the other two were just deionized water. The task was to classify the container with the taste stimuli, followed by the identification of the taste. The order was randomized. The lowermost concentration which they were able to identify and differentiate between the tastes correctly was noted. This threshold was considered as a recognition threshold. To avoid carryover effect, the participants were asked to spit out the stimulus and then rinse the whole mouth in deionized water after each trial. The results revealed that the taste perception threshold was higher for all four tastes for the type II diabetic group as compared to the normoglycemic group. The authors associated this higher sensitivity with the increase in Body mass index. The increased taste perception threshold was also attributed to the reduced salivary flow and the increase in the density of the saliva in the DM population along with a higher incidence of oral complications like oral candidiasis. According to them, these hampered the transportation of tastant to the receptor leading to an escalation in the recognition threshold. One shortcoming of this study was a smaller and unequal sample size, due to which the generalization of the result to a larger population for management is difficult.

In 2017, a study was carried out by Yolanda, Antono, and Kurniati in 20-55-year-old Indonesian participants. There were two tests, taste threshold test for sweet and Hedonic test for sweet at five different concentrations. For preparing sample was used. The ascending forced-choice method using sucrose was used to find the RT. For the Hedonic test, the participants were asked to give a score on the 9-point hedonic

scale for sweet tea at various intensities. They found that females were more sensitive towards sweet and obtained lower scores on the hedonic scale, indicating low liking. The authors explained that sensitivity towards the taste might influence the food choice. Reduction in sweet taste sensitivity was noticed even in healthy individuals with positive family history. Such individuals tend to prefer more sweet in food, leading to overconsumption of sugar which may lead to the development of diabetes mellitus (Yolanda, Antono, & Kurniati, 2017).

A study was carried out by Khera and Saigal (2018) to identify the taste perception threshold differences between normal healthy individuals, controlled T2DM and uncontrolled T2DM within the age range of 24- 73 years. There were three groups; Group I comprised of uncontrolled diabetics and Group II comprised of controlled diabetics, and Group III consisted of normal healthy individuals. A total of 120 participants were considered for the study. This study used the whole mouth above threshold and localized taste test, using the four tastes, sucrose (sweet), sodium chloride (salt), citric acid (sour), and quinine hydrochloride (bitter). In the whole mouth, above the threshold method, the participant was presented with three sets of stimuli in a set. One which contained 5ml of stimulus and the other 2 had 5ml distilled H2O. The participants were asked to take one cup at a time and keep the content for 15 seconds, stimulating the whole oral cavity. Then the participants were asked to spit out and rinse the oral cavity with distilled water after each trial and identify taste perceived. If they were not able to recognise the taste, a higher concentration. The procedure was continued until the taste was correctly identified. The level at which they recognise the taste appropriately, noted as detection threshold. Scores were assigned to each concentration level; 1 for the highest concentration level and 5 for the lowest concentration level. The second test was the spatial (localized) taste test, which was

used to identify the ability of participants to identify taste at different points of the tongue. Right and left anterior and posterior-lateral surface of the tongue and two sides of soft palate, lateral to the midline were the six sites considered for the study. The tastant was kept in these areas for 5 seconds. The stimuli were of the highest concentration mixed in distilled water. The two-centimetre distance was kept as a reference from each point of application of the stimulus. The results of the whole-mouth, an above-threshold taste test of the sweet, salty and sour taste suggested that there was a trend toward decreased sensitivity from Group III to Group II to Group I ($P< 0.01$). However, there was no significant difference for the bitter taste in all the three groups ($P > 0.05$). Sixteen participants in Group I and one participant in Group II had hypogeusia of sweet taste. Seven participants in Group no participants and I in Group II had hypogeusia of salt taste. In Group I, six participants showed hypogeusia to sour taste, whereas no participant showed hypogeusia in Group II and III. None of the participants across the three groups exhibited hypogeusia of the bitter taste. This study reported an altered taste perception for all the four tastes and more for sweet. The results of localized taste test showed that all the areas for taste in tongue were affected except, right posterior tongue for salty taste and left posterior tongue for bitter taste. It was concluded that the diabetic patients had an increased satiation effect of sweet, sour and salty taste and consequently needed an increased quantity of these for them to be perceived. Recent studies have reported that peripheral neuropathy associated with duration of diabetes has a secure link with disruption in taste (Puranik, 2017)**.** They did a study to compare the taste perception ability of DM and non-DM individuals. They concluded that sweet and salty taste perception was significantly lowered for diabetic participants. However, for bitter, sour and umami taste, no significant change was found amongst both groups.

Diabetes Mellitus and Xerostomia

Saliva acts as a medium that transmits the tastants or the taste molecule to the taste buds so that the sensation can be detected for processing (Dietsch et al., 2018). However, in persons with DM, dry mouth or xerostomia is commonly reported. Xerostomia is defined as the subjective complaint of dry mouth (Villa, Connell, & Abati, 2015). This can be manifested as dryness in the oral cavity and lips, urge to drink more water. Xerostomia is the perception of dryness of the mouth. In contrast, the objective measure of the same is Hyposalivation (decreased saliva flow), as reported by López-Pintor et al. in 2016.

According to Ship (2003), dry mouth is a principle complaint associated with individuals diagnosed with Diabetes. It may or may not be accompanied with salivary gland hypofunction. According to Saleh et al. (2014), the reduction in salivary flow in individuals with diabetes could be due to the dysfunction of gland parenchyma or due to the disturbances in the microcirculation to the salivary glands, dehydration or the imbalance in the glycaemic level. This may be an indication before the actual medical diagnosis of Diabetes. Chronic dryness in mouth or xerostomia may affect swallowing, speech, chewing, denture usage broad well- being (Villa et al., 2015).

Ambaldhage et al. (2014) reported that disruptions in taste could be related to xerostomia. López-Pintor et al. (2016) reviewed articles related to dryness, Hyposalivation and salivary flow in DM. They reported that most of the studies found a higher prevalence of xerostomia and reduced salivary flow rates in individuals with diabetes. They reported that several epidemiologic studies indicated xerostomia as one of the customary conditions that accompanies diabetes. They also stated that individuals with diabetes mostly have lower salivary rate, all of which can lead to poor quality of life.

A study was conducted on 154 DM patients and 50 normals to investigate the presence of Xerostomia along with DM. Three questions from Xerostomia inventory given by Fox, Busch, and Baum (1987) was used. The questions were 1) Do you feel that your mouth is dry? 2) Do you have any difficulty eating dry food? 3) Do you feel that your tongue sticks to the palate when you wake up in the morning? They had used intraoral examination to check for symptoms of oral dryness. It was found that 64% of the total participants had oral dryness, and 62% had xerostomia (Fox, Busch, & Baum, 1987).

Another study was carried out in 17 DM patients and 16 controls to check for the prevalence of xerostomia (Carda, Mosquera-Lloreda, Salom, Gomez De Ferraris, & Peydró, 2006). It was found that the prevalence of xerostomia was 76%.

Summary of literature

The quality of life is disturbed when any factor disturbs the taste sensation, in turn affecting the total physiological and psychological well- being of the individual (Kumbargere Nagraj et al., 2017). There are reports that in individuals with DM, the taste perception can get affected due to complications such as neuropathy and microangiopathy. Several studies assess the taste perception in DM using varied methods.

From the literature review, it is clear that there exists no consensus between the results, even if there is an overlap between the procedure and variables. Certain studies reported that all the tastes are affected, while certain other studies advocate that only sweet taste was affected. Some studies report that it is getting affected in a hierarchy, which is a reduced taste response for sweet followed by sour and salty tastes. Thus,

there is a need to confirm as to which tastants' perception is affected in individuals with Diabetes Mellitus Type II.

The existing studies explore the taste perception in T2DM, however, the literature exploring the effect of palatability and xerostomia on taste perception is scarce. Pleasantness is a factor that determines how well a person consume that food. Thus, it is essential to assess this factor. Another point is that most of the individuals with T2DM also complain about dryness in the mouth. This is also considered as one of the early symptoms. None of the existing sources of the literature suggests about the link between xerostomia and dryness of mouth, palatability and Taste perception. Thus, it is very indispensable to test and know the relation between these three.

There exists a debate about the effect of gender on taste perception. Some studies report that women have higher taste perception problems, while others report that males have more issues. Certain other studies report that there is no gender effect. Thus, studies assessing the effect of gender on taste are also indispensable.

One more significant need for the current study is that most of the studies done in this are in the western context. Of the Indian studies, most of them are done in the Northern part of India. Since India is a diverse country with different culture, tradition, cuisines, there exist a need to study the taste perception in individuals with Diabetes Mellitus Type II, particularly from the southern part of the country. The understanding of the taste perception abilities will help to enhance treatment programmes to compensate for these sensory losses. Keeping all these aspects in view, the present study was designed to investigate the taste perception in individuals with Diabetes Mellitus Type II. The details of the method are presented in the next chapter.

Chapter III

Method

The current study aimed at investigating the taste perception in individuals with Diabetes Mellitus Type II, for three different tastes (sour, sweet, salt).

Participants

A total number of 100 participants were included in the study. The participants were selected from a health check-up camp conducted by Government of Kerala at a public health centre, Poothadi, Wayanad. The 100 participants involved in the study were divided into two groups, 50 in each group. Group I consisted of 50 neurotypical and normoglycemic adults (25 males and 25 females) with no history of Diabetes Mellitus (control group), and Group II was inclusive of 50 adults (25 males and 25 females) with Type II Diabetes Mellitus (T2DM, experimental group). The age of the participants ranged from 40 to 70 years of age.

Of the fifty participants in the experimental group, forty seven were having diabetes since 5-15 years, whereas three of them were having diabetes since 16-25 years. They were under medication since 5-15 years and 16-25 years respectively. Forty seven participants were taking metformin as their medication whereas three of them were taking insulin. Thirty seven participants were having blood sugar level between 125-300 mg/dl and fourteen of them had blood sugar level between 300-500 mg/dl. All the participants of the control group had normal blood sugar level (<200 mg/dl). Twenty eight participants in the experimental group reported of dryness and twenty two of them reported no dryness. Whereas in the control group two participants reported of dryness and forty eight reported no dryness. In the experimental group thirty two participants reported taste change eighteen had no change in taste reported. In the

control group two reported of change in taste and forty eight participants reported no taste change.

Participant selection criteria

All ethical procedures were followed. Consent letter was obtained from all the participants by explaining the procedure and purpose to each of them separately. Permission to conduct data collection was obtained from the medical officer of the area through a letter.

