The Role of Saliva in Taste
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Abstract

The breakdown of food is a complex and intricate process that is successful in large part due to saliva. Not only does saliva help with the breakdown of food for the nutritional value that it has, but saliva also aids in conveying this nutritional information to the brain through the gustatory system.

Both animals and humans use saliva on a daily basis to help transduce taste signals to the brain that relay nutrition and ultimately survival information. A key component to perceiving and digesting food is saliva. This review focuses on the role that saliva plays in the perception of taste. In addition to evaluating how it is that saliva can influence taste, the role of orosensory cues in regards to stimulating saliva production will be examined. In addition, evidence revealing both objective and subjective salivary dysfunctions will be discussed. Both types of dysfunction incorporate the effects that can arise when there is a partial or a whole lack of saliva. Additionally, taste dysfunctions that involve the salivary system will also be discussed.

Primarily for its involvement in taste, but also for its involvement in the digestive process and in other real world applications, it is surprising how important and powerful something as simply as saliva is to everyday life. Overall, saliva’s role in taste and the interruptions from dysfunction are examined in this review.
Introduction

Saliva is a catalyst for the gastrointestinal system aiding in the breakdown of food and the identification of nutrients that need to be extrapolated. Before and during the onset of this process is the phenomenon that we often overlook called taste. Saliva facilitates the transduction and therefore the recognition of tastants. It is in the recognition that the brain is able to decipher if a tastant is of nutritional value and thus beneficial for survival. Although seemingly simple, the process of producing, excreting, and using saliva is complex and detailed.

Salivation is a process originating with the origin of saliva in the salivary glands. There are three main salivary glands in the oral cavity: the parotid, submandibular, and the sublingual glands (Matsuo, 2000). In addition there are several minor salivary glands, which vary only in anatomical size, not in function from the major glands. The salivary glands consist of acini cells, which are clustered together to form the glands themselves. Components of saliva include water, enzymes, mucous, and electrolytes that flow out of the acini cells and into the collecting ducts. The epithelial acinar cells can be divided into two categories based on their excretion being either mucous or serous. The difference in these cells types lies in the consistency of their secretion. As the name implies, the secretion of the mucous acinar cells is dominated by mucous with very little water, whereas the secretion of the serous type is very watery with little to no mucous. Of the three main salivary glands, two are characteristically linked to a specific type of acinar cell, and therefore to a specific type of secretion. Submandibular is associated with the mixed secretion of mucous as well as serous. The parotid gland is linked to the serous and watery secretion. The third salivary gland, the sublingual is responsible for the
secretion of the mucous based saliva. The variation in the type of saliva secreted by these differing glands is important to note as each type of saliva has a different function. The mucous is in large part responsible for the lubrication and binding of the food in the oral cavity, which assists in the swallowing of food without damage to the esophagus, whereas a main function of the serous cells is to initiate starch digestion with the secretion of alpha-amylase.

This whole system of secretion is initiated by neural stimulation of the myoepithelial cells that are wrapped around the acinar cells producing constriction of acinar cells and thus releasing the accumulated fluid. Salivation is triggered by three things: chewing as the mechanical stimuli, gustatory for which acidic stimuli produce the strongest response and sweet produces the least, and the third is olfactory (Humphrey and Williamson, 2000).

One of the most famous studies on saliva was done by Ivan Pavlov. A physiologist who also found what we call today classical conditioning while doing research on saliva. Pavlov’s carried out his experiment with a bell and food. Over time this combination caused salivation at the sound of the bell in anticipation for food. Pavlov’s experiment is good indicator of the fact that saliva is controlled internally by parasympathetic stimulation of the brain.

Saliva plays a vital role in the taste process both before and during the transduction of taste stimuli. Although saliva’s role in digestion has been the focus of much research, the primary focus of this review will be on the contributing factors that saliva has on taste.
Role of Saliva in Normal Taste Sensitivity

Naturally Present Saliva

Humans produce an average of one to one and a half liters of saliva per day. This clear, somewhat acidic fluid with a range of six to seven pH is produced by the salivary glands. These glands have been classified major and minor, yet, this inference is only in regard to the anatomical size of the glands. The minor glands should not be discounted in terms of importance; since they are in large part responsible for the protection of the oral cavity and the components within it. It is the consistency of the saliva secreted from the minor salivary glands that provides protection for the teeth and gums (Humphrey and Williamson, 2001). This idea of protection is one that is discussed in the Matsuo (2000) review article which points out the main role of saliva as a solvent and transporter of taste substances to the taste receptor cells (TRC). In fact, the diffusion and dilution of all tastants into saliva occurs because all substances must pass through saliva to reach the TRCs.

