Graduation Project

Maximizing the taste perception of instant vegan soup powders using natural taste enhancers

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Executive Summary

The increasing trend of sustainable and on-the-go healthy food products results in consumers demanding more 'natural and organic ingredients. Not only do consumers want healthier options, but there is also an increasing concern on part of governments and legislation makers on reducing salt levels in food products to tackle the current high salt consumption in human diets. Additionally, as a consequence of consumers becoming more concerned about how certain food products are manufactured and what they are consuming, the current trend of 'natural' and 'organic' has also pushed manufacturers to introduce 'clean' label products containing no synthetic ingredients, additives, or E-numbers. Numerous studies show that consumers do not trust E-numbers, or ingredients with 'chemical' or synthetic-sounding names. This has resulted in food manufacturers researching alternative 'natural' taste enhancers to enhance taste perception of food products to reduce salt levels without compromising the overall quality and taste of the product. The purpose of this thesis is to investigate which 'natural' taste enhancers can be used to enhance taste perception simultaneously maintaining or reducing salt levels in instant soup powders produced by Future Kitchens. This research aims to answer the question; ***"How to maximize the taste perception in healthy vegan instant soups produced from overproduction streams by the addition of 'natural' taste enhancers without increasing the salt levels?".*** Literature research, kitchen trials, and a consumer acceptance test were used to answer this question. The obtained results were used to improve existing recipes and developed new instant soup recipes.

This project focused on the enhancement of savory perception of instant soup powders through the addition of natural taste enhancers rich in umami compounds such as glutamate, aspartic acid, and 5'ribonucleotides; 5'-inosine monophosphate (IMP), and 5'guanosine monophosphate (GMP). The instant soup powders were produced from overproduced vegetables using the novel drying technique freeze-drying to obtain a premium soup product simultaneously reducing global food waste and extending the shelf life of the product. Several kitchen trials were conducted to develop the new recipes where different natural taste enhancers were combined to obtain the most flavorful recipe. During these kitchen trials, taste interactions of flavoring components were taken into account to evaluate which components could positively impact the flavor profile of the recipes. Furthermore, the addition of components rich in umami compounds such as cherry tomatoes, soy sauce powder, shiitake, kombu, and "clean label" broth allowed for an enhancement in savory perception and a fuller mouthfeel.

The enhancement in savory perception was achieved by maintaining the salt levels below 20% of the recommended daily intake (6g/day) and maintained the cost of production for low volumes within the cost margin established of €0.60-0.90 per serving. Additionally, the addition of these compounds reduced the salt levels by 23-30% compared to the existing recipes without compromising the quality or taste of the final product.

A consumer acceptability test was conducted to assess the overall likeliness of the newly developed soups in terms of color, taste, mouthfeel, and texture. From the results obtained the newly developed soups (spicy tomato, onion-potato, and pumpkin-coco) were all liked by the consumers as all three soups obtained an average score of 7 or higher for all the four attributes measured, with spicy tomato being the most liked by the respondents. However, none of the newly developed soups obtained a satisfactory net promoter score (NPS). This was due to the structuring of the survey which should have taken into account more factors affecting the NPS and should have been conducted with only a consumer panel instead of a combination of consumers and non-consumers.

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1. Introduction

The population growth throughout the years has led to higher demand for food resources resulting in a global food crisis. According to the United Nations, around 25000 people die each day from hunger-related causes *(Holmes, 2009)*. However, the Food and Agricultural Organization (FAO), reported that every year about a third of the food produced for human consumption around the world is either lost or wasted, which amounts to 1.3 billion tons *(FAO, 2011)*. This not only results in economic losses but contributes to global warming, lack of food security in the world's poorest countries, and waste of natural resources used for growing, packaging, transportation, and marketing of food. The agricultural industry is one of the greatest contributors to global warming, it is estimated that food loss or waste accounts for 8% of the annual global greenhouse gas emissions *(FAO, 2015)*.

It is important to understand the difference between food loss and food waste, to be able to tackle the problem of how to prevent it. According to the FAO, food loss is the reduction of edible food at the end of the manufacturer throughout the part of the supply chain. This loss is often considered unintentional and takes place during production, postharvest, and processing stages in the food supply chain *(FAO, 2011)*. As for food waste, it is considered to be an intentional behavior and occurs at the retailer and consumer's end. Food waste often occurs in medium and high-income countries and food loss occurs in low-income countries during the early and middle stages of the food supply chain, and at lower levels at the consumer's end. Food loss occurs due to a variety of reasons depending on the local conditions within each country. In low-income countries, food loss occurs due to a lack of infrastructure, insufficient knowledge on proper storage and food handling, and a combination of unfavorable climatic conditions that lead to food spoilage. Furthermore, overproduction also results in food loss; this is when the supply exceeds demand. Overproduction can occur for several reasons, ranging from market behavior to seasonal fluctuations. Farmers often overproduce to guarantee the delivery of agreed quantities, in the event of unexpected bad weather or pest attacks they tend to produce larger quantities to not have a shortage in produce. This results in surplus crops which are either sold at lower retail prices to processors, as animal feed or becomes food loss due to lack of conservation methods. Unfortunately, a major part of the overproduced fruits and vegetables are burned, thrown away, or left rotting on the field. Further contributing to current problems such as global warming, hunger or malnutrition, and economic losses for farmers.

Future Kitchens was founded with the concept of tackling these problems by producing premium instant soup and smoothies from overproduction and side streams. The fruits and vegetables are preserved using the freeze-drying technique that allows for the dehydration of products without altering the valuable nutrients and vital chemicals of the raw material. Freeze-drying allows the removal of water in substances by freezing the water and subliming the ice formed by applying heat to the frozen products under vacuum conditions. The removal of water extends the shelf life of the product, as water removal is key to reducing material degradation. Additionally, the lower temperatures applied during this process allows for the maximal nutrient and bioactive compound retention in comparison to other dehydration processes *(Bhatta et al, 2020)*. This process is one of the best methods for water removal, delivering high-quality products simultaneously extending the shelf life of the product up to 2 years for a product with 2% residual moisture *(Williams-Gardner, 1971)*. The utilization of this process allows for long-term consumption of these overproduced fruits and vegetables subsequently, reducing the annual amount of food loss and providing the farmer with economical gain. However, one disadvantage is that it is the most expensive drying process due to the slow drying rate and the use of vacuum conditions which increases energy consumption.

Currently, Future Kitchens has a business-to-business model with a focus on Belgium and the Netherlands market. Based on consumer feedback, the instant soup products are lacking taste as consumers often find the taste to be 'very' bland or missing salt. Additionally, the current broth contains yeast extracts and some synthetic additives, which do not align with the company's vision of the ingredient list. Therefore the company is looking for 'clean label' broths and other natural taste enhancers that could be used to enhance the taste perception simultaneously maintaining or reducing the current salt levels without reducing the quality or taste of the final product.