The participants in the experimental group were selected based on the medical reports regarding the diagnosis of T2DM. Those with the FPG (Fasting Plasma Glucose) Level ≥ 126 mg/dl or higher was considered under the experimental group. This criterion was recommended by the American Diabetes Association (2010). With the help of an informal assessment sensory, cognitive, communicative, oro-motor, neurological and psychological issues were ruled out. Also, the individuals with the presence of mucosal diseases or cancerous conditions of the tongue, infections (e.g. viral/ bacterial/ fungal infections), trauma to tongue, thyroid issues, poor oral hygiene, habits such as alcohol consumption, smoking, dental problems, nutritional deficiencies (e.g. Iron/ Zinc/ Copper deficiencies), peripheral or central nervous system problems like head trauma, cerebral infarction, cerebral haemorrhage were excluded.

Fifty individuals matched on age and gender comprised the control group in this study. Those individuals without any history of neurological disease or psychological illness and with no history of cognitive, communicative and sensory deficits were selected, which was ruled out through an informal assessment.

Materials

The materials utilized for the study were:

Xerostomia Inventory (W. Murray Thomson, Chalmers, Spencer, & Williams, 1999) It is a questionnaire with a severity rating scale to assess the dryness in the mouth. It consists of 11 questions which can be rated as Never-score 1, Hardly ever- score 2, Occasionally- score 3, Fairly often- score 4, Very often- score 5. The questions and the rating scale were explained to each participant for better results. The Xerostomia Inventory provides a continuous scale score that represents the severity of xerostomia, which indicates the underlying characteristics. It is a summated rating scale. This inventory consists of behavioural and experiential aspects. This 11 question inventory is a short version of the original, and it also has acceptable psychometric properties. Researchers reported that this short version is valid concerning self-reported oral dryness (Thomson, Murray, Putten, De Baat, Ikebe, Matsuda, Enoki, Ling et al., 2011).

Words only version of 9 points Hedonic rating scale: This scale was used to measure the palatability of the tastant (Peryam & Pilgrim, 1957). This was used after the presentation of each tastant. The participants were asked to assess the taste and score on this scale of liking. It consists of numbers from 1 to 9, where the numbers are labelled as 1-dislike extremely, 2- dislike very much, 3-dislike moderately, 4- dislike slightly, 5-neither like nor dislike, 6-like slightly, 7- like moderately, 8- like very much, 9- like extremely. This words only version was chosen for the study as it is better than the Hedonic general labelled magnitude scale (Kalva, Sims, Puentes, Snyder & Bartoshuk, 2014) as, the Words the only version of 9 point Hedonic rating scale has the description of each number, thus avoiding confusions while rating.

Kalva et al. (2014) stated that the 9-point scale is the most commonly used scale by food scientists. This hedonic scale is handy to know the food preference, also called as overall liking of food. They also reported that it is easy to use and understand. It is a self-explanatory scale and requires moderate instructions from the tester.

Stimuli

Three different tastants were used as the stimuli, namely salt, sugar, and sour. All the tastants were prepared from commercially available eatable products. Concentrated solutions were prepared by mixing cooking salt, powdered sugar and cooking purpose citric acid to distilled water to make salt, sugar and sour solutions respectively. To measure, a measuring spoon and measuring cup was used.

Stimulus preparation

All the three stimuli were prepared from commercially available cooking purpose products, that is cooking salt, sugar powder, citric acid powder. The concentrated stimuli were prepared in 100ml of distilled water. For sugar solution, 100 ml of distilled water was taken, measured in a measuring cup, and ¼ teaspoon of powdered sugar (0.25 grams) was added and mixed. The sugar powder was continuously added until the saturated solution is formed, that is, the level at which 100 ml of distilled water can no longer dissolve the sugar powder. The same procedure was practised for preparing salt and citric acid solution. The final concentrated sugar solution salt solution and the citric acid solution contained 3 grams of sugar powder, 1.25grams of salt powder and 1.5 grams of citric acid powder respectively in 100ml of distilled water. The same proportion was followed to make a larger quantity of concentrated solution for testing purposes.

Pilot study

A pilot study was conducted before the actual study to check if the framework for the study was feasible and also to estimate the approximate time required to complete data collection for each participant. For the pilot study, three healthy adults and three individuals diagnosed with T2DM were selected. All the steps and procedures planned for the study was executed. The results showed that the framework was feasible

and the approximate time required to collect data was from 15-20 minutes for each participant. The instructions and explanations given were in their regional language, which was Malayalam in such a manner that it was comprehensible for the participants.

Procedure

The participants were grouped under diabetic and neurotypical and normoglycemic group after checking their recent medical record consisting of their medical history and blood glucose level.

Test environment and patient preparation

The procedure for data collection started by obtaining consent from all the participant. This was followed by collecting demographic details using demographic data sheet prepared for the study. The information about the participant's general health status, medical history and associated problems were obtained. Through informal assessment, the presence of elements under exclusionary criteria was identified, and the individuals with sensory, cognitive, communicative oro-motor, neurological and psychological issues were eliminated. Also, those with the presence of any of the exclusionary criteria were excluded from the study.

The participants were seated upright on a comfortable chair and were asked to clear their mouth using distilled water. The participants were asked to sit upright in a chair comfortably in a room with no distracters. The seating was made near to a washbasin, for the ease of spitting the solution after each trial.

Each participant was instructed separately before the data was obtained from them. The instruction given was "Please sit straight and comfortably, you will be given a solution, which you will have to keep in the mouth for 5 seconds and then spit it out to the washbasin. After spitting, indicate if you perceived any taste. If yes, you have to

tell the taste." The participants were instructed to clear their mouth with distilled water to clear out the residue after every trial.

Data acquisition

The Xerostomia Inventory (Thomson et al., 1999) was administered, and the dryness in the mouth was rated. While administering the questionnaires, the participant was asked to choose the appropriate option. The Forced choice method was used to identify the taste perception threshold using the following procedure. A mixture of 10 ml distilled water and 1ml saturated solution of one of the tastant was provided, and the patient was asked to keep the entire solution in the oral cavity for 5 seconds. Then the participant was asked to report if any kind of taste is perceived. If the participant was able to identify the taste without any confusion, then that level was considered as the taste perception threshold. If no taste was perceived, then the concentration was gradually increased by adding one more ml of the saturated solution. The measuring cup was used to measure distilled water, and a syringe was used to measure the concentrated solution. The stimuli were presented to the participant in a transparent cup. Between each trial, the participant was provided with distilled water and was instructed to clear mouth by rinsing water in the mouth for three times as recommended by Todd, Butler, Plonk, Grace-Martin, and Pelletier (2012).

Once the taste perception threshold was identified, then the Words only version of 9 point Hedonic rating scale (Peryam & Pilgrim, 1957) was provided to measure the palatability of that tastant, say saturated sugar solution. The nine points in the rating scale were explained to the participant, and the participants' response was documented. The numbers and what it represents was explained to the participants. The participants were asked to give the rating separately for each tastant.

Likewise, second tastant salt (saturated salt solution) and third tastant sour (citric acid solution) were presented to the participant in the same manner to assess the taste perception threshold, followed by the administration of the hedonic rating scale. The order of presentation of stimuli was randomized and was unknown to the participants to avoid bias. For each participant, the minimum level at which a taste is perceived was noted as the Taste Perception Threshold (TPT). Special care was taken to avoid bias from others, such as caretakers or other participants.

Assessment of test-retest reliability

To ensure the test-retest reliability, all the procedures were administered again on ten per cent of the participant sample selected randomly from both the groups after 1 week. Testing was done again on 10 random participants from each group.

Analysis

The set of data of interest was acquired from all the participants of both the groups; the taste perception threshold in ml, Oral dryness severity rating scores based on Questionnaire to assess dry mouth and the ratings of palatability based on words only version of 9 point Hedonic rating scale for all the three tastes. The independent variables were the three tastants, namely salt, sugar and sour, gender, blood sugar level, the onset of diabetes. The dependent variables were the Taste Perception Threshold (TPT), Palatability and Dryness of mouth.

Statistical analysis

The responses obtained from each participant in both the groups were averaged and fed to the computer for statistical analysis. Descriptive statistics were computed to obtain mean, median and standard deviation. The data were analysed using statistical

analysis using SPSS. Cronbach's alpha was used to determine test-retest reliability. The correlation between xerostomia, palatability and Hypogeusia was analysed using Spearman's Rank correlation. Mann-Whitney and Friedman's test was performed as a part of the analysis. The results obtained have been discussed in the next chapter.

Chapter IV

Results and Discussion

The study aimed to investigate the taste perception in individuals with Diabetes Mellitus Type II. The objectives of the study were to identify the taste perception threshold in individuals with Type II Diabetes Mellitus (T2DM) and to compare the same with the neurotypical and normoglycemic healthy adults for the three taste stimuli namely sweetness, saltiness and sourness. The other objectives were to investigate the relationship between xerostomia and taste perception in individuals with T2DM and to explore the influence of palatability of tastant in the perception of the three tastes in both the groups of individuals. Additionally, the taste perception threshold, palatability on the three taste conditions and xerostomia were compared across gender.

A total number of 100 participants in the age range of 40 to 70 years were included in the study. The participants were selected from a health check-up camp conducted by Government of Kerala at a public health centre, Poothadi, Wayanad. The 100 participants involved in the study were divided into two groups, 50 in each group. The control group consisted of 50 neurotypical and normoglycemic adults (25 males and 25 females) with no history of Diabetes Mellitus, and the experimental group was inclusive of 50 adults (25 males and 25 females) with T2DM.

The Forced choice method was used to identify the taste perception threshold (TPT). The TPT is indicated in ml. Higher the value, more the impairment in TPT, that is, as the TPT increases, the difficulty in identifying the taste also increases. The Xerostomia Inventory (W. Murray Thomson et al., 1999) was administered to assess the dryness in the mouth. Higher values indicate more severe xerostomia symptoms.

The Words only version of 9-point Hedonic rating scale (Peryam & Pilgrim, 1957) was administered to measure the palatability of each tastant. In this, higher hedonic values indicate more liking towards the taste and lower values indicate more dislike towards the taste.

The data from both groups were subjected to statistical analysis using SPSS software (version 20). Descriptive statistics were performed to compute the mean, median and standard deviation. To determine the normality of the sample selected for the study, Shapiro Wilk's test was carried out, which revealed that the parameters were not normally distributed with $p>0.05$. Hence the non-parametric test, Mann Whitney U test was carried out for between-group comparison and gender comparison in both groups, for TPT, palatability and xerostomia score. The non-parametric alternative to ANOVA, Friedman's test was also done for within-group comparison for the palatability and TPT for three taste conditions (Sweet, Sour and Salt). Since a significant difference between groups was observed for TPT and palatability, Wilcoxon signed-rank test was carried out for pairwise comparison. To check the test-retest reliability, Cronbach's Alpha was used. The results have been presented and discussed under the following heads:

1. Test-retest reliability
2. Comparison of TPT and palatability on the three tastants and xerostomia across gender in both the groups
3. Comparison of TPT on the three tastants between groups
4. Comparison of palatability of the three tastants between groups
5. Comparison of xerostomia between groups
6. Relationship between TPT, palatability and xerostomia

I Test-retest reliability

The test-retest reliability was assessed using Cronbach's alpha. Cronbach's alpha is a statistical test that measures internal consistency or reliability. Cronbach's alpha was run for TPT of sour in both the groups and both the groups had 100% agreement, as the alpha value was 1. The Cronbach's alpha for TPT of sweet was 0.93 in the experimental group and 0.89 in the control group. The Cronbach's alpha for TPT of salt was 0.94 in the experimental group and 0.95 in the control group. These values indicated high test-retest reliability, as α value of 0.70 or above is considered to be reliable or acceptable.