Breakdown of food with the assistance of saliva is best understood with proper knowledge of the oral cavity anatomy. This includes the location of the taste receptor cells on the fungiform and circumvallate papillae. The transduction sites are found on the membranes of the microvilli, which emerge from the apical region of the TRC on the taste buds. Most taste buds are found in the folds of the foliate and circumvallate papillae, with some also located on the anterior fungiform papillae and on the soft palate. Once the tastant has been perceived on the TRC, a signal is sent to the insula cortex in the brain. This occurs due to ionotropic or metabotropic receptors transducing the signal that then is sent via the chorda tympani nerve, the glossopharyngeal nerve, or the vagus nerve to the
insula cortex. The transduction pathway of taste signals has been the basis of much research that is looking at the effects of damaging one of these nerves and the outcome on taste. One important distinction to make about the anatomy of the tongue, is that a majority of taste research has been done using rats. In terms of taste and anatomy of the tongue, rats are different from humans because they only have one circumvallate papilla, whereas humans have many more. This difference ultimately becomes a limiting factor in the amount of comparisons that can be made between the species.

Along with being a transport mechanism for taste substances, saliva contains components that can stimulate the taste receptor in a non-stimulated environment. Meaning that continuous stimulation of the TRC with saliva can decrease the sensitivity to the salivary components. The implication is that over time there is adaptation to saliva, which influences the ability of TRCs to recognize tastants. Studies like that of Matsuo (1997) have shown that lack of saliva due to the removal of glands leads to a reduction in taste nerve responses. Overall, adaptation of saliva decreases taste sensitivity.

The ability to dissolve taste solutions influences the rate that the taste stimulus is recognized by the TRCs (Matsuo, 2000). This is characterized by an initial transient phase, which is then proceeded by a tonic or steady phase. The flow rate of saliva influences the initial phase of taste perception, such that higher flow rates cause greater perceived intensity. This also means that the smaller the magnitude of a tastant the smaller the response and the longer it takes to reach the tastant peak in the TRC (Matsuo, 2000). Therefore indicating that the tonic phase is unaffected by flow rate. Mastication facilitates the breakdown of food to elevate flow rates of saliva, producing greater taste
intensity. The majority of the daily production of saliva takes place during food consumption.

Salivary gland distribution is an important issue. The submandibular gland produces more than half of the unstimulated saliva, contributing 65 percent. The second most productive gland is the parotid, contributing 20 percent. Minor salivary glands produce 10 percent of the remaining unstimulated flow with the 7 percent produced by the sublingual gland. These percentages change drastically when salivary glands are stimulated. The parotid gland is responsible for producing more than half of stimulated secretion. It is crucial to understand that each salivary gland produces varying types of saliva. Therefore making the production percentages during stimulation more important because the type of secretion influences taste recognition.

The secretion pathway originates in the acinar cells, where the saliva is first secreted. Acinar cells are also responsible for deciding if saliva type will be serous, mucus or both. The type of saliva produced is linked to the gland that produces it. Specifically, the parotid gland secretes serous saliva, the minor glands secret mucus based saliva, and the sublingual and submandibular glands produce a mixture of both serous and mucus.

After the acinar cells, the salivary system is comprised of duct cells. Classifications of duct cells include intercalated, striated, and excretory. The main role of intercalated duct cells is to connect the acinar secretions to the rest of the salivary gland. Both the striated and the excretory cells work to modify electrolytes. As the second in the network, the striated cells work to reabsorb sodium as means of modifying electrolytes.
Last in the duct network, the excretory cells, also help to reabsorb sodium in addition to secreting potassium.

Salivary glands are innervated by both the sympathetic and the parasympathetic nerve fibers. Salivation controlled by the sympathetic nerve fibers has more protein in the acinar cells than when the parasympathetic innervations are prevalent, generating more watery secretions. The parasympathetic transmission of taste impulses is due to cranial nerve transportation of these signals and is the trigeminal nerve for most transmitted information (Pederson et al, 2002). Taste stimulation is conveyed to the brain from sensory nerves. The facial nerve transmits information for the sweet, salty, and acidic stimuli, while the glossopharyngeal relays information from the circumvallate papillae and the back of the tongue (Pederson, 2002).