This project will focus on the development of three new soup recipes using overproduced vegetables together with natural taste enhancers that will enhance the taste perception of the consumer, without surpassing the price margin. The taste of the soups should not be enhanced using any synthetic additives, E-numbers, or high salt amounts. This project will aim to answer the thesis question: **"*How to maximize the taste perception in healthy vegan instant soups produced from overproduction streams by the addition of 'natural' taste enhancers without increasing the salt levels?*".** This will be determined by conducting literature research on the legislation concerning natural taste enhancers, factors influencing taste perception, and the availability of vegetables during seasonal changes. Additionally, research will be conducted on 'natural' vegan taste enhancers as a replacement for synthetic additives and e-numbers. Furthermore, after developing several recipes taking into account the aforementioned criteria, a consumer acceptability test will be conducted to rate the recipe in terms of taste/popularity to select the highest scoring recipes.

Chapter 2 describes the theoretical framework defining the European legislation on natural taste enhancers, components responsible for savory perception, taste interactions, flavor release mechanism in food matrices and vegetables, and freeze-drying principles. Chapter 3 describes the materials and methods used to develop the new soup recipes. Thereafter, chapter 4 describes the results obtained together with the discussion. Chapter 5 concludes the results and provides recommendations to improve and continue with the product development stage. Lastly, the appendixes contain the questionnaire used for the consumer acceptance test and the nutritional values of the newly developed soups.

2. Theory and Background

As the lifestyle of consumers evolves so does their consummatory behavior, consumers nowadays have less 'free' time to prepare homemade meals due to longer working hours, longer commute times, urbanization, and increased participation of women in the workforce. This fast-paced lifestyle has resulted in high demand on-the-go food products, to facilitate their hectic life schedules. According to Statista, the convenience food segment (ready-made meals, wet and dry soups) accounts for 6% of the global food market, which had around US$ 433 billion in sales in 2019, and is expected to continue rising and is estimated to reach US$ 585 billion in sales by 2025 as the consumer's busy lifestyles lead to greater demand for convenience food products. Not only do consumers demand convenient food products but also demand healthy and sustainable on-the-go food products at a reasonable price. The growing number of food and lifestyle-related diseases such as obesity, diabetes, and other chronic diseases has resulted in consumers becoming more concerned about how certain foods are manufactured, the use of synthetic ingredients and additives, increasing the demand for healthier food products, and more natural/organic foods. It has been proposed that the consummatory behavior of consumers is influenced by three major trends; health concerns, sustainability thus the contribution of the food system to climate change, and convenience *(Asioli, 2017)*. Other important drivers include high nutrient content, flavor, and price *(MacFie, 2007).* These trends have shifted the market towards natural, organic, and/or free from synthetic additives, preservatives, and E-numbers providing food products with a 'clean label'. The food industry has started to meet the demand for 'cleaner' food products by adjusting their manufacturing practices and ingredient list to be able to provide products that are perceived as 'cleaner' or 'natural' by the consumers. However, even though the market has shifted to 'clean label' food, there are still consumer misconceptions of what natural is, the usage of chemicals in food, and the application of industrial processes to food *(Baines, 2012)*. Therefore, it is important to understand what can be deemed as natural following regulations and legislation to be able to identify natural flavor enhancers that can be used for the development of 'clean label' soups for Future Kitchens. As the products are mainly/only sold in countries within the European Union, subchapter 2.1, will only focus on the regulations and legislation involving products sold within the European Union.

2.1. Natural Flavor Enhancers

In Europe, food additives (such as preservatives, flavor enhancers, and colorings) have been used for decades and today they can be found in almost any kitchen. Food additives such as flavor enhancers and fillers are often used to improve the organoleptic quality (color, flavor, appearance, taste, and texture) in many processed food products. The usage of food additives is strongly regulated by the European authorities and national authorities. The European Food Safety Authority (EFSA) introduced an E-number labeling system in 1962, as a method of indicating that the additive has been scientifically tested and proven to be safe for consumption *(Meijer, 2010)*. Each additive is given an acceptable daily intake amount (ADI) by the EFSA, which provides information on how much of the substance a consumer could safely consume without having any adverse health effects*.* After establishing that a food additive is safe for consumption it is given an E-number which is also used to replace the chemical name of the substance. Food manufactures are obligated to declare the E-number and name of the food additive used on the product label or its sales description. However, even though the introduction of the E-number labeling system was conceived with the purpose to inform consumers of what exactly they are buying and eating and for the introduction of safe food products within the European community, many consumers associate E-numbers with chemicals that should not be in the ingredient declaration of food products. Additionally, there is a lot of controversy regarding the utilization of additives in food products due to the health risk posed by regular consumption of these additives in processed food. Additives do not pose a health risk when consumed in small amounts but eating processed food regularly can have in the long run an effect on the consumer's health. In today's fast-moving society, consumers tend to eat processed food daily due to their busy schedules this results in high consumption of additives which can result in long-term effects. The negative impact of synthetic food additives has been confirmed by several studies that high consumption of these additives may cause gastrointestinal, respiratory, dermatologic, and neurologic adverse reactions *(Wijayasekara et al, 2020).*

In the last decades, public awareness of the impact of food products on health in the developed world has resulted in an increase in the market for natural flavorings. It is estimated that the annual average growth rate for the market of natural flavor enhancers is around 6.2% and continues to further increase due to rising pressure on regulations worldwide on flavors enhancers used in the food industry, consumer perception of healthiness of natural flavor enhancers, and newer technologies allowing for cost-effective productions *(Baines et al, 2012)*. Flavor enhancers or flavoring additives are chemical substances that are used by food manufactures because of their flavoring properties and represent the largest class of food additives (*Inetianbor, et al 2015)*. In 2010 Regulation (EC) No. 1334/2008 on Food additives was implemented with the objective to protect consumers and inform consumers of their food choices.

In the European Union regulation on flavorings (EC) No. 1334/2008, a flavoring substance is described as *"products not intended to be consumed as such, which are added to food in order to impart or modify odor and or taste"*. These substances are also classified into six categories in the regulation:

1. Flavoring substances
2. Flavoring preparations
3. Thermal process flavorings
4. Smoke flavorings

5. Flavor precursors
6. Other flavorings or mixtures thereof

The term 'other' in category 6, is to define other flavoring substances not described within the first five categories. A flavor enhancer can be considered natural only if it is obtained from a material of an animal, vegetable, or microbiological origin, by natural processes, and has been 'found in nature'. Article 16 of the Regulation (EC) No. 1334/2008 describes how the term 'natural' can be applied to two of the abovementioned categories.

Using the term 'Natural';

Article 16.2; "*The term 'natural' for the description of a flavoring may only be used if the flavoring component comprises only flavoring preparations and/or natural flavoring substances".*

Following article 16.2, only two categories can be deemed as 'natural'; category 1. Flavoring substances and 2. Flavoring preparations. However, both categories should follow certain guidelines to be considered 'natural', Regulation (EC) No. 1334/2008 Article 3.2(c) describes when can a flavoring substance be called natural and (EC) No. 1334/2008 Article 3.2(d) describes when can a flavoring preparations be called natural.