II Comparison of TPT and Palatability on the three tastants and xerostomia across gender in both the groups

A comparison across gender in the two groups for the TPT and palatability across three taste conditions (Salt, Sweet and Sour) and xerostomia were carried out. The mean, median and standard deviation are shown in table 4.1. A comparison between TPT of males and females of the experimental group revealed that the mean scores of TPT in females were lower for sweet and sour tastes compared to males; however, the mean TPT of salt taste was higher for females than males. Further, in the experimental group, the mean TPT of males for sweet and salt was the same, which were higher than that for the sour taste. The mean TPT in females was highest for salt taste, followed by the sweet taste and the lowest for the sour taste.

In the control group, a comparison between males and females revealed that the mean scores of TPT for all tastes were lower for females than males. Further, in the

control group, the mean TPT of males for sweet and salt was the same, and the lowest mean TPT was for sour. In the case of females, the mean TPT was the highest for salt, followed by sweet and sour.

When across gender comparison for palatability was made in the experimental group, it was found that the mean palatability score was lower in females compared to males for sweet taste and the reverse was seen for the sour taste. For salt, both males and females had the same palatability score. The mean palatability score for males in the experimental group for salt was highest, followed by the Palatability for sour. The sweet taste had the least Palatability. In the females, the mean palatability score for salt and sour taste was almost the same, which were higher than the mean palatability score of sweet taste.

Across gender comparison in the control group revealed that females had lower mean palatability scores for sweet and sour taste. However, they had higher mean palatability scores for salt taste compared to males. For males in the control group, the mean palatability for sweet taste was the highest followed by salt taste. The palatability for the sour taste was the lowest. For females in the control group, the mean palatability for salt taste was the highest, followed by sour taste. The palatability for sweet taste was the lowest.

When the mean xerostomia scores were compared in both the groups, it was seen that females obtained higher scores than males.

Table 4.1

Mean, median and standard deviation (SD) of TPT, palatability across three taste conditions and xerostomia for both the groups across gender

Groups	**Experimental Group**						**Control Group**					
Gender	**Male**			**Female**			**Male**			**Female**		
TPT in ml	**Mean**	**SD**	**Median**	**Mean**	**SD**	**Median**	**Mean**	**SD**	**Median**	**Mean**	**SD**	**Median**
Sweet	4.04	1.03	4.00	3.92	1.70	4.00	1.72	0.61	2.00	1.48	0.51	1.00
Salt	4.04	1.28	4.00	4.13	1.62	4.50	1.72	0.67	2.00	1.68	0.55	2.00
Sour	1.73	0.60	2.00	1.71	0.86	1.50	1.04	0.20	1.00	1.00	0.00	1.00
Palatability												
Sweet	6.31	0.78	6.00	6.00	1.28	6.00	6.36	0.90	6.00	5.96	1.13	6.00
Salt	6.50	1.24	6.50	6.50	1.28	7.00	6.28	1.17	7.00	6.68	0.80	7.00
Sour	6.23	0.76	6.00	6.46	1.44	7.00	6.24	1.23	6.00	6.40	1.00	7.00
Xerostomia	22.58	4.54	24.00	27.54	8.23	26.50	13.84	4.02	12.00	14.12	3.87	12.00

Mann Whitney U test revealed a significant difference only for xerostomia in the experimental group between males and females. For all the other variables (TPT and palatability across three taste conditions), no significant difference was found ($p>0.05$) between gender in both groups. The /z/ vales and p values for all the variables in both the groups are shown in table 4.2.

Table 4.2

Results of Mann Whitney Test indicating the effect of gender on TPT, palatability and xerostomia on three taste conditions in both the groups

Measures	**Experimental group**		**Control group**	
	/z/ value	**p value**	**/z/ value**	**p value**
TPT of Sweet	0.50	0.61	1.36	0.17
TPT of Salt	0.19	0.85	0.08	0.93
TPT of Sour	0.53	0.59	1.00	0.31
Palatability of sweet	0.45	0.65	1.06	0.28
Palatability of salt	0.16	0.87	0.97	0.33
Palatability of sour	1.41	0.15	0.51	0.61
Xerostomia	2.03	0.04*	0.31	0.75

*p value of <0.05 indicates a significant difference

The current study thus revealed no statistically significant difference between males and females for TPT and palatability across three tastants in both the groups. However, for xerostomia, there was a substantial difference in the experimental group between males and females, which was not seen in the control group.

The lack of significant difference between taste perception of males and females seen in both groups could be attributed to the homogenous population considered in the study since all the participants were from the same geographical area, which is a village in the north-eastern part of Kerala. Their dietary habits, physical activity and lifestyle, were almost the same. Also, the food consisted of a variety of spices produced in the same locality, which was consumed by all of them.

Though there were no significant differences, in the current study, it was seen that the TPT of females in the control group were lower than the TPT of males for all tastants and the females had higher TPT for salt followed by sweet and sour taste. This indicated that the normoglycemic and neurotypical females were able to detect tastes at a lower level than males, which reflects the fact that females are generally more sensitive to all tastes. The finding of lower TPT of the sour taste is divergent from the findings of Hyde and Feller (1981). This could be attributed to the difference in the age group of the participants across these studies, the population considered and other methodological differences. It has been reported that eating habits, diet and cultural differences between populations affect the results of taste tests (Yang, 2010; Ribeiro, Chaves, Chaves, Lemos et al., 2016, Leong, Forde, Tey, & Henry, 2018). Yang (2010) proposed that Asians are more taste-sensitive. Leong et al. (2018) reported that Indians have recognition thresholds for all taste qualities higher than Chinese. Few authors compared taste thresholds between populations with different food culture, i.e. Thai and Japanese, they also reported that food culture also influences taste perception

(Trachootham Satoh-Kuriwada, Lam-ubol, Promkam, Chotechuang, Sasano & Shoji, 2018). The males in the control group had a higher TPT for salt in the present study, which is in agreement with the findings of Hyde and Feller (1981).

The findings of the present study are in agreement with the results by Murphy and Gilmore, (1989)and Hyde and Feller (1981) who did not report of a significant difference across gender in young neurotypical and normoglycemic individuals, however, Hyde and Feller (1981)reported that the taste perception threshold of caffeine and citric acid (sour) were higher for females than males and that the males were less sensitive to salt taste. The authors attributed the difference to the masculine and feminine traits rather than any physiological causes.

Fikentscher et al. (1977) also reported no significant differences across gender; however, they stated that females were more sensitive to all tastes, which was particularly significant after the age of 40 years. These findings are also in agreement with the present study. Wang, Liang, Lin, Chen, and Jiang, (2020) also reported no significant differences between neurotypical males and females, except that women had better identification scores than men for sweet quality in the age group of 40-59 years. Yolanda, Antono, and Kurniati (2017) also found that females were more sensitive towards sweet and had a lower threshold.

In the experimental group as well, there was no significant gender difference found in the present study. This aligns with several studies done on the T2DM population. In 2009, Gondivkar et al., found no gender effect in gustatory function in individuals with T2DM. Navvabi, Farzad, and Alaeei (2009) evaluated the taste sensitivity between diabetic and non-diabetic individuals for all the four tastes and reported that there were no gender differences for taste perception. Dey and Inamdar

(2012) also studied taste perception of different tastes like sweet, sour, salty, bitter and PTC in diabetic subjects. They did not find a significant difference across different taste parameters.

Though no significant difference was seen in the experimental group, females had lower TPT for all tastes except salt. For salt taste, a higher TPT was seen than males. This could be attributed to the diabetic condition, per se. They had a history of diabetes and were overtly conscious about the sugar level in the food they eat. Thus, they could detect sweet taste at a lower level than salt taste. Among all the tastes, the lowest TPT was for sour taste, followed by sweet and then by salt taste, which was the highest.

It was also seen that the males in both groups had similar levels of TPT for sweet and salt, which were higher than the TPT of the sour taste. The female participants in both the groups, exhibited high TPT for salt followed by sweet, with the least TPT for sour. Females in both the experimental and control group had the highest mean TPT for salt, which could be attributed to their diet patterns. Females tend to follow diet and other weight control plans than males, indicating a lesser variety of tastes in the diet. In literature (Westenhoefer, 2005), it is stated that females tend to consume more vegetables and fruits than males, in turn consuming more fibres and less fat as compared to males, which indicates that the lifestyle and food habits of males and females are different. Since females are conscious about their sugar intake, they tend to detect sugar at relatively lower levels than salt. Since males are not that diet conscious, they had similar levels of TPT for sweet and salt.

It is interesting to note that the TPT for males and females of both the groups was lowest for sour taste. These findings indicated that all the participants in both

groups were susceptible to sour taste. This can be because the body generally detects sourness as a harmful substance to the body (Melis & Barbarossa, 2017). The participants detecting sourness can be a protective mechanism of the body.

The current study also revealed no statistically significant difference between males and females for Palatability across three tastants in both groups. This indicated that both males and females had similar Palatability for all tastes. However, small differences between genders were seen in both groups. The scores on the hedonic scale of sweet taste were higher in males compared to females in both groups. This indicated that the males of both groups liked sweet taste than females. Barragán, Coltell, Portolés, Asensio, Sorlí, Ortega-Azorín, and Corella (2018) reported that males prefer sweet taste over other tastes, which explains the more excellent palatability scores, which was seen in both groups. About the sour taste, the scores on the hedonic scale were higher for females than males in both the groups. This indicated that the females preferred and liked the sour taste better than males.

For the salt taste, in the control group, the scores on the hedonic scale for females in the control group was higher than males, whereas, in the experimental group, both males and females had similar scores. This indicated that females, in general, prefer and like salty based food items rather than sweet, since they are more diet conscious, especially those in the older age group. As individuals grow older, they realize that they could develop other medical complications and hence are incredibly conscious of their diet (Mathus-Vliegen, 2012). However, Yolanda, Antono, and Kurniati (2017) found that neurotypical females obtained higher scores on the hedonic scale, indicating deep liking for sweet. This difference could be attributed to the age group differences and cultural differences between both studies. Males in the

experimental groups obtained high score for salt, which indicated that males with diabetes become more conscious and change their liking from sugar to salt taste.