An important distinction to make about saliva is the difference between contents when unstimulated and stimulated. Due to the body’s circannual regiment, salivary flow rates in the summer are typically elevated and reduced in the winter. When rates end up being below that of what is considered to be normal, they are considered to be insufficient and can have one of two general effects as a result. The first one being reduced preparation of food for taste and digestion and the other is a heightened chance for a structural oral disease (Humphrey and Williamson, 2001).

The most important aspect of saliva is its solubility for taste substances as Birch and Ray (1979) speculated in their paper; that if something is not soluble to saliva then you won’t be able to taste it. It is their reference to a 1932 article by Blakeslee addressing the idea that pH was not a factor in taste acuity and suggesting that saliva probably was a
factor that seems to have spurred their own study. Birch and Ray chose to work with specific tastant concentrations to see if there was an effect on threshold levels.

They picked glucose and administered it at varying concentrations over many trials. They found that glucose concentrations do have a highly significant presence in saliva short periods after ingestion. Specifically at 5 seconds and 5 minutes for both the 10 and 50 gram concentrations. The long term effects, measured at 30 minutes after ingestion found to be significant from regular saliva in the 50 gram does, but not in the 10 gram does (Birch and Ray, 1979).

Ingestion of a specific tastant is limited to effecting that tastant’s threshold and does not affect others. In this case, the glucose had no effect on the threshold for bitter tastes. Birch’s earlier research with Mylvaganam(1976), found that persistence and intensity of response are both contributing factors to the overall gustatory score of basic taste. Birch also refers to Bartoshuk’s 1977 research on the effect of adaptation with regard to direct adaptation results. Bartoshuk’s results point to the idea that adaptation might be a time-limited phenomenon and related to the retention of elevated sugar concentrations in the saliva. In other words, sensory adaptation occurs when there is a decline of intensity in a sensation due to constant stimulation. Overall, Birch and Ray noted that similar to pH levels, glucose concentrations must not really play a role in affecting taste acuity since they discovered that threshold levels were unaltered after 30 minutes of ingestion.
Saliva Present Due to Induction

The concept of using tastants to demonstrate the effect of stimulation is a topic that has been looked at from many angles, including the contributions of temperature and texture. The idea of affecting the flow rate of saliva with a variation of temperatures in stimuli was examined by Dawes et al (2000) with the conclusion that stimulation is higher when ice than when a 37° Celsius liquid. Dawes et al based their research on work that had previously been carried out by Pangborn (1970), who found that the reaction to the temperature stimuli was distributed as follows: 0, 55, 22, and 37 degrees Celsius, with 0° producing the highest stimulation.

One difference in the two studies is that Dawes et al looked specifically at the salivary flow rates that were produced as a result of the varying thermal stimulants. The first part of the study focused on the effect of non-traditionally heated liquids and the effect of heating them. These results yielded that for the whole saliva at each temperature, with the exception of sweet and carbonated ice, the results were significantly reflective of thermal stimulation. The saliva specifically collected was that from the parotid gland with results demonstrating that the sour stimulus presented the most significant flow rate. All the other liquids in a solid ice form produced a higher flow rate then when the same stimuli were presented in the liquid form. These results indicate the possibility that a mechanical aspect of stimulation is taking place in addition to the gustatory stimulation. This possibility was also tested by using an acrylic block in the mouth as a control for the ice cube and found that it only produced a third of what the normal ice cube produced. This relies on the likelihood that the temperature of the ice is the cause of such a difference in response. Another important factor attributing to the first part of this study
is the thought that when in the liquid form, with the exception of the sour stimuli, temperature did not have a significant effect on salivary flow rates. According to Dawes and Lagerlof (1985), the sweet stimulus in the liquid form is hardly considered to be more effective in producing a salivary response than water. Therefore suggesting that sweet stimuli are ineffective gustatory stimuli when compared to the others.