Regulation (EC) No. 1334/2008 Article 3.2 (c) *'Natural flavoring substance' shall mean a flavoring substance obtained by appropriate physical, enzymatic, or microbiological processes from the material of vegetable, animal, or microbiological origin either in the raw state or after processing for human consumption by one or more of the traditional food preparation processes listed in Annex II. Natural flavoring substances correspond to substances that are naturally present and have been identified in nature.*

Regulation (EC) No. 1334/2008 Article 3.2(d)
'Flavoring preparation' shall mean a product, other than a flavoring substance, obtained from;
(i) food by appropriate physical, enzymatic, or microbiological processes either in the raw state of the material or after processing for human consumption by one or more of the traditional food preparation processes listed in Annex II; and/or
(ii) material of a vegetable, animal, or microbiological origin, other than food, by appropriate physical, enzymatic, or microbiological processes, the material being taken as such or prepared by one of the traditional food preparation processes listed in Annex II.

Following the guideline on the source of material and the process used to obtain these flavoring substances adhere to what is considered to be the "traditional food preparation process" as shown in Table 1, the flavoring substance can be deemed natural.

Table 1: Annex II Regulation (EC) No. 1334/2008: List of traditional food preparation processes

Chopping	Steeping
Heating, cooking, baking, frying (up to 240°C at atmospheric pressure) and pressure cooking (up to 120°C)	Coating
Cutting	Cooling
Drying	Distillation/rectification
Evaporation	Emulsification
Fermentation	Extraction, including solvent extraction in accordance with Directive 88/344/EEC
Grinding	Filtration
Infusion	Maceration
Microbiological processes	Mixing
Peeling	Percolation
Pressing	Refrigeration/freezing
Roasting/grilling	Squeezing

Further information on the definition of food, natural flavoring substances, natural flavoring ingredients, and production of natural flavoring substances can be found in Regulation (EC) No. 1334/2008. Additionally, the European Flavor and Fragrance Association (EFFA) has composed a guidance document based on the EU regulation with the objective to integrate the regulation into the practical application *(EFFA 2019)*. This document together with the EU regulation can be used as a reference on the labeling of flavoring substances by flavoring manufacturers (B2B) and by food manufacturers (B2C) on how to label these flavoring substances on the final product. Furthermore, the guidance document gives insight to companies to determine what can be deemed natural and whatnot, and how they can adequately adhere to the regulations.

Another tool that can be useful for business is the Authorization of Additives within the European Union database. This database can inform the consumer and the food manufacturer about approved food additives and their conditions of use. The idea of an ingredient declaration containing a food additive or E-number often does not sit well in consumers' perception of natural, even if the food additive used is natural and may offer benefits for the consumer, it still decreases the purity and wholeness of the product. An example of this is *beta-carotene* (E160a) which is also known as pro-vitamin A, if this product would be listed as an E-number the product will not be considered a 'clean label' product. Consumers' understanding of what natural means does not often align with reality, therefore, to meet the demands of consumers on their idea of natural, the term 'clean label' was developed. The term was developed to simplify ingredient declarations making them more consumer-friendly and viewed as healthier by the consumers *(Baines et al, 2012)*. Food products that do not contain chemicals or E-numbers are products that are referred to as 'clean label' products.

As above mentioned, flavor enhancers are used to enhance flavor characteristics of other ingredients, as these food additives are not flavors themselves. The enhancement of the flavor of certain ingredients occurs through a synergistic effect. Humans can identify flavors in food not only through taste but a complex interaction between different sensory impressions, starting with taste and aromas, accompanied by a variety of oral sensations and the visual aspect of a food product, texture, and acoustic impressions *(Parker et al, 2015)*. The olfactory system of humans is in charged to detect different odors within their environment, when food is consumed, the olfactory system is identifying different aromas that allow us to recognize nutritive foods and potential toxins and rancid foods *(Russel et al, 2002).* Simultaneously, aromas stimulate appetite and can provide an emotional connection from past experiences. Furthermore, the gustatory system of humans can identify five basic tastes; sweet, sour, bitter, salty, and savory also known as umami. According to Keast (2002), there are four attributes that make an individual flavor sensation unique; quality, intensity, temporal and spatial patterns. Quality is a descriptive noun used to describe the five basic tastes, that flavoring compounds bring out, which defines the taste sensation of the compound. This helps to know what sensation this compound would bring to the food product if added. Intensity is used to describe the abundance of a taste sensation of a certain compound at a given time. This key attribute helps to distinguish between perceived intensity and differences between food products to reveal palatable and unpalatable food products depending on the taste sensation perceived. The lingering effect of the intensities of certain taste sensations is referred to as the temporal pattern. For example, certain compounds linger in the mouth for a longer period of time compared to other compounds. Lastly, spatial pattern expresses where a certain taste sensation is located on the tongue and oral cavity. The human taste sensors are located in papillae throughout the oral cavity and therefore can localize taste there despite whole mouth exposure *(Webb et al, 2015)*. These papillae are able to detect taste through taste receptor cells (TRCs), once a non-volatile chemical enters the mouth it stimulates the TRCs and with enough stimulation, the impulse is decoded which results in a person perceiving taste.

For the development and improvement of food products taste interactions are essential. Taste-taste interactions can give guidance on how certain flavor enhancers with the same or opposite qualities can interact with the food product and can result in enhancement or inhibition of intensity. These scenarios are not only faced by food product developers but also by consumers on a day-to-day basis; Does the addition of certain spices increase the salt perception in my dish? Is 1 teaspoon of honey enough to sweeten my tea? Or would it make my tea too sweet? Therefore, it is important to take a look at taste-taste interactions to evaluate how mixing different substances can bring out different tastes and this results in enhancement, suppression, chemically synthesizing new taste, or uncovering a new taste not initially recognized. When mixing two compounds, numerous possible interactions can occur which can result in enhancement, additivity, or suppression of intensity. According to Keast (2002), enhancement, additivity, and suppression of intensity can be explained as follows, "enhancement equates to 1+1>2, additivity 1+1=2 and suppression to 1+1<2". When compounds that perceive similar qualities are mixed, various interactions could occur depending on the concentrations (low, medium, or high). For taste-mixture interactions, a simple sigmoidal-shaped psychophysical function for a hypothetical mixture can be completed to predict whether enhancement or suppression would occur when mixing two flavor substances *(Keast et al, 2002)*. In figure 1, a theoretical psychophysical concentration function for a taste mixture is demonstrated. This graph is composed of three different phases, expensive, linear, and compressive, and plotted as concentration (x-axis) against intensity (y-axis). As can be seen, when the concentration of a compound is increased so does the perceived intensity but at varying rates. The initial phase of the graph also known as the expansive phase (n>1) has an exponential growth, where the intensity increases at a faster rate compared to the concentration. Therefore, doubling concentration at this phase results in greater perceived intensity instead of doubling perceived intensity. The second phase linear ($n=1$) is at a medium concentration, the intensity increases in a linear manner. Thus, increasing concentration leads to an increase of intensity at a proportional rate. Finally, the third phase compressive is at a high concentration, an exponential deceleration function is observed, where the intensity reaches a plateau which is the result of receptor saturation or the upper limit of intensity of corresponding taste mixture is achieved *(Keast et al, 2002)*. In this phase, if the concentration is doubled the perceived intensity will not increase.