For xerostomia, a substantial difference between males and females were found in the experimental group, which was not seen in the control group. The females had a higher mean xerostomia score, which indicated that females had more symptoms of dryness while comparing to men. Lower salivary flow rate has been reported in females because of the smaller size of the salivary gland compared to males (Scott, 1975). Besides, there is a coexistence of Hyposalivation with T2DM (López-Pintor et al., 2016). When both Hyposalivation consequent to Diabetes and lower salivary flow in females coexists, the overall perception of dryness can be seen to a greater extent in the females of the experimental group.

III Comparison of TPT on the three tastants between groups

Table 4.3 depicts the mean, median and standard deviation scores of TPT for the three tastants in both the groups. When the means for TPT of both the groups were compared, it was seen that the participants in the experimental group had lower TPT for all tastants than the participants in the control group. Mann Whitney test revealed that there was a significant difference between TPT of the experimental and control group for all the three taste conditions. The /z/ and p values have also been depicted in table 4.3.

Table 4.3

Mean, median, standard deviation (SD), /z/ and p values of TPT across three taste conditions for both the groups.

Groups	**Experimental group**			**Control group**			**/z/ value**	**p value**
TPT	**Mean**	**SD**	**Median**	**Mean**	**SD**	**Median**		
Sweet	3.98	1.37	4.00	1.60	0.57	2.00	7.93	0.00*
Salt	4.08	1.44	4.00	1.70	0.61	2.00	7.49	0.00*
Sour	1.72	0.87	2.00	1.02	0.14	1.00	6.04	0.00*

**p*-value of<0.01 indicates significant difference

Further, in the experimental group, the mean TPT for salt taste was highest (4.08), followed by mean TPT of sweet taste (3.98). The TPT of sour taste was found to be the least (1.72). In the control group, the mean TPT for salt was the highest (1.70), followed by mean TPT of sweet (1.60) and that of sour, which was the least (1.02). This in both groups, the mean TPT was high for salt, followed by the sweet taste and the least for sour taste. Friedman's test was carried out to check the difference in TPT across three tastes, separately for each group (experimental and control group). The results revealed a significant difference between the three tastants for the experimental (X^2=78.01, p=0.00) and control group (X^2=44.58, p=0.00).

Since there was a significant difference, the Wilcoxon Signed Rank test was carried out to check if there was any statistically significant difference within tastes in both the groups. The test was conducted to compare TPT of salt and sweet, sour and

sweet and sour and salt, for each group separately. The test results suggested that there was no statistically significant difference between the TPT of salt and sweet in the experimental group. However, there was a statistically significant between TPT of sour and sweet and TPT of sour and salt. In the control group, a similar pattern of results was seen. The results of the Wilcoxon signed-rank test are shown in table 4.4.

Table 4.4

Results of Wilcoxon Signed Rank Test between various tastants in both the groups

	Experimental group		**Control group**	
TPT	**/z/ value**	**p value**	**/z/ value**	**p value**
Salt vs Sweet	0.70	0.48	1.09	0.27
Sour vs Sweet	6.04	0.00**	5.20	0.00**
Sour vs Salt	6.01	0.00**	5.35	0.00**

** *p value* of<0.01 indicates a highly significant difference

The current study revealed a statistically significant difference for TPT on the three taste conditions between the two groups. The experimental group had a higher TPT than the control group, which indicated reduced taste perception in persons with T2DM. Ship (2003) reported that more than one-third of adults with diabetes had reduced taste perception. This reduced taste perception could be attributed to some dysfunction in the taste buds/receptors due to microangiopathy or some dysfunction in the nerve tracts due to neuropathy seen secondary to Diabetes. Majority of the participants had a history of diabetes since 5-15 years and were also under medication since 5-15 years, which could have led to this secondary complication. Keny et al. (2014) and Khera and Saigal (2018) reported that dysfunction in the taste

buds/receptors due to microangiopathy and the dysfunction in the nerve tracts due to neuropathy could alter the taste perception in individuals with DM. Gondivkar et al. (2009) reported that previous studies suggest a direct correlation between the blood glucose level and taste perception ability, which they attribute to a generalized taste sensing defects in the taste receptors. Another study suggests that this reduction in taste sensitivity for sweet can be due to the satiation effect (Mann, 2002). This satiation effect is because of the elevated blood sweet level. De Carli, Gambino, Lubrano, Rosato, Bongiovanni, Lanfranco et al. (2017) attributed the increased TPT to the reduced salivary flow and the increase in the density of the saliva in the diabetic population, which hampered the transportation of tastant to the receptor.

Support for this finding can be drawn from the studies by Lawson et al. (1979) and Dias, Brazil, Almeida, Silva, and Milagres (2016), who found decreased taste perception for sweet taste. Mann (2002) and Dey and Inamdar (2011) and De Carli, Gambino, Lubrano, Rosato, Bongiovanni, Lanfranco et al. (2017) reported reduced taste perception in the Diabetic population for sweet, salty, and sour taste. Navvabi, Farzad, and Alaeei (2009) and Gaphor and Saeed (2014) and Khera and Saigal (2018) found reduced taste sensitivity in diabetic for sweet and salty taste. Gondivkar (2009) found reduced taste sensitivity for diabetic for sour and salty taste. Wasalathanthri, Hettiarachchi, and Prathapan (2014) also found a blunted taste response for all the tastes that in the diabetic group.

III Comparison of palatability on the three tastants between groups

Table 4.5 depicts the mean, median and standard deviation of the scores on the hedonic rating scale, indicating palatability for the three tastants in both the groups. When the means of both the groups were compared, it was seen that there was not much of a difference between the experimental group and the control group for all tastants.

Mann Whitney test revealed no significant difference in palatability of the three tastants between the experimental and control group. The /z/ and p values have also been depicted in table 4.5.

Table 4.5

Mean, median, standard deviation (SD), /z/ and p values of Palatability across three taste conditions for both the groups.

Groups	**Experimental group**			**Control group**			**/z/ value**	**p value**
Palatability	**Mean**	**SD**	**Median**	**Mean**	**SD**	**Median**		
Sweet	6.16	1.05	6.00	6.16	1.03	6.00	0.12	0.90
Salt	6.50	1.24	7.00	6.48	1.01	7.00	0.12	0.89
Sour	6.34	1.13	6.00	6.32	1.11	7.00	0.38	0.70

Further, the mean scores on the hedonic scale of the participants in both the groups were highest for salt taste, followed by a sour taste, with the lowest score for sweet taste. This indicated that all the participants liked the taste of salt, followed by the taste of sour. All of them relatively disliked the taste of sweet. Friedman's test, a non-parametric test was used to identify any statistically significant difference in the hedonic scale score across three taste conditions in both groups. The test results indicated that there were no statistically significant difference in both groups for salt, sweet and sour tastes, as $p>0.05$. Since there was no statistically significant difference in the palatability of sugar, salt and a sour taste in both the groups, the Wilcoxon Signed Rank test was not carried out.

Thus, the current study revealed that there was no statistically significant difference across groups on the scores on the hedonic scale for all the three tastes. Also, there was no significant difference across tastes in both groups. This can be attributed to the same food culture of all the participants. All the participants were from the same geographical area with a similar diet and lifestyle, and this can be the reason for no difference in Palatability obtained in this study.

In literature (Bhatia & Sharma, 1991), it is reported a decrease in palatability of the glucose solutions induced by the glucose load (negative alliaesthesia). However, in the present study, there was no significant difference in the palatability of sweet taste between the experimental and control group.

The taste of salt was most liked by all participants followed by sour. They did not prefer the sweet taste. These differences can be attributed to several factors including genetics (i.e. the number of taste buds), age, gender, race and culture can also influence the pleasantness or the hedonic tone (Drewnowski, 1997). Since the study was done on an older population, and they are in general, more careful about their diet and avoid sugar for various reasons, one of the reasons being diabetes. A few authors report that older people prefer to consume foods with salt taste (Web, 2016). From the current study, it is clear that the TPT of salt is highly impaired compared to sweet and sour in both groups. This means that they are having difficulty in detecting salt taste, which could have led to the increased Palatability of salt. This also explains why the Palatability of sweet taste was the lowest.

V Comparison of xerostomia between groups

When the means for xerostomia score of both the groups were compared, it was seen that the participants of the experimental group obtained a higher score (24.96±6.77), compared to the control group (13.98±3.91). This indicated that a more significant number of participants in the experimental group had xerostomia compared to the control group. Mann Whitney test revealed a significant difference (/z/= 7.50, p=0.00) between the groups.

Xerostomia has been reported in patients as an associated symptom. According to Ship (2003), dry mouth is a principle complaint associated with individuals diagnosed with Diabetes. Fox, Busch, and Baum (1987) found that 62% of the total participants had xerostomia. Carda, Mosquera-Lloreda, Salom, Gomez De Ferraris, and Peydró (2006) also reported the prevalence of xerostomia as 76% in patients with T2DM. A review by López-Pintor et al. (2016) also reported that most of the studies found a higher prevalence of xerostomia and reduced salivary flow rates in individuals with Diabetes. Saleh et al. (2014) attributed xerostomia to the reduction in salivary flow in individuals with Diabetes which could be due to the dysfunction of gland parenchyma or due to the disturbances in the microcirculation to the salivary glands, dehydration or the imbalance in the glycaemic level.

V. Relationship between TPT and Palatability and Xerostomia

A Spearman's rank-order correlation was run to determine the relationship between the taste perception threshold and palatability of all the tastes. The results revealed that there was a weak negative correlation between TPT and palatability for all the tastes in the experimental group. However, this was not statistically significant. A spearman's rank-order correlation was also run to determine the relationship between TPT sweet and HR Sweet in the control group as well. The result revealed a weak

positive correlation between TPT and palatability for all the tastes. However, this was not statistically significant. The result of the Spearman's rank-order correlation has been depicted in table 4.6.

Table 4.6

Results of Spearman's rank-order correlation between TPT and palatability of various tastants in both the groups

	Experimental group		**Control group**	
Tastants	***r* value**	***p* value**	***r value***	***p value***
Sweet	0.09	0.50	0.24	0.08
Sour	0.05	0.68	0.08	0.54
Salt	0.19	0.17	0.18	0.20

The results of Spearman correlation revealed a weak negative correlation (statistically not significant) between TPT and palatability in the experimental and a weak positive correlation in the control group for all tastes. This indicated that in the control group as the TPT increased, palatability increased, whereas, in the experimental group, the reverse was seen. However, in a previous study by Chamoun, Duizer, Darlington, Duncan, Haines, and Ma (2019), a weak positive correlation was reported between TPT and palatability for all tastes in healthy individuals. This difference could be consequent to differences in the method adopted in the studies. The study by Chamoun et al. (2019) used taste strips, which were immersed in taste solutions for 1second and kept on a drying rack overnight. These strips were then immersed in the solutions and were kept in a re-sealable bag and were maintained at 4 degree Celsius.