In the second part of this study, Dawes and Lagerlof used brewed tea at a wide range of temperatures to determine the effects of varying thermal astringent reactions. This portion of the research found significantly lower saliva flow rates when the water and the tea astringent were presented at 37° C. Thus suggesting that the tea astringent and the water at 0° C is more “effective” at stimulating saliva than these same fluids at 37° C or 70° C. According to Breslin et al from 1993, oral astringency has been “reported” as being a tactile sensation as opposed to a taste sensation. This is due to the increased friction of the saliva with the opposing areas of the oral mucosa. A concept looked at in a study by Guinard (1997) on astringency as being a mouth feel sensation along with other sensory attributes.

Guinard et al examined the connectivity of the parotid gland salivary flow in relation to perceived intensity of taste, mouth feel, and texture attributes in both liquid and real solid food (1997). This study also examined the differences between males and females on saliva flow for the various items tested. Finding that males had a higher amount of saliva than females, but ultimately that there were no gender differences when looking at real and consistent differences (1997). A key component to this study was that perception of the sensory attributes of food is a time sensitive phenomena. Therefore a time-intensity method was used to evaluate and monitor the selected taste, mouth feel and
texture during collection of data. This time sensitive phenomena refers to the idea that when a tastant is presented, a certain amount of time is needed for it to be perceived. The stronger the tastant the faster it is perceived. When a less strong tastant is presented, it will take more time for it to be perceived by the TRCs and ultimately by the brain. Overall the results from this study only showed an effect on the time-intensity parameters in regard to the textual attributes of the solid food.

All in all, both of these studies on the stimulated response of saliva show that there is a wide variety of reactions which are dependent on a combination of factors with regard to the taste substances that is going to interact with the saliva.

**Absence of Saliva**

Even when unstimulated, saliva is almost always present. It is during sleep that saliva is not being produced. In most cases, the lack of saliva during sleep doesn’t cause any deficiencies. However, there are some cases of self reported xerostomia, or dry mouth, that occur due to this normal hiatus of saliva production. The specifics of how the mouth is able to compensate for such a long period of not producing saliva is not fully understood. It’s also still unknown as to why the body still produces rhythmic masticatory muscle activity and swallowing while we sleep. Aside from avoiding cavities, one important reason to brush your teeth before sleeping is that with this lack of saliva, the lysozomes in saliva are not active and do not have the ability to break down bacteria.
Salivary Dysfunction

Taste loss, or the sensation of taste loss can occur for a number of different reasons. In Bartoshuk’s 1988 paper, it talks about dealing with the psychophysics of taste. Specifically, that patchy taste loss can be the result of head trauma, viral infections, and due to aging. The basis for partial or localized taste loss is that different areas of the tongue are linked to different nerves which send stimulant signals to the brain. The mention of aging and the elderly with taste problems can be attributed to the raised threshold that they experience. Simply put, their taste sensitivity may become patchy or selectively localized if one sensation is registering as it normally would while another one is not. Another variable that seems to cause “patchy” taste loss is in those who have bulimia, yet their taste loss is less of the patchy form and more localized to the palate region (Bartoshuk, 1988). In other words, those who are bulimic often loose only certain areas of taste as opposed to several locations. Previous research done by Bartoshuk found that localized taste loss is not a conscious factor to those who have altered taste. This is due in part to the compensation from other areas which diminishes the ability to notice a lack of taste in one area.

One of the most extensive taste problems is a disorder termed xerostomia. This subjective disorder is considered to be dry mouth. Xerostomia is a self reported condition that can be due to evaporation. A more objective form of dry mouth is hyposalivation, which is indicated by a physiological reduction in the amount of saliva that is being produced. Having xerostomia or hyposalivation can lead to one or several of these things: soreness, gingivitis, infection of salivary glands, yeast infections, hard time chewing or
swallowing and difficulty speaking, callus deposits in salivary ducts, burning mouth (Dawes, 2004).