The theoretical psychophysical concentration-intensity graph can easily be explained as follows in order to perceive certain intensity, it has to be great enough to create stimuli, for a mixture that has a high concentration of a flavoring substance by adding another flavor, that flavor intensity must be greater than the existing intensity for you to perceive it. If that is not the case this flavor will not be perceived. At higher stimulus intensities or higher stimulus concentration, you will need greater stimulus change to perceive a higher intensity or to have a noticeable difference. Thus, the greater the stimulus is, the more you need to detect a change or perceive a change.

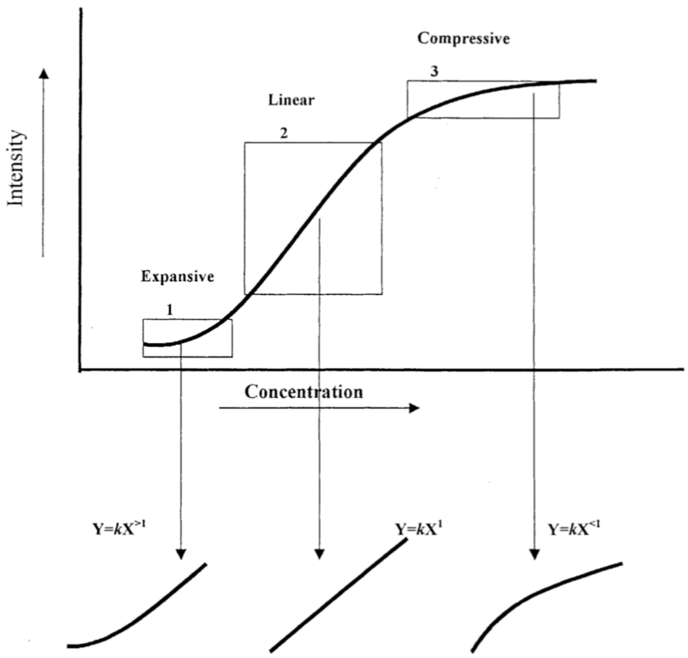

Figure 1 (Keast et al, 2002): Theoretical psychophysical concentration-intensity graph for a flavoring substance

Mixing two compounds with the same flavoring profile can result in psychophysical function with a sigmoidal shaped function which is often used to predict the type of interaction; additivity, enhancement, or suppressive *(Keast et al, 2002).* For mixtures of sweet flavoring substances, it has been reported that at low intensity/concentrations, results in enhancement in perceived intensity. However, at higher intensity/concentrations, it is common to see suppression instead of enhanced sweet perception. This information correlates with the psychophysical graph shown in figure 1. It has also been reported that mixing two substances with an umami flavoring profile, such as MSG and sodium salts of ribonucleotides results in a synergy effect where the intensity perceived is enhanced *(Vasilaki et al, 2021).* As for salt mixtures, it has been reported that mixing NaCl and KCl at low concentrations, enhanced the perceived intensity, and at higher concentrations, the perceived intensity was suppressed *(Breslin, et al 1995).* The predictions based on the psychophysical function are not always accurate when mixing two compounds with different flavoring profiles. Numerous interactions could occur when mixing substances with different flavoring profiles such as enhancement, suppression, or both (non-monotonic). It has been reported that umami substances can enhance the perception of sweetness, saltiness at moderate concentrations while suppressing sourness and bitterness *(Woskow et al, 1969).* Another study conducted by Kemp and Beauchamp (1994), reported that MSG a substance known for its umami profile, suppressed the perceived intensity of sweet and bitter at moderate concentrations, and at high concentrations, it enhanced the saltness perceived intensity. The addition of salt in sour mixtures or vice versa has resulted in enhancement in perceived intensity at low concentrations, at high concentration, this resulted in suppression or no effect. As for bitter interactions with salt, many studies have shown suppression of bitterness by the addition of salt, however salt taste is not affected by the addition of substances with a bitter profile *(Keast et al, 2002).* In figure 2, an overall picture of different quality binary taste interactions can be seen at the corresponding intensity/ concentration (low, medium, or high). The term variable was used for contradictory literature, each picture represents a phase of the graph shown in figure 1.

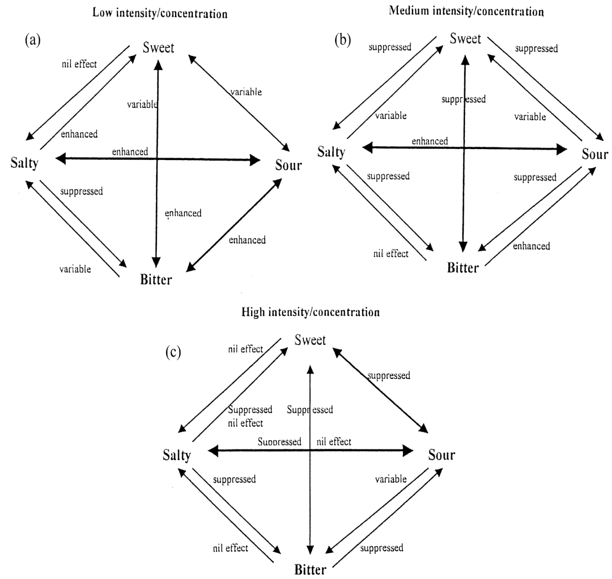

Figure 2 (Keast et al, 2002): A schematic review of taste interactions between substances with different quality interactions at different phases of the theoretical psychophysical concentration-intensity graph. (a) represents the expansive phase, (b) portrays the linear phase, and (c) the compressive phase.

Besides taste interactions having an essential role in how to combine ingredients with different or similar flavor qualities, it is important to take a look at what factors influence the eating mechanism. Taste is an incredibly complex mechanism that not only consists of flavor molecules within the food matrix but is a combination of taste, smell, and touch *(Tracy, 2021)*. Additionally, other external factors such as environment, cultural background, personal preferences, first childhood memories, and other psychological factors have an impact on our taste perception, the overall likeness of a product, and how we judge a food product *(Visser, 2020)*. As these factors variate between individuals and are out of work scope, this report will not dive into these factors influencing taste experience.