During the testing, the taste strip was placed at the centre of the tongue for 5 seconds. Thus the current study used a whole mouth stimulation, while Chamoun et al.'s study used taste strips that stimulated only the middle part of the tongue, thus missing out the function of receptors of other parts of the tongue. Differences also arose because of the differences in temperature and mode of presentation. In this study, the stimuli were presented at room temperature, and the presentation of the stimulus was with water, but in the study by Chamoun et al. (2019), the temperature was 4-degree Celsius, and the mode of presentation of the stimuli was through a taste strip. Similar studies assessing the relationship between TPT and palatability in persons with T2DM are limited, and hence comparisons with the findings of the present study cannot be made. However, all these correlations were weak and not significant, and therefore generalization of these results should be made with caution.

The relationship between TPT and xerostomia was assessed using Spearman's rank-order correlation. The results revealed a weak, negative correlation for the sour taste and a weak positive correlation for sweet and salt taste between TPT and xerostomia in the experimental group, all of which were not significant. A spearman's rank-order correlation was also run to determine the relationship between TPT and xerostomia in the control group as well. The result revealed a weak positive correlation between TPT and xerostomia for all the tastes. However, this was not statistically significant. The result of the Spearman's rank-order correlation has been depicted in table 4.7.

Table 4.7

Results of Spearman's rank-order correlation between TPT of various tastants and xerostomia in both the groups

	Experimental group		**Control group**	
	***r* value**	***p* value**	***r value***	***p value***
Sweet	0.09	0.52	0.06	0.66
Sour	0.01	0.94	0.19	0.18
Salt	0.16	0.25	0.25	0.07

The results of Spearman correlation revealed a weak negative correlation (statistically not significant) for the sour taste and a weak positive correlation for sweet and salt taste in the experimental group between TPT and xerostomia. In the control group, a weak positive correlation was found for all tastes. All these correlations, however, were not statistically significant. This indicated that in the control group, as xerostomia was not reported, the TPT was also lesser. This shows that the presence of saliva can result in lower TPT. Saliva is essential for taste perception. According to Ambaldhage et al. (2014), saliva production can improve taste sensation. We can assume that in normals as the taste receptors and salivary glands are functioning normally, they may not have a taste perception problem or dryness. They also have an average blood sugar level. As the blood sugar level increases, the chances of affecting the taste buds and salivary glands are more (Duggal, 2018). Similar studies on healthy individuals are limited. Hence it is difficult to draw a comparison with other studies.

Similar results were found in the experimental group as well, only for the sweet and salt tastes. The experimental group had a history of xerostomia. Hence the TPT also increased for sweet and salt taste. However, the reverse was found for sour taste. This indicated that the TPT for sour taste was less affected by the presence of xerostomia. It is known that sour taste can induce salivation. As reported by Spanne, (2018) the brain detects sour taste as sharp and acidic, it signals the salivary glands to increase the amount of saliva, so that the strong acidic taste can be neutralized, thus reducing dryness. However, all these correlations were weak and not significant, and therefore generalization of these results should be made with caution. Support can be drawn from the findings of De Carli, Gambino, Lubrano, Rosato, Bongiovanni, Lanfranco et al. (2017). She attributed the increased TPT to the reduced salivary flow and the increase in the density of the saliva in the diabetic population, which hampered the transportation of tastant to the receptor.

To summarize, the present study revealed several interesting findings. There was no significant gender difference for TPT and palatability in both the groups; however, there was a significant difference for xerostomia in the experimental group, with the females obtaining higher scores. The individuals with T2DM had a significantly higher TPT for salt, sweet and sour tastes than the neurotypical and normoglycaemic controls. The TPT of salt taste was the highest, followed by sweet taste in both the groups. The TPT of sour taste was the lowest in both groups. No significant difference was seen in the palatability of the three tastants between the two groups. However, there was a significant difference seen across groups concerning xerostomia, with the individuals with T2DM having greater xerostomia. The palatability was highest for salt taste, followed by a sour taste, with the lowest score for sweet taste. A weak negative correlation was found between TPT and palatability in the

experimental group, while a weak positive correlation was seen in the control group for all tastes. Between TPT and xerostomia, a weak negative correlation for the sour taste and a weak positive correlation for sweet and salt taste was found in the experimental group. In the control group, a weak positive correlation was observed for all tastes. All these correlations, however, were not statistically significant.

Chapter V

Summary and Conclusions

Diabetes mellitus (DM), according to the American Diabetes Association (2004) is a cluster of metabolic diseases portrayed by hyperglycemia resulting in subsequent shortcomings in insulin secretion, its action or both the processes. This vast population with Diabetes fall under two major categories: Type I Diabetes mellitus or immune-mediated Diabetes and Type II Diabetes mellitus. Diabetes Type I is inclusive of about 5-10% of the total individuals with Diabetes, whereas, Type II Diabetes Mellitus (T2DM) accounts for approximately 90-95%. Renal disease, retinal problems, neuropathy, peripheral vascular diseases, coronary heart disease, xerostomia or decreased salivary production, diabetic neuropathy and difficulty perceiving taste are the various complications associated with T2DM (Hillson, 2014; Begic et al., 2016). These complications are due to the pathological and functional changes in these target tissues (Kahn, 1997).

Taste is one of the most vivid and intricate pieces of human lifestyle, which, when affected, can impair the quality of life of a person. Taste is a sensation upon the taste organ due to a substance that a person has enjoyed (Brillat-Savarin, 2019). It involves the oral perception of food that stimulates receptor cells within taste buds. Taste perception can be affected by various factors. One of them is Diabetes. One of the initial symptoms of Diabetes Mellitus is taste disturbance (Keny et al., 2014), which can be present in conjunction with the other symptoms such as polyphagia, polydipsia and polyuria. Taste perception problems and dryness of mouth are two of the most commonly reported symptoms. Nevertheless, the association between this and Diabetes is less studied.

The pleasantness or palatability is a factor that determines how well a person consumes that food and can be related to taste perception. The existing studies explore the taste perception in Type 2 Diabetes Mellitus. However, the literature is scarce that explores the effect of palatability and xerostomia on taste perception. As all these aspects, i.e., taste perception, saliva production, and palatability are interrelated, it is vital to assess the relationship between these.

One more significant need for the current study is that most of the existing studies are in the western context. Of the Indian studies, most of them are done in the Northern part of India. Since India is a diverse country with different culture, tradition, and cuisines, there exist a need to study the taste perception in individuals with Diabetes Mellitus Type II, particularly from the southern part of the country. Keeping all these aspects in view, the present study was designed to investigate the taste perception in individuals with Diabetes Mellitus Type II. The objectives of the present study were a) To identify the taste perception threshold in individuals with Type II Diabetes Mellitus and to compare the same with the neurotypical and normoglycemic healthy adults for the three taste stimuli (sweetness, saltiness and sourness), b) To investigate the relationship between xerostomia and taste perception in individuals with Type II Diabetes Mellitus (T2DM), c) To explore the influence of palatability of tastant in the perception of the three tastes in both the groups of individuals and d) To compare the taste perception threshold and palatability across three taste conditions (Salt, Sugar and Sour) and xerostomia across gender.

A total number of 100 participants were included in the study. The participants were selected from a health check-up camp conducted by Government of Kerala at a public health centre, Poothadi, Wayanad. The 100 participants involved in the study were divided into two groups, 50 in each group. The control group consisted of 50

neurotypical and normoglycemic adults (25 males and 25 females) with no history of Diabetes Mellitus, and the experimental group was inclusive of 50 adults (25 males and 25 females) with Type II Diabetes Mellitus. The age of the participants ranged from 40 to 70 years of age.

The following procedure identified the taste perception threshold. A mixture of 10 ml distilled water and 1ml saturated solution of one of the tastant was provided, and the patient was asked to keep the entire solution in the oral cavity for 5 seconds. Then the participant was asked to report if any kind of taste is perceived. If the participant can identify the taste without any confusion, then that level is considered as the taste perception threshold. If no taste is perceived, then the concentration is gradually increased by adding one more ml of the saturated solution. TPT for salt, sweet and sour were tested using a concentrated solution of salt powder, sugar powder and citric acid powder. Higher the value, more the impairment in TPT, that is, as the TPT increases, the difficulty in identifying the taste also increases. Questionnaire to assess dry mouth, given by Thomson et al. 1999 was used to assess the presence of xerostomia. Higher values indicate more severe xerostomia symptoms. To assess the palatability of the tastants, Words only version of 9-point Hedonic rating scale was used (Peryam & Pilgrim, 1957). In this, higher hedonic values indicate more liking towards the taste and lower values indicate more dislike towards the taste.

The test-retest reliability was assessed using Cronbach's alpha. These results indicated that the study had high internal consistency, which meant that the test was reliable. The individuals with T2DM had a significantly higher TPT for salt, sweet and sour tastes than the neurotypical and normoglycaemic controls. The TPT of salt taste was the highest, followed by sweet taste in both the groups. The TPT of sour taste was the lowest in both groups. No significant difference was seen in the palatability of the

three tastants between the two groups. However, there was a significant difference seen across groups concerning xerostomia, with the individuals with T2DM having greater xerostomia. The palatability was highest for salt taste, followed by a sour taste, with the lowest score for sweet taste. A weak negative correlation was found between TPT and palatability in the experimental group, while a weak positive correlation was seen in the control group for all tastes. Between TPT and xerostomia, a weak negative correlation for the sour taste and a weak positive correlation for sweet and salt taste was found in the experimental group. In the control group, a weak positive correlation was observed for all tastes. All these correlations, however, were not statistically significant.

It can be concluded from the study that the taste perception of salt, sweet and sour tastes was affected in individuals with T2DM. This reduced taste perception could be attributed to some dysfunction in the taste buds/receptors due to microangiopathy or some dysfunction in the nerve tracts due to neuropathy seen secondary to Diabetes. Majority of the participants had a history of diabetes since 5-15 years and were also under medication since 5-15 years, which could have led to this secondary complication. However, the palatability was unaffected for all the tastes. Xerostomia was present to a greater extent in the persons with T2DM. There was a weak relationship between taste perception, saliva production, and palatability.

This study provides us with the taste perception threshold values for three tastes with which we can assess the minimum level of taste solutions to be provided to activate the brain, especially during the management. Ding, Logemann, Larson, et al., (2003) hypothesized that higher taste concentration would activate a more significant number of sensory neurons in nucleus tractus solitaries, which in turn activates the motor neurons, ultimately resulting in a safer swallow. The present study also provides an

insight into the dietary management in these patients in the event of dysphagia, since it provides information on the most and least affected taste. This study also revealed the fact that xerostomia is a frequent finding in patients with T2DM, which affects the taste perception threshold. Consequently, during the management, it is imperative to assess the extent of xerostomia and apply strategies to reduce this, to improve taste perception. This study also provides an insight into the palatability of each stimulus. The most palatable stimuli can be selected during taste stimulation therapy, which in turn can trigger increased salivation. Taking all these aspects into consideration during the management could lead to a better quality of life in persons with Diabetes.