An important factor to examine when considering taste dysfunction is the saliva production from each of the glands. The benefit of looking at the individual gland production is to ensure you are not overlooking a potential problem that cannot be spotted when looking solely at overall production. This method allows you to rule out the idea that it is one specific gland that is causing the problem. Since the lack of saliva output from one gland can seriously affect a variety of things. If there is a problem with an individual gland, the repercussions could affect taste perception and digestion due to the varying composition of each gland. In most cases of dry mouth, the treatment includes the administration of Pilocarpine as a chemical treatment. Pilocarpine is taken in the form of tablets which is known to stimulate salivary flow and has clinically been proven to relieve dry mouth in patients. The less than desirable side effects include those reported by Hendrickson et al. found in a Sjogren’s syndrome patient taking pilocarpine. This case is the first to be reported for overdose and resulted with the patient complaining of sweating, abdominal cramping, vomiting, anxiety, and diarrhea (2003). Although these symptoms seem to be the result of inadequate dosing, further studies need to be done to determine if these symptoms are typical of prolonged, normal doses used in patients with dry mouth.

Xerostomia and hyposalivation are serious problems that affect the quality of living in numerous people. More research in this area would allow for increased effectiveness and a reduction in side effects for treatment of these disorders. For now, even with side effects as a result, solutions to alleviate these disorders are available.
Dysfunction Due to Drug or Radiation Treatments

Taste complaints are common in those who are on certain medications and who have recently undergone chemotherapy. For those who have undergone chemotherapy, the complaint often voiced is of “phantom” tastes of bitter or metallic substances. Taste phantoms are a real problem and can occur for several reasons. Dysgeusia is the technical term associated with this altered perception. It occurs when there is a taste that seems to be perceived, yet there is no real stimulation. These phantoms are therefore suggesting that saliva has been affected, but not completely destroyed or fully dysfunctional. For these patients, there is still an ability to perceive tastes. This ability to still perceive other tastes is only possible with the help of artificial saliva (Bartoshuk et al, 1994). Even with active and normal saliva if there are neural signals that are misdirected the end result might be the phantom tastes that Bartoshuk et al discuss.

Phantom tastes are a great example of drug treatments side effects. It is also interesting to see the effects on taste when saliva is not the sole cause of the dysfunction. Another example of taste dysfunction occurs in patients with schizophrenia being treated with clozapine. Research on this topic was examined by Ben-Aryeh et al (1996) with their focus was on the hypersalivation that has been reported by those patients. A correlation was originally speculated due to the autonomic nervous system regulation of saliva and because of clozapine’s strong anticholinergic nature, making a connection between the two seem obvious. Although no significant correlations were found, it is interesting to note that the majority of complaints from patients arose from night-time, potentially indicating the effect of reduced saliva during sleep.
Overall, it is hard to draw conclusions for all dysfunctions in people due to the vast variance from patient to patient. However, the benefits of knowing about a potential problem in taste when encountering treatments such as the clozapine of schizophrenic patients or the chemotherapy for cancer can help prepare patients for taste deficiencies.

**Discussion**

Taste is everything when it comes to food. People tend to choose the foods that taste best when given a choice. It is this choice of taste that food companies strive to maximize with their own products. Therefore making research about the chemical and physical components of tastants essential to their work environment. This need to understand taste components and the role of saliva has been heightened with the outpouring of dieting books and the renewed focus on fat free and healthy foods. The focus on saliva makes understanding the inter workings of saliva the ticket to success for these food companies. If one can figure out how saliva works and its interactions with varying types of food, then one can try to manipulate their new product to produce the effects favored in the regular, less healthy version of their product.

It seems as though most of the western culture is for diets that require you to get away from fatty foods. The lack of the fat in these new and healthy products could be the reason that they are not as popular as their “bad for you” non diet counterparts. So if a manufacturer can figure out how to merge the healthy aspect of the less appealing foods to stimulate the recognition of the fatty foods, it would be a win win for both the consumer and the provider. Olestra strives to do just this. However, on every product using olestra are warning labels that indicate a probability of intestinal problems. It
makes sense that tampering with or altering the make up of what starts the digestion process by tricking the brain to think it has received the appropriate tastant to stimulate the release of enzymes would incur gastrointestinal complications.

It is fascinating to know that saliva contains the information, genetically speaking of who people are. In addition, the knowledge of saliva composition has played a large role in the forensics and political arena that uses saliva to identify people. Since everyone is different, it is exciting to know that our tastes are also different, and our saliva can prove that.

More than being a clue for today’s science and solving age old mystery’s, saliva’s role in everyday life is what is essential. Though not noticed by those with normal functioning saliva, without it humans would be unable to thrive to the extent that they do now. It is saliva’s ability to make tastants perceivable to the brain that makes it an invaluable resource to everyday life and to survival of the fittest.
References