In a food matrix, flavor perception is influenced not only by the composition of odorant molecules but conjointly with the number of molecules released in the mouth during eating *(Tromelin et al, 2006)*. Food matrices are composed of a multi-component system that consists of volatile and non-volatile substances. Aromas are a complex mixture of both volatile and non-volatile compounds that are in the vapor phase at room temperatures and can reach the olfactory receptors for them to be perceived. Additionally, these molecules also release specific notes during consumption. The release of aroma compounds in the vapor phase in food matrices is influenced by several factors including, their interaction with non-volatile compounds, compounds present in the food matrix such as carbohydrates, lipids, proteins, and hydrocolloids. Apart from aromas influencing taste perception, food texture also has a big impact on flavor release, depending on the type of food system (emulsion, solid, or liquid systems). For emulsion systems, mainly dressings such as mayonnaise, the aroma compounds are dispersed between the aqueous phase and lipids of the system. As for solid systems, which have a heterogeneous composition and structure, where proteins, carbohydrates, and lipids interact together influencing the flavor release and texture. For liquid systems, the flavor perception is impacted by the combination of a short residence time in the mouth and limited retention of aroma compounds in the food matrix. It is hypothesized that a longer residence time in the oral mucosa will result in a higher taste intensity. However, as there is no mechanical aid of mastication when consuming liquid or semi-solid food systems, flavor intensity depends on how fast flavor is being released, because residence time in the oral mucosa cannot be prolonged by oral processing of the food matrix. Furthermore, besides texture, residence time in the mouth, flavor release is also impacted by manufacturing processes, depending on the process conditions flavor release is either suppressed or enhanced. In general, flavor release is influenced by the intrinsic chemical properties of the flavor such as hydrophilicity, hydrophobicity, volatility (vapor-pressure), the composition of the medium, and lastly the environmental conditions such as temperature and pH *(Hannson et al, 2001)*. In conclusion, the flavor intensity of a food product is determined under the given environmental conditions which determine the flavor intensity retention or release from a food matrix. These factors are key factors that influence flavor release and are essential when formulating a food product.

Aforementioned, there are five basic tastes that the human gustatory system can identify, there are two basic tastes that can contribute to the enhancement of the savory flavor profile: salt and umami. The salty taste perception is generated by sodium ions which are present in table salt. Additionally, other metal cations are also characterized as being salty; potassium, lithium, and magnesium or the halide anion; chlorine, bromine, and Iodine. However, only sodium chloride ions can deliver that clean salty perception without any other underlying tastes. On the other hand, in recent years concerns have been raised due to the high salt consumption mainly sodium. A food diet high in salt above the recommended dosage (6g/day) can result in an adverse effect on health resulting in cardiovascular disease or hypertension *(Kilcast et al, 2007)*. Even though salt

(NaCl) is the most accepted natural taste enhancer, there is an increased interest in reducing the daily salt intake in human diets. Therefore, food manufacturers are producing and developing natural taste enhancers that could replace or/and reduce the salt levels in food products without compromising the quality and sensory attributes of food products. There are three major functions of salt in food products, preservation, flavor, and process-ability. Salt enhances the flavor of food products, by increasing the overall flavor and contributing to a fuller mouthfeel both in savory and sweet products *(Hutton, 2000).* The addition of salt to a solution results in a difference in solute concentrations and water activity, which generates, at the vapor-liquid interface, a vapor pressure decrease. This decrease in vapor pressure results in a decrease in freezing point and an increase in solubility of certain materials, particularly hydrophobic aroma compounds. By increasing the solubility of certain materials, there is an impact on the volatility of flavors, mainly those with low solubility. The addition of salt in a food system decreases the water activity due to salt molecules binding with water molecules reducing the water activity. This results in a decrease of 'free' liquid which increases the flavor concentration promoting flavor release, a mechanism known as ''salting-out''. The function of salt in flavor cannot be undermined, without the addition of salt in a food product such as soup, bread, and biscuits they are perceived as having a bland taste. Therefore, the complete elimination of salt as a fundamental block in food products will have a serious effect on overall flavor *(Kilcast et al, 2007)*. Other common natural taste enhancers used in the industry and households are spices and herbs, which is an excellent method of adding texture, color, and aroma to food products.

Another basic taste that is known to provide a savory taste perception is known as umami. It has been suggested that the ability to identify the taste umami emerged from the detection of foods high in protein or an indicator for the presence of valuable amino acids. The taste receptor for umami was only discovered/accepted as an independent taste impression in 2002 and started to be considered as a basic taste only then. However, this flavor was first identified in Japanese cuisine/foods such as kombu *(Johnson et al, 2013)*. The Japanese scientist Ikeda managed to isolate L-glutamate from seaweed, which is considered to be the key stimulus for the umami taste receptor. Glutamate is an amino acid found in many natural foods such as tomato, milk, cheese, fish, meat, and several different vegetables, which is released by breaking down proteins during cooking or fermentation of proteinaceous foods *(Tracy, 2021).* High levels of glutamate are found in tomatoes, mushrooms, and parmesan cheese. Additionally, glutamate is also naturally produced in our bodies, not only does it provide an enhancement in savory taste but it also plays a crucial role in our digestion, muscle function, and immune system. However, for glutamate to be able to act as a taste enhancer it has to be in its 'free' form, meaning it cannot be bound to other amino acids in proteins. Ikeda managed to isolate L-glutamate and combined it with sodium resulting in the formation of L-monosodium glutamate known as MSG. MSG is a very known taste enhancer in the food industry and it is used in many households to enhance the savory taste of dishes. However, there is a lot of controversy regarding the utilization of MSG in food products due to studies labeling MSG as 'toxic'. According to Day (2015), regular or excessive consumption of MSG is linked with Metabolic syndrome, which includes cardiovascular dysfunction, diabetes, and high blood pressure. According to the same study, excessive consumption of MSG results in obesity and then Metabolic syndrome. Therefore, researchers have called out for more extensive studies to identify if MSG is the reason for developing Metabolic syndrome or other possible factors accompanied by overeating. This is the reason why many food manufacturers look into the possibility of replacing MSG with other natural taste enhancers due to the bad image it currently has.

Besides glutamate, other compounds can activate the umami receptors in the mouth. Compounds that are also responsible for enhancement or higher intensity of umami taste in food products are aspartic acid which is also an amino acid very similar to glutamate, and 5'ribonucleotide such as inosinate and guanylate. Ribonucleotides are organic molecules consisting of a phosphate group and a nucleoside group, which are known to act in a synergistic effect with amino acids. A study conducted by Kurihara (2009), demonstrated that combining kombu which has high amounts of glutamic acid and bonito flakes which have high amounts of inosinate increased the umami taste perception. Kombu is not known to have high umami taste alone. The taste synergy between glutamate and ribonucleotides is most notably seen with monophosphates such as 5'-inosine monophosphate (IMP), and 5'guanosine monophosphate (GMP) *(Delay et al, 2000)*. However, the ribonucleotides IMP and GMP alone cannot activate the umami receptors. The third group that also contributes to enhancing the umami taste perception is low molecular weight organic acids those that are soluble in water such as succinic acid, tartaric acid, and lactic acid *(Parker et al, 2015).* Umami taste has been used to combat the high consumption of salt in the food industry as it has the ability to increase the salt perception in food products. According to a study conducted by Methven (2012), the addition of natural ingredients rich in umami components increased salt perception in minced meat formulation at maintained sodium level, using a trained sensory panel. Based on these arguments, it should be possible to control the total levels of salt used in food products to acceptable or low levels since glutamate could potentially increase salt perception. Therefore, a list of vegan natural taste enhancers was composed together with natural sources rich in umami compounds is displayed in table 2.