Additionally, the threshold values can serve as a basis of reference during the management for making pre and post-therapy comparisons of taste perception. This study was done in a village in south India. Most of the existing studies are done in the western population or the Northern part of India. Thus, this study is one of its kind on the persons hailing from the Southern part of India.

However, there are some limitations to the study. Bitter taste could not be included as the availability of Quinine hydrochloride was limited, and other bitter-tasting agents could not be dissolved water to make a concentrated solution. Moreover, quinine is an anti-malaria drug, so it cannot be used when available in tablet forms in medical stores. Umami taste was also not considered. It was not considered because it was challenging to find the desired participants. If umami was considered, the grouping of vegetarians and non-vegetarians could have been made. The factors such as onset and duration of diabetes, blood sugar level, type of medication, medication since taste impairment reported, and dryness reported. The age-wise comparison also could have provided additional insight into the effect of age on the variables such as xerostomia, taste perception and palatability; however, this could not be undertaken owing to small

sample size. Hence, future studies can be taken up with a larger sample size and analysing based on these variables and including the bitter taste. Umami is another taste that can be considered for future studies in which the taste perception threshold of vegetarians and non-vegetarians can be analysed separately.

References

American Diabetes Association. (2010). Diagnosis and Classification of Diabetes Mellitus, from https://care.diabetesjournals.org/content/33/Supplement_1/S62.full.

Ashi, H., Campus, G., Klingberg, G., Forslund, H., & Lingström, P. (2019). Childhood obesity in relation to sweet taste perception and dental caries – A cross-sectional multicentre study. *Food & Nutrition Research*, 63(0). doi: 10.29219/fnr.v63.1682.

ADA (American Diabetes Association). (2019). Standards of medical care in diabetes : classification and diagnosis of diabetes. *Diabetes Care*. https://doi.org/10.2337/dc19-S002

Anjana, R. M., Pradeepa, R., Deepa, M., Datta, M., Sudha, V., Unnikrishnan, R., … Mohan, V. (2011). Prevalence of diabetes and prediabetes (impaired fasting glucose and/or impaired glucose tolerance) in urban and rural India: Phase i results of the Indian Council of Medical Research-INdia DIABetes (ICMR-INDIAB) study. *Diabetologia*, *54*(12), 3022–3027. https://doi.org/10.1007/s00125-011-2291-5

Barik, A., Mazumdar, S., Chowdhury, A., & Rai, R. K. (2016). Physiological and behavioral risk factors of type 2 diabetes mellitus in rural India. *BMJ Open Diabetes Research and Care*. https://doi.org/10.1136/bmjdrc-2016-000255

Barker, N., Bartfeld, S., & Clevers, H. (2010). Tissue-resident adult stem cell populations of rapidly self-renewing organs. *Cell Stem Cell*. https://doi.org/10.1016/j.stem.2010.11.016

Barragán, R., Coltell, O., Portolés, O., Asensio, E. M., Sorlí, J. V., Ortega-Azorín, C., … Corella, D. (2018). Bitter, sweet, salty, sour and umami taste perception decreases with age: Sex-specific analysis, modulation by genetic variants and taste-preference associations in 18 to 80 year-old subjects. *Nutrients*. https://doi.org/10.3390/nu10101539

Bartoshuk, L. M., Gent, J., Catalanotto, F. A., & Goodspeed, R. B. (1983). Clinical evaluation of taste. *American Journal of Otolaryngology--Head and Neck Medicine and Surgery*, *4*(4), 257–260. https://doi.org/10.1016/S0196-0709(83)80069-6

Bartoshuk, L. M., & Pangborn, R. M. (1993). *Linda M. Bartoshuk*. *4*, 21–32.

Bearse, M. A., Han, Y., Schneck, M. E., Barez, S., Jacobsen, C., & Adams, A. J. (2004). Local multifocal oscillatory potential abnormalities in diabetes and early diabetic retinopathy. *Investigative Ophthalmology and Visual Science*. https://doi.org/10.1167/iovs.04-0308

Beidler, L. M., & Smallman, R. L. (1965). Renewal of cells within taste buds. *The Journal of Cell Biology*, *27*(2), 263–272. https://doi.org/10.1083/jcb.27.2.263

Berling, K., Knutsson, J., Rosenblad, A., & Von Unge, M. (2011). Evaluation of electrogustometry and the filter paper disc method for taste assessment. *Acta Oto-Laryngologica*. https://doi.org/10.3109/00016489.2010.535850

Bhatia, S., & Sharma, K. N. (1991). Taste impairment for glucose in diabetic PTC tasters and non-tasters. *Diabetes Research and Clinical Practice*. https://doi.org/10.1016/0168-8227(91)90077-Q

Boesveldt, S., & Graaf, K. De. (2017). *The Differential Role of Smell and Taste For*

Eating Behavior. https://doi.org/10.1177/0301006616685576

Boyce, J. M., & Shone, G. R. (2006). Effects of ageing on smell and taste. *Postgraduate Medical Journal*, *82*(966), 239–241. https://doi.org/10.1136/pgmj.2005.039453

Breslin, P. A. S. (2013). An evolutionary perspective on food and human taste. *Current Biology*, *23*(9), R409–R418. https://doi.org/10.1016/j.cub.2013.04.010

Breslin, P. A. S., & Spector, A. C. (2008). Mammalian taste perception. *Current Biology*, *18*(4), 148–155. https://doi.org/10.1016/j.cub.2007.12.017

Carda, C., Mosquera-Lloreda, N., Salom, L., Gomez De Ferraris, M. E., & Peydró, A. (2006). A structural and functional salivary disorders in type 2 diabetic patients. *Medicina Oral, Patologia Oral y Cirugia Bucal*.

Care, D., & Suppl, S. S. (2019). 2. Classification and diagnosis of diabetes: Standards of medical care in diabetesd2019. *Diabetes Care*, *42*(January), S13–S28. https://doi.org/10.2337/dc19-S002

Carterette, E. C., & Friedman, M. P. (1978). Handbook of Perception VIA: Tasting and smelling. *Handbook of Perception v 6A, VI*, xvii, 321 p.

Cecchini, M. P., Cardobi, N., Sbarbati, A., Monaco, S., Tinazzi, M., & Tamburin, S. (2018). Post-traumatic taste disorders: a case series. *Journal of Neurology*, *265*(4), 836–844. https://doi.org/10.1007/s00415-018-8776-0

Chamoun, E., Liu, A. A. S., Duizer, L. M., Darlington, G., Duncan, A. M., Haines, J., & Ma, D. W. L. (2019). Taste sensitivity and taste preference measures are correlated in healthy young adults. *Chemical Senses*. https://doi.org/10.1093/chemse/bjy082

Chandrashekar, J., Hoon, M. A., Ryba, N. J. P., & Zuker, C. S. (2006). The receptors and cells for mammalian taste. *Nature*. https://doi.org/10.1038/nature05401

Chang, Y. F., & Ou, A. S. M. (2000). Altered taste sensation in newly-diagnosed NIDDM elderly subjects. *Nutritional Sciences Journal*.

Chaudhari, N., & Roper, S. D. (2010). The cell biology of taste. *Journal of Cell Biology*. https://doi.org/10.1083/jcb.201003144

Chaudhari, N., Yang, H., Lamp, C., Delay, E., Cartford, C., Than, T., & Roper, S. (1996). The taste of monosodium glutamate: Membrane receptors in taste buds. *Journal of Neuroscience*. https://doi.org/10.1523/jneurosci.16-12-03817.1996

Chauhan, J. (1989). Relationships between sour and salt taste perception and selected subject attributes. *Journal of the American Dietetic Association*.

Cho, N. H., Shaw, J. E., Karuranga, S., Huang, Y., da Rocha Fernandes, J. D., Ohlrogge, A. W., & Malanda, B. (2018). IDF Diabetes Atlas: Global estimates of diabetes prevalence for 2017 and projections for 2045. *Diabetes Research and Clinical Practice*. https://doi.org/10.1016/j.diabres.2018.02.023

Cohen, J. Y., Haesler, S., Vong, L., Lowell, B. B., & Uchida, N. (2012). Neuron-type-specific signals for reward and punishment in the ventral tegmental area. *Nature*. https://doi.org/10.1038/nature10754

Conger, A. D., & Wells, M. A. (1969). Radiation and Aging Effect on Taste Structure and Function. *Radiation Research*. https://doi.org/10.2307/3572749

COWART, B. J. (1989). Relationships between Taste and Smell across the Adult Life Span. *Annals of the New York Academy of Sciences*. https://doi.org/10.1111/j.1749-6632.1989.tb20968.x

De Jong, N., De Graaf, C., & Van Staveren, W. A. (1996). Effect of sucrose in breakfast items on pleasantness and food intake in the elderly. *Physiology and Behavior*. https://doi.org/10.1016/S0031-9384(96)00306-X

Dias, V. R., Brazil, J. M., Almeida, J. A. R., Silva, C. D. S., & Milagres, M. P. (2016). Evaluation of the sensory perception of sweet taste in people with Diabetes Mellitus type 2. *Revista Da Rede de Enfermagem Do Nordeste*. https://doi.org/10.15253/2175-6783.2016000400007

Drewnowski, A. (1997). TASTE PREFERENCES AND FOOD INTAKE. *Annual Review of Nutrition*. https://doi.org/10.1146/annurev.nutr.17.1.237

Dye, C. J., & Koziatek, A. (1981). Age and diabetes effects on threshold and hedonic perception of sucrose solutions. *Journals of Gerontology*. https://doi.org/10.1093/geronj/36.3.310

Easterby-Smith, V., Besford, J., & Heath, M. R. (1994). The effect of age on the recognition thresholds of three sweeteners: sucrose, saccharin and aspartame. *Gerodontology*. https://doi.org/10.1111/j.1741-2358.1994.tb00101.x

Enns, M. P., Van Itallie, T. B., & Grinker, J. A. (1979). Contributions of age, sex and degree of fatness on preferences and magnitude estimations for sucrose in humans. *Physiology and Behavior*. https://doi.org/10.1016/0031-9384(79)90346-9

FIKENTSCHER, R., ROSEBURG, B., SPINAR, H., & BRUCHMÜLLER, W. (1977). Loss of taste in the elderly: sex differences. *Clinical Otolaryngology & Allied Sciences*. https://doi.org/10.1111/j.1365-2273.1977.tb01356.x

Finger, T. E., Danilova, V., Barrows, J., Bartel, D. L., Vigers, A. J., Stone, L., …

Kinnamon, S. C. (2005). Neuroscience: ATP signalling is crucial for communication from taste buds to gustatory nerves. *Science*. https://doi.org/10.1126/science.1118435

Fischer, M. E., Cruickshanks, K. J., Schubert, C. R., Pinto, A., Klein, R., Pankratz, N., … Huang, G. H. (2013). Factors related to fungiform papillae density: The beaver dam offspring study. *Chemical Senses*. https://doi.org/10.1093/chemse/bjt033

Fox, P. C., Busch, K. A., & Baum, B. J. (1987). Subjective reports of xerostomia and objective measures of salivary gland performance. *Journal of the American Dental Association (1939)*. https://doi.org/10.1016/S0002-8177(87)54012-0

Friedman, M. I., & Stricker, E. M. (1976). The physiological psychology of hunger: A physiological perspective. *Psychological Review*. https://doi.org/10.1037/0033-295X.83.6.409

Fukunaga, A., Uematsu, H., & Sugimoto, K. (2005). Influences of aging on taste perception and oral somatic sensation. *Journals of Gerontology - Series A Biological Sciences and Medical Sciences*. https://doi.org/10.1093/gerona/60.1.109

Galindo-Cuspinera, V., Waeber, T., Antille, N., Hartmann, C., Stead, N., & Martin, N. (2009). Reliability of threshold and suprathreshold methods for taste phenotyping: Characterization with PROP and sodium chloride. *Chemosensory Perception*. https://doi.org/10.1007/s12078-009-9059-z

Gatto, A. R., Cola, P. C., Gonçalves, R., Spadotto, A. A., Carvalho, L. R. De, & Gatto, A. R. (2013). *Sour taste and cold temperature in the oral phase of swallowing in patients after stroke Sabor azedo e temperatura fria na fase oral*

da deglutição. *25*(5).

Gutch, M., Razi, S. M., Kumar, S., & Gupta, K. K. (2014). Diabetes mellitus: Trends in northern India. *Indian Journal of Endocrinology and Metabolism*. https://doi.org/10.4103/2230-8210.139219

Hyde, R. J., & Feller, R. P. (1981). Age and sex effects on taste of sucrose, NaCl, citric acid and caffeine. *Neurobiology of Aging*. https://doi.org/10.1016/0197-4580(81)90041-5

Kahn, R. (1997). Report of the Expert Committee on the Diagnosis and Classification of Diabetes Mellitus. *Diabetes Care*. https://doi.org/10.2337/diacare.20.7.1183

Kaneda.K, Maeshma.N, & Goto.T, (2000). Decline in Taste and Odor Discrimination Abilities with Age, and Relationship between Gustation and Olfaction. *Chemical Senses*.

Kennedy, O., Law, C., Methven, L., Mottram, D., & Gosney, M. (2010). Investigating age-related changes in taste and affects on sensory perceptions of oral nutritional supplements. *Age and Ageing*. https://doi.org/10.1093/ageing/afq104

Khera, S., & Saigal, A. (2018). Assessment and evaluation of gustatory functions in patients with diabetes mellitus Type II: A study. *Indian Journal of Endocrinology and Metabolism*. https://doi.org/10.4103/ijem.IJEM-555-17

Khobragade, R. S., Wakode, S. L., & Kale, A. H. (2012). Physiological taste threshold in type 1 diabetes mellitus. *Indian Journal of Physiology and Pharmacology*, *56*(1), 42–47.

Krishnaa, & Jayaraj, G. (2017). Effect of age on taste perception: A survey. *International Journal of Orofacial Biology*.

https://doi.org/10.4103/IJOFB.IJOFB_10_17

Kumbargere Nagraj, S., George, R. P., Shetty, N., Levenson, D., Ferraiolo, D. M., & Shrestha, A. (2017). Interventions for managing taste disturbances. *Cochrane Database of Systematic Reviews*. https://doi.org/10.1002/14651858.CD010470.pub3

Kurihara, K., & Kashiwayanagi, M. (1998). Introductory remarks on umami taste. *Annals of the New York Academy of Sciences*. https://doi.org/10.1111/j.1749-6632.1998.tb10597.x

Lawless, H. T., Sinopoli, D., & Chapman, K. W. (2010). A comparison of the labeled affective magnitude scale and the 9-point hedonic scale and examination of categorical behavior. *Journal of Sensory Studies*. https://doi.org/10.1111/j.1745-459X.2010.00279.x

Lawson, W. B., Zeidler, A., & Rubenstein, A. (1979). Taste detection and preferences in diabetics and their relatives. *Psychosomatic Medicine*. https://doi.org/10.1097/00006842-197905000-00005

Leong, C. S. F., Forde, C. G., Tey, S. L., & Henry, C. J. (2018). Taste perception and diet in people of Chinese ancestry. *Asia Pacific Journal of Clinical Nutrition*. https://doi.org/10.6133/apjcn.052017.08

Lim, J., Wood, A., & Green, B. G. (2009). Derivation and evaluation of a labeled hedonic scale. *Chemical Senses*. https://doi.org/10.1093/chemse/bjp054

Liman, E. R., Zhang, Y. V., & Montell, C. (2014). Peripheral coding of taste. *Neuron, 81*(5), 984–1000. https://doi.org/10.1016/j.neuron.2014.02.022

Lindemann, B. (2001). Receptors and transduction in taste. *Nature, 413*(6852), 219–

225. https://doi.org/10.1038/35093032

Little, M., Humphries, S., Patel, K., & Dewey, C. (2016). Factors associated with BMI, underweight, overweight, and obesity among adults in a population of rural south India: A crosssectional study. *BMC Obesity*. https://doi.org/10.1186/S40608-016-0091-7

López-Pintor, R. M., Casañas, E., González-Serrano, J., Serrano, J., Ramírez, L., De Arriba, L., & Hernández, G. (2016). Xerostomia, Hyposalivation, and Salivary Flow in Diabetes Patients. *Journal of Diabetes Research*, *2016*. https://doi.org/10.1155/2016/4372852

Loret, C. (2015). Using Sensory Properties of Food to Trigger Swallowing: A Review. *Critical Reviews in Food Science and Nutrition*. https://doi.org/10.1080/10408398.2011.649810

Magliano, D. J., Islam, R. M., Barr, E. L. M., Gregg, E. W., Pavkov, M. E., Harding, J. L., … Shaw, J. E. (2019). Trends in incidence of total or type 2 diabetes: Systematic review. *The BMJ*, *366*, 1–12. https://doi.org/10.1136/bmj.l5003

Maheswaran, T., Abikshyeet, P., Sitra, G., Gokulanathan, S., Vaithiyanadane, V., & Jeelani, S. (2014). Gustatory dysfunction. *Journal of Pharmacy and Bioallied Sciences*, Vol. 6. https://doi.org/10.4103/0975-7406.137257

Mann, N. M. (2002). Management of smell and taste problems. *Cleveland Clinic Journal of Medicine*. https://doi.org/10.3949/ccjm.69.4.329

Marín-Peñalver, J. J., Martín-Timón, I., Sevillano-Collantes, C., & Cañizo-Gómez, F. J. del. (2016). Update on the treatment of type 2 diabetes mellitus. *World Journal of Diabetes*. https://doi.org/10.4239/wjd.v7.i17.354

Mascioli, G., Berlucchi, G., Pierpaoli, C., Salvolini, U., Barbaresi, P., Fabri, M., & Polonara, G. (2015). Functional MRI cortical activations from unilateral tactile-taste stimulations of the tongue. *Physiology and Behavior*. https://doi.org/10.1016/j.physbeh.2015.07.031

Mathus-Vliegen, E. M. H. (2012). Obesity and the elderly. *Journal of Clinical Gastroenterology*. https://doi.org/10.1097/MCG.0b013e31825692ce

Melis, M., & Barbarossa, I. T. (2017). Taste perception of sweet, sour, salty, bitter, and Umami and changes due to L-arginine supplementation, as a function of genetic ability to taste 6-n-propylthiouracil. *Nutrients, 9*(6). https://doi.org/10.3390/nu9060541

Methven, L., Allen, V. J., Withers, C. A., & Gosney, M. A. (2012). Ageing and taste. *Proceedings of the Nutrition Society, 71*(4), 556–565. https://doi.org/10.1017/S0029665112000742

Mojet, J. (2004). Effect of Concentration on Taste-Taste Interactions in Foods for Elderly and Young Subjects. *Chemical Senses, 29*(8), 671-681. doi: 10.1093/chemse/bjh070

Mojet, Jos, Christ-Hazelhof, E., & Heidema, J. (2005). Taste perception with age: Pleasantness and its relationships with threshold sensitivity and supra-threshold intensity of five taste qualities. *Food Quality and Preference*. https://doi.org/10.1016/j.foodqual.2004.08.001

Mojet, Jos, Heidema, J., & Christ-Hazelhof, E. (2003). Taste perception with age: Generic or specific losses in supra-threshold intensities of five taste qualities? *Chemical Senses, 28*(5), 397–413. https://doi.org/10.1093/chemse/28.5.397

Murphy, C., & Gilmore, M. M. (1989). Quality-specific effects of aging on the human taste system. *Perception & Psychophysics*. https://doi.org/10.3758/BF03208046

Murphy, C., Quiñonez, C., & Nordin, S. (1995). Reliability and validity of electrogustometry and its application to young and elderly persons. *Chemical Senses*. https://doi.org/10.1093/chemse/20.5.499

Nagai, A., Kubota, M., Katayama, Y., & Kojima, C. (2012). Evaluation of taste acuity by the filter-paper disc in Japanese young women: The relationship with micronutrients status. *Asia Pacific Journal of Clinical Nutrition*. https://doi.org/10.6133/apjcn.2012.21.3.12

Navvabi, N Farzad, M & Alaeei, A. (2009). Taste threshold of four main tastes between healthy and diabetic individuals Farsi. *Journal of Dental School*.