Table 2: Vegan natural taste enhancers and ingredients containing umami compounds (mg/100 g food) (Baines, et al 2012)

Food category	**Product name**
	Salt
	MSG
Soy sauce	China
	Japan

	Korea
	Philippines
Seaweed	Kombu dried
	Irish Kombu dried
	Irish dulse dried
	Makombu Kelp
	Wakame
	Nori dried
	Japanese Wakame dried
	Irish Wakame dried
Fermented beans	Natto
	Daw Dawa
	Soumbara
	Douchi
	Haccho miso
Vegetable Mushroom	Shiitake Fresh
	Shiitake dried
	Fungi porcini
	Oyster dried
	Morel dried
	Taiwanese dried
	Taiwanese black dried
	Taiwanese king bolete dried
	Winter dried
	Abalone dried
	Tree oyster dried
Vegetable other	Cabbage
	Lettuce
	Cauliflower
	Broccoli
	Spinach
	Green asparagus
	Corn
	Green peas
	Onion
	Potato
	Carrot
Vegetable tomato	Tomato
	Sun-dried tomato
	Cherry tomato
Yeast Extract	Extract produced from *Candida sp.*
	Extract produced from *Saccharomyces sp.*
Hydrolysed vegetable protein (HVP)	Soybean-based enzyme hydrolysed vegetable protein

Levels of glutamate in the products listed in table 2 vary substantially between category and product, for seaweed the Japanese kombu (*Laminaria japonica or Saccharina japonica)* has been found to have the highest levels of glutamate. There is no clear reason as to why levels of glutamate vary between species, but it has been proposed that it may be due to differences in species, and other environmental factors *(Parket et al, 2015).* Other factors that may affect the glutamate level are harvest time, post-harvest, drying conditions, and preparation/cooking method. According to a study conducted by Blumenthal (2009), there were no significant differences in levels of glutamate when seaweed was soaked at 2, 6, or 12 hours using soft vs hard water. The levels of glutamic acid, aspartic acid, and other amino acids in soy sauces vary depending on the species of *Aspergillus* and lactic acid bacteria used for fermentation. Furthermore, tomatoes are also a natural source rich in glutamic and aspartic acids. Mushrooms also have high levels of umami compounds including glutamic acid and it also contains the most potent 5'ribonucleotide GMP. The mushroom type shiitake has the highest amounts of glutamate and GMP compared to other types *(Parker et al, 2015).* Finally, another product containing high levels of umami compounds and often used to replace MSG and HVP is yeast extracts. Yeast extracts are widely used in the food industry as taste enhancers. Yeast extracts manufacturers often work on developing extracts that can satisfy consumers' demand for sodium reduction and high savory profile. The high levels of protein in yeast cells allow for extracts containing high levels of amino acids, and the high RNA level also results in high levels of 5'ribonucleotides. However, yeast extracts are not an option for

Future Kitchens to be used as a flavor enhancer, therefore this project will focus on finding broths that do not contain any yeast extracts, synthetic additives, and E-numbers.

2.2. Consumer-Oriented Product Development

Regular consumption of vegetables is an important part of a balanced diet. The composition of vegetables includes a high water content (80-90%), (3-20%) carbohydrates, (1-5%) protein, fats and also contain phytonutrients such as dietary fiber, minerals, vitamins, and phytochemicals which have proven to be beneficial for human health. Many epidemiological studies have shown the positive effects of a rich vegetable diet on health, high vegetable consumption could reduce the risk of chronic diseases *(Mirmiran et al, 2009).* Additionally, a rich vegetable diet has also been linked to overall good health, lowered risk for the formation of certain forms of cancer, stroke, diabetes, heart disease, anemia, gastric ulcer, improvement in gastrointestinal health and vision, and other chronic diseases *(Dias et al, 2012).* A rich vegetable diet might help reduce the consumption of foods high in trans and saturated fats and high caloric density foods which results in a more balanced diet and better overall health. Therefore, the WHO recommends a daily intake of 400g of fruits and vegetables. It is important to have a great diversity of vegetables to guarantee the consumption of different phytochemicals to contribute to overall good health. As there is a general belief among nutritionists and health professionals that health benefits should not be linked to only one type of vegetable but instead to a balanced diet that includes a combination of vegetables. Currently, the mechanism by which vegetables help reduce the risk for chronic diseases is complex and mostly unknown. It is assumed that for example, some phytonutriceuticals such as flavonoids have strong antioxidant properties that might interact indirectly with cell signaling pathways sensitive to redox balance or quenching of free radicals to form products that are not free radicals. The content of phytonutrients varies between the vegetable group, and type of vegetable, but primarily consist of vitamin C, folate, selenium, fiber, and polyphenolics which include quercetin, carotenoids, and flavonoids. In the paper "Nutritional Quality and Health Benefits of Vegetables: A review" by Dias (2012), the author explains in detail the vegetable family rich in which type of phytonutrient including their function and benefits in the human body. Besides the many health benefits a vegetable-rich diet has on humans, the flavor of the vegetables is also a driving force for their consumption. Therefore, it is important to take a look at the flavor formation pathways of vegetables. Unlike fruits, vegetables do not form primary flavor compounds during maturation and ripening. Most of the primary flavor compounds of fruits are formed during the ripening stage, however, since vegetables do not have a ripening stage but only maturation there is no primary flavor compounds formation *(Parker et al 2015)*. This results in not very pronounced flavors in many raw vegetables. Therefore, it is important for vegetables to undergo a pre-treatment such as steaming to obtain those pronounced flavors. This results in tissue disruption by the release of enzymatic systems from the cell structures of the vegetable. The flavor compounds formed during this step, are known as secondary flavor compounds or secondary metabolites. These can only be formed during and after tissue disruption either by enzymatically catalyzed reactions and/or autoxidation reactions from primarily non-volatile precursor compounds. The metabolites formed are derived from amino acids, lipids, phenolics, terpenoids, and glucosinolates *(Parker et al 2015)*. It should be noted that secondary flavors are formed during the pretreatment step, however harsh pretreatment conditions can result in loss of micronutrient content, texture, flavor, and color of the vegetable *(Fabbri et al, 2015)*. Flavor and micronutrients are thermal sensitive components and can be volatilized during cooking. As for texture, flavor, and nutrition are factors influencing consumers' decision-making when buying a product, it is important to select a proper pre-treatment/ process to preserve most of the micronutrient content, flavor, color, and texture of the product.

Furthermore, to develop a product consisting of 90% or more of overproduced vegetables it is important to evaluate the seasonal availability of vegetables. As this can be a good indication of possible surplus. In table 3, a list of vegetables together with their season availability is displayed.

Table 3: Vegetable seasonal availability in the Netherlands

Vegetable	**Family**	**Season availability**
Celery	*Umbellifers*	around the year
Cauliflower	*Brassicaceae*	around the year
Broccoli	*Brassicaceae*	around the year
Iceberg lettuce	*Asteraceae*	around the year
Kohlrabi	*Brassicaceae*	around the year
Leek	*Amaryllidaceae*	around the year
Turnip	*Brassicaceae*	around the year
Radish	*Brassicaceae*	around the year
Beetroot	*Amaranthaceae*	around the year
Red cabbage	*Brassicaceae*	around the year

Pointed cabbage	*Brassicaceae*	around the year
Brussels sprout	*Brassicaceae*	around the year
Tomatoes	*Solanaceae*	around the year
Onion	*Amaryllidaceae*	around the year
Carrots	*Umbellifers*	around the year
Chicory	*Asteraceae*	around the year
White cabbage	*Brassicaceae*	around the year
Garden Rhubarb	*Polygonaceae*	around the year
Corn salad	*Caprifoliacea*	around the year
Asparagus	*Asparagaceae*	Spring
Napa (Chinese) cabbage	*Brassicaceae*	Spring, summer, fall
Cucumber	*Cucurbitaceae*	Spring, summer
Mediterranean sea lavender	*Plumbaginaceae*	Spring, summer
Bok choy	*Brassicaceae*	Spring, summer, fall
Pumpkin	*Cucurbitaceae*	Spring, fall, winter
Roma tomato	*Solanaceae*	Spring, summer
Black salsify	*Asteraceae*	Spring, fall, winter
Tomato	*Solanaceae*	Spring
Vine tomato	*Solanaceae*	Spring
Broad bean	*Fabaceae*	Spring, summer
Beefsteak tomato	*Solanaceae*	Spring
Miner’s lettuce	*Montiaceae*	Spring
Salicornia	*Amaranthaceae*	Spring
Endive	*Asteraceae*	Summer, fall
Spring onion	*Amaryllidaceae*	Summer, fall
Kale	*Brassicaceae*	Summer, fall
Zucchini	*Cucurbitaceae*	Summer
Pea	*Fabaceae*	Summer, fall
Radicchio	*Asteraceae*	Summer
Arugula	*Cruciferous*	Summer
Savoy cabbage	*Brassicaceae*	Summer, winter
Green beans	*Fabaceae*	Summer
Spinach	*Amaranthaceae*	Summer
Oxheart cabbage	*Brassicaceae*	Summer, fall, winter
Sweet corn	*Gramineae*	Summer
Salicornia	*Amaranthaceae*	Summer
Jerusalem artichoke	*Asteraceae*	Fall
Parsnip	*Apiaceae*	Fall, winter
Common Purslane	*Portulacaceae*	Fall, winter
Turnip greens	*Brassicaceae*	Fall
Radicchio	*Asteraceae*	Fall
Black Spanish radish	*Brassicaceae*	Fall, winter
Flat bean	*Fabaceae*	Fall
Fennel	*Umbellifers*	Fall
Rutabaga	*Brassicaceae*	Winter
Miner’s lettuce	*Montiaceae*	Winter

It is important to keep in mind that some of the vegetables shown in table 3 are available throughout the whole year in the Netherlands but are imported from other countries. Surplus production is likely to occur if the product is available throughout the year. Another opportunity to gather or find raw materials is from the waste streams of food manufactures.

Instant soup market
Prior to starting the experimentation phase, small market research was done to gather knowledge on the most popular instant soup flavors in the world. This would allow for some inspiration when developing the soup recipes. The soup market size is predicted to grow in the upcoming years and is projected to reach 21.0 billion US dollars in sales by 2027 *(Fortune Business insight, 2021)*. As the trend of health-on-the-go continues to rise, so do the sales of instant soup. Around the world, soup is considered to be healthy and nutritious while easily digested. Soups are also popular because they contain vegetables that are rich in vitamins and other important phytonutrients. The top plant-based soup flavors are; tomato, mushroom, pumpkin, French onion, and broccoli. The highly competitive global soup market will continue to drive companies to launch new soup products with innovative ingredients and flavors. Additionally, as consumers opt for animal cruelty-free food products more vegan soup options will start to be available on the market.

Net promoter score
The net promoter score (NPS) is a known measurement tool that companies use to measure the loyalty of their customers. The NPS measures the perception of customers using a simple question such as: "How likely is it that you would recommend (organization, product, or service) to someone else?" Based on this question respondents will give a score between 1 (extremely unlikely) and 10 (extremely likely). From the results, 3 categories can be made:

- Promoters which are respondents that give it a score of 9 or 10, are considered to be loyal and enthusiastic customers
- Passive respondents that gave a score of 7 or 8. These are consumers that are considered to be satisfied with the service, product, or company however not happy/satisfied enough to be considered promoters
- Detractors' respondents that gave it a score of 1-6. They are considered to be unhappy customers that will likely not buy from the company again and could potentially discourage others from buying from the company.

The NPS is measured with a single equation shown in equation 2, and it can be used to calculate the NPS score of a product, company, or a service *("NPS Qualtrics", n.d.)*:

$$Promoters\ \% - Detractors\ \% = NPS$$

Eq 1

The equation above can be used to calculate the NPS, for example, if from the data it is observed that only 10% of the respondents are detractors, 20% passives and 70% promoters filling in the equation (70%-10%) will result in an NPS of 60. An NPS above 0 is considered to be good; anything below 0 is a point of improvement. It should be noted that NPS surveys are designed to collect consumer feedback and the consumers' overall perception of the brand. Thus the survey should be structured in a way to obtain/ask these questions: the reason for the score, how can the company make the customers' experience better, and permission to follow up with the customer. The NPS is an indicator of how companies can improve the overall liking of products, services, or companies. It allows for the company to easily track and monitor improvements.

2.3. Freeze-Drying Principles

The market for "natural" and "organic" continues to rise along with consumers' demand for food products with minimal processing, only 'natural' ingredients thus no synthetic additives, no E-numbers, or synthetic ingredients, and high quality and nutritive products produced with a minimal environmental load. Additionally, the leading trend of minimizing nutrient loss and maximizing nutrient retention in food products to produce better quality products has resulted in the food industry taking steps in optimization of current processes and implementing new innovative processes to meet these requirements. Increasing concern on global food waste and scarcity of food has resulted in more companies opting for processes that can naturally extend the shelf life of food products without the addition of synthetic preservatives or high salt concentrations. This has resulted in the implementation of the novel drying techniques such as freeze-drying. Freeze-drying allows for the dehydration of products such as biological materials, pharmaceuticals, and food products that cannot be dried even at moderate temperatures. It is known that freeze-drying has many advantages compared to other drying techniques and allows for the production of the highest quality product compared to other drying techniques. Additionally, the low processing conditions allow for minimal flavor and aroma loss. This process is one of the best methods for water removal, delivering high-quality products simultaneously extending the shelf life of the product up to 2 years for a product with 2% residual moisture *(Williams-Gardner, 1971)*. However, it is well known that freeze-drying is the most expensive process for the production of a dehydrated product due to the slow drying rate and the use of vacuum conditions which increases energy consumption.

Freeze-drying, also known as lyophilization, allows the removal of water in substances by freezing the water and subliming the ice formed by applying heat to the frozen products under vacuum pressure. The low temperatures applied during drying and the absence of water allow for the prevention of microbiological activities and most of the deterioration reactions such as non-enzymatic browning, protein denaturation, and enzymatic reactions. Freeze drying consists of three different stages (1) the freezing stage, (2) the primary drying stage, and (3) the secondary drying stage *(Liapis et al, 2006).*

Firstly the temperature in the drying chamber is lowered until the food material is in a frozen state. After the freezing stage, the water in the frozen material is removed by sublimation. During the primary drying stage, the water is maintained in the frozen state, and for it to be dried the pressure must be less or near the equilibrium vapor pressure of the frozen 'solvent' in this case the water. During this stage, it is important to maintain the temperature and pressure below the triple point of water to prevent the ice from melting, which would result in the destruction of the physical structure to be achieved *(Corver, 2009).* Therefore, during this stage, the temperature of the frozen layer is often at -10°C at absolute pressures of 2mmHg or less. Sublimation occurs under these conditions and the water vapor evaporates through the porous layer of the dried material. The structural rigidity of the frozen substance at the surface where sublimation takes place largely prevents the dried solid matrix from collapsing. Since water usually exists in a combined state or solution, and in any food material, there will be non-frozen water, also known as *bound* or *sorbed water;* this water needs to be removed to improve the quality of the product *(Liapis et al, 2006).* This sorbed water is removed by desorption commonly under reduced pressure. This brings us to the secondary drying stage. During this stage, the sorbed water is removed and is carried out of the dried material via its porous structure. This results in a dried product with a porous, non-shrunken structure which allows for fast and almost complete rehydration due to the larger surface area. A greater surface area means that the product will dissolve faster, however, it does not affect the solubility of the product, only the solubility rate. A product with a higher surface area would dissolve faster compared to a product with a low surface area. A high surface area allows for a higher contact area where molecules of water can have contact with the molecules of the product being dissolved.

The methodology chapter will include the experimental design taking into account taste interactions, factors influencing flavor and flavor perception, and the natural vegan taste enhancers listed in chapter 2 for the development of the new soup recipes

3. Methodology

This study examined numerous natural taste enhancers available on the market for the development of flavorful healthy vegan instant soup powders. Prior to starting the experimentation phase, a comprehensive literature review was carried out. To identify potential natural ingredients with the highest umami compounds, these ingredients are listed in table 2. This chapter will be divided into three sections which will contain a detailed explanation of the process of creating new soup powders. Chapter 3.1. will include the process steps for the manufacturing of the vegetable powders including a block flow diagram. Chapter 3.2. The vegetable powders used for the development of new recipes together with the ingredients used as natural taste enhancers. The amounts used varied depending on the ingredient to help obtain the most flavorful final products, this will be further explained in chapter 4. Finally, subchapter 3.3. will include the structure of the survey for the final recipes developed which are shown in chapter 4 Results and Discussion.

3.1. Process Block Flow Diagram

Before the preparation of the vegetable powders, several recipes were prepared which will be shown in chapter 3.2. This was done to prepare all the ingredients necessary for the execution of the recipe development step. The vegetables used for the experimentation step were prepared according to the steps shown in Figure 3. The vegetables used for the experimentation step were bought from Hoogvliet or Albert Heijn.

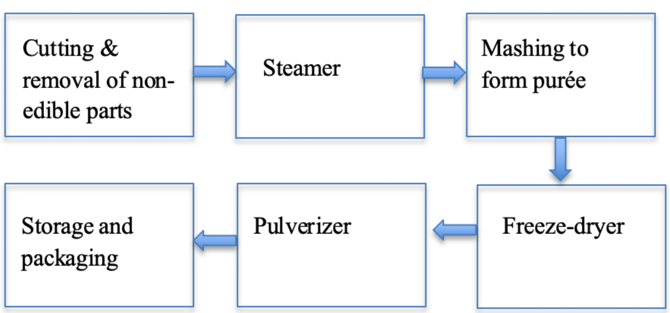

Figure 3: Block flow diagram of the production process of vegetable powders

Firstly, the vegetables were washed and cut into pieces where the non-edible parts were removed. They were then steamed for a certain amount of time variating between 10-30 minutes depending on the vegetable. After steaming, the vegetables were put into a food processor to form a purée which was then added to the freeze-dryer trays with a maximum weight of 1.2kg. After preparing the trays with the vegetable purée they were added into the Harvest right freeze-dryer where the vegetables were dried for a period of time until all the moisture was removed. Finally, the dried product was removed from the freeze dryer and pulverized into a fine powder. The powders were then stored until experimentation day in a glass container in the dark cold room below the collapsing temperature to prevent the product from losing its porous structure and absorbing moisture.

3.2. Kitchen Trials

To produce the new recipes several recipes were developed taking into account the most popular instant soup flavors shown in chapter 2. In table 4, the base of the recipes is presented. The amount (gr) of ingredients varied depending on the ingredient to help obtain the most flavorful recipes. The additional ingredients such as spices and natural taste enhancers used for the development of the recipes were bought from retailers such as Pit & Pit, Albert Heijn, Exter, Natural spices, Tera Sana, and Jorda. Table 5 includes the natural taste enhancers used to enhance the taste of the recipes, the amount of taste enhancers were also tweaked to achieve the most flavorful recipes. Using information from chapter 2, different ingredients rich in umami compounds were combined using different amounts per ingredient and were named umami mixes; these were used as taste enhancers also shown in table 5. For the kitchen trials, a small tasting was conducted with the New Product Development (NPD) team. This allowed for feedback for improvements or tweaks to be made to the recipe to narrow down the 'best recipes' and to get a better perspective from other individuals on their taste perception.

Table 4: Base recipes for kitchen trials

Recipe names	***Ingredients***
Spicy Tomato	Tomatoes, onion, red bell pepper, sweet potato, leek, potato, cherry tomatoes
Onion- Potato	Onion, potato, leek
Mushroom Almond	White button mushrooms, potato, leek, yellow onion, shiitake, almond milk, arrow root
Spicy Sweet Potato	Sweet potato, yellow onion, red bell pepper, leek, coconut milk or almond milk
Pumpkin coco	Unpeeled butternut squash pumpkin, leek, yellow onion, potato, coconut milk
Pumpkin	Unpeeled butternut squash pumpkin, yellow onion, cherry tomatoes, leek, potato
Parsnip- Pear	Parsnip, yellow onion, coconut milk or almond milk, pear, leek, potato
Broccoli- Spinach	Broccoli, spinach, yellow onion, potato, leek
Broccoli- Zucchini	Broccoli, zucchini, yellow onion, potato, leek
Broccoli	Broccoli, yellow onion, potato, leek
Iron spinach	Spinach, onion