Neff, K. D., Whittaker, T. A., & Karl, A. (2017). Examining the Factor Structure of the Self-Compassion Scale in Four Distinct Populations: Is the Use of a Total Scale Score Justified? *Journal of Personality Assessment*. https://doi.org/10.1080/00223891.2016.1269334

Ng, K., Woo, J., Kwan, M., Sea, M., Wang, A., Lo, R., … Henry, C. J. K. (2004). Effect of age and disease on taste perception. *Journal of Pain and Symptom Management*. https://doi.org/10.1016/j.jpainsymman.2003.11.007

Nordström, A., Hadrévi, J., Olsson, T., Franks, P. W., & Nordström, P. (2016). Higher prevalence of type 2 diabetes in men than in women is associated with differences in visceral fat mass. *Journal of Clinical Endocrinology and Metabolism*. https://doi.org/10.1210/jc.2016-1915

Ogurtsova, K., da Rocha Fernandes, J. D., Huang, Y., Linnenkamp, U., Guariguata,

L., Cho, N. H., … Makaroff, L. E. (2017). IDF Diabetes Atlas: Global estimates for the prevalence of diabetes for 2015 and 2040. *Diabetes Research and Clinical Practice*, *128*, 40–50. https://doi.org/10.1016/j.diabres.2017.03.024

Olokoba, A. B., Obateru, O. A., & Olokoba, L. B. (2012). Type 2 diabetes mellitus: A review of current trends. *Oman Medical Journal*. https://doi.org/10.5001/omj.2012.68

Pavlidis, P., Gouveris, H., Gorgulla, H., Hast, H. J., & Maurer, J. (2015). Electrogustometry and contact endoscopy findings in patients with head and neck malignancies treated with chemotherapy, radiotherapy, or radiochemotherapy. *Chemical Senses*. https://doi.org/10.1093/chemse/bju060

Pedersen, A. M., Bardow, A., Jensen, S. B., & Nauntofte, B. (2002). Saliva and gastrointestinal functions of taste, mastication, swallowing and digestion. *Oral Diseases*. https://doi.org/10.1034/j.1601-0825.2002.02851.x

Peryam, D. R., & Pilgrim, F. J. (1957). Hedonic scale method of measuring food preferences. *Food Technology*. https://doi.org/10.1037/0021-9010.69.1.85

Piero, M. N. (2015). Diabetes mellitus – a devastating metabolic disorder. *Asian Journal of Biomedical and Pharmaceutical Sciences*, *4*(40), 1–7. https://doi.org/10.15272/ajbps.v4i40.645

Pop-Busui, R. (2010). Cardiac Autonomic Neuropathy in Diabetes. *Diabetes Care*. https://doi.org/10.2337/dc09-1294

Potten, C. S., Saffhill, R., & Maibach, H. I. (1987). Measurement of the transit time for cells through the epidermis and stratum corneum of the mouse and guinea-pig. *Cell Proliferation*. https://doi.org/10.1111/j.1365-2184.1987.tb01355.x

Ramachandran, A. (2014). Know the signs and symptoms of diabetes. *Indian Journal of Medical Research*.

Ribeiro, J. C., Chaves, M., Chaves, C., Lemos, L., Silva, E. D., Paiva, A., & Hummel, T. (2016). Cross-cultural validation of a taste test with paper strips. *European Archives of Oto-Rhino-Laryngology*. https://doi.org/10.1007/s00405-016-4037-y

S, L., M, C., & Puranik, N. (2017). Altered taste threshold in chronic Type 2 diabetes mellitus. *National Journal of Physiology, Pharmacy and Pharmacology*, *8*(4), 1. https://doi.org/10.5455/njppp.2018.8.0823530072017

Scott, J. (1975). Age, sex and contralateral differences in the volumes of human submandibular salivary glands. *Archives of Oral Biology*. https://doi.org/10.1016/0003-9969(75)90071-0

Ship, J. A. (2003). Diabetes and oral health: an overview. *Journal of the American Dental Association (1939)*. https://doi.org/10.14219/jada.archive.2003.0367

Spitzer, M. E. (1988). Taste acuity in institutionalized and noninstitutionalized elderly men. *Journals of Gerontology*. https://doi.org/10.1093/geronj/43.3.P71

Tepper, B. J., Hartfiel, L. M., & Schneider, S. H. (1996). Sweet taste and diet in type II diabetes. *Physiology and Behavior*. https://doi.org/10.1016/0031-9384(95)02242-2

Thomson, W. Murray, Chalmers, J. M., Spencer, A. J., & Williams, S. M. (1999). The Xerostomia Inventory: A multi-item approach to measuring dry mouth. *Community Dental Health*, *16*(1), 12–17.

Thomson, William Murray, Van Der Putten, G. J., De Baat, C., Ikebe, K., Matsuda, K. I., Enoki, K., … Ling, G. Y. (2011). Shortening the xerostomia inventory.

Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology. https://doi.org/10.1016/j.tripleo.2011.03.024

Trachootham, D., Satoh-Kuriwada, S., Lam-ubol, A., Promkam, C., Chotechuang, N., Sasano, T., & Shoji, N. (2018). Differences in taste perception and spicy preference: A thai-japanese cross-cultural study. *Chemical Senses*. https://doi.org/10.1093/chemse/bjx071

Tripathy, J. P., Thakur, J. S., Jeet, G., Chawla, S., Jain, S., Pal, A., … Saran, R. (2017). Prevalence and risk factors of diabetes in a large community-based study in North India: results from a STEPS survey in Punjab, India. *Diabetology and Metabolic Syndrome*, *9*(1), 1–8. https://doi.org/10.1186/s13098-017-0207-3

Wang, J. J., Liang, K. L., Lin, W. J., Chen, C. Y., & Jiang, R. S. (2020). Influence of age and sex on taste function of healthy subjects. *PloS One*. https://doi.org/10.1371/journal.pone.0227014

Wardwell, L., Chapman-Novakofski, K., & Brewer, M. S. (2009). Effects of age, gender and chronic obstructive pulmonary disease on taste acuity. *International Journal of Food Sciences and Nutrition*. https://doi.org/10.1080/09637480802710224

Wasalathanthri, S., Hettiarachchi, P., & Prathapan, S. (2014). Sweet taste sensitivity in pre-diabetics, diabetics and normoglycemic controls: A comparative cross sectional study. *BMC Endocrine Disorders*. https://doi.org/10.1186/1472-6823-14-67

Webb, J., Bolhuis, D. P., Cicerale, S., Hayes, J. E., & Keast, R. (2015). The Relationships Between Common Measurements of Taste Function. *Chemosensory Perception*. https://doi.org/10.1007/s12078-015-9183-x

Weiffenbach, J. M., Cowart, B. J., & Baum, B. J. (1986). Taste intensity perception in aging. *Journals of Gerontology*. https://doi.org/10.1093/geronj/41.4.460

Westenhoefer, J. (2005). Age and gender dependent profile of food choice. *Forum of Nutrition*. https://doi.org/10.1159/000083753

Wichchukit, S., & O'Mahony, M. (2015). The 9-point hedonic scale and hedonic ranking in food science: Some reappraisals and alternatives. *Journal of the Science of Food and Agriculture*, *95*(11), 2167–2178. https://doi.org/10.1002/jsfa.6993

Wild, S., Roglic, G., Green, A., Sicree, R., & King, H. (2004). Global Prevalence of Diabetes: Estimates for the year 2000 and projections for 2030. *Diabetes Care*. https://doi.org/10.2337/diacare.27.5.1047

Wu, Y., Ding, Y., Tanaka, Y., & Zhang, W. (2014). Risk factors contributing to type 2 diabetes and recent advances in the treatment and prevention. *International Journal of Medical Sciences*, *11*(11), 1185–1200. https://doi.org/10.7150/ijms.10001

Yang, Q. (2010). Gain weight by "going diet?" Artificial sweeteners and the neurobiology of sugar cravings: Neuroscience 2010. *Yale Journal of Biology and Medicine*.

Yolanda, V., Antono, L., & Kurniati, A. (2017). Sensory Evaluation of Sweet Taste and Daily Sugar Intake in Normoglycemic Individuals with and without Family History of Type 2 Diabetes : A Comparative Cross-sectional Study. *International Journal of Diabetes Research*, *6*(3), 54–62. https://doi.org/10.5923/j.diabetes.20170603.02

APPENDIX I

Informed Consent

ALL INDIA INSTITUTE OF SPEECH AND HEARING: MYSORE-6

DEPARTMENT OF SPEECH-LANGUAGE PATHOLOGY

Title: "Taste perception in individuals with Diabetes Mellitus Type II"-

Guide: Dr. Swapna N, Associate Professor of Speech Pathology, AIISH, Mysore

Student: Ms. Neeraja Sunil, AIISH, Mysore

Description of the study:

This study aims at investigating the taste perception in individuals with Diabetes Mellitus Type II within the age range of 40-70 years. This study involves answering few questions to assess the presence of dry mouth, and tasting a mixture of distilled water and saturated solution (sugar, salt and citric acid) by keeping it in the oral cavity for 5 seconds and then spitting it out to a wash basin. The responses will be recorded and analysed later. The approximate time of testing would be 20 minutes to half an hour per individual. This data will help in the assessment and intervention of individuals with Dysphagia and allied symptoms when associated with Diabetes mellitus Type II. The procedure is harmless and has only research benefits and you will not receive any financial benefits from it. Confidentiality will be maintained.

Consent for participation

I have been informed about and understand the purpose of the study and my participation in it. I also understand that the procedure is purely harmless and it has only research benefits and personally I do not receive any benefits from it. I give my consent for the testing for the research purposes.

(AGREE / DISAGREE)

Date:

Signature of the subject
Name of the subject

APPENDIX II

Demographic Datasheet

I. Demographic data

Participant name: _____

Age/gender: _____

Contact number: _____

Diabetic since: _____

Under medication since: _____

Type of medicine: _____

Regular/Irregular: _____

H/O T1DM/ GD: _____

Blood sugar level: _____

Taste change reported: _____

Presence of dietary changes: _____

Dryness of mouth: _____

Relevant medical history: _____

II. Taste perception threshold

Salt	
Sugar	
Sour	

III. Xerostomia Inventory- Thomson et al. (1999)

Sl. No.	Questions	1	2	3	4	5
1.	My mouth feels dry					

2.	I have difficulty in eating dry foods					
3.	I get up at night to drink					
4.	My mouth feels dry when eating a meal					
5.	I sip liquids to aid in swallowing food					
6.	I suck sweets or cough lollies to relieve dry mouth					
7.	I have difficulties swallowing certain foods					
8.	The skin of my face feels dry					
9.	My eyes feel dry					
10	My lips feel dry					
11	The inside of my nose feel dry					
Total score						

Never = scoring 1, Hardly ever = scoring 2. Occasionally = scoring 3, fairly often = scoring 4, Very often = scoring 5

IV. Words only version of 9 point hedonic rating scale

DISLIKE EXTREMELY	DISLIKE VERY MUCH	DISLIKE MODERATELY	DISLIKE SLIGHTLY	NEITHER LIKE NOR DISLIKE	LIKE SLIGHTLY	LIKE MODERATELY	LIKE VERY MUCH	LIKE EXTREMELY
1	2	3	4	5	6	7	8	9

____

DISLIKE EXTREMELY	DISLIKE VERY MUCH	DISLIKE MODERATELY	DISLIKE SLIGHTLY	NEITHER LIKE NOR DISLIKE	LIKE SLIGHTLY	LIKE MODERATELY	LIKE VERY MUCH	LIKE EXTREMELY
1	2	3	4	5	6	7	8	9

____

DISLIKE EXTREMELY	DISLIKE VERY MUCH	DISLIKE MODERATELY	DISLIKE SLIGHTLY	NEITHER LIKE NOR DISLIKE	LIKE SLIGHTLY	LIKE MODERATELY	LIKE VERY MUCH	LIKE EXTREMELY
1	2	3	4	5	6	7	8	9

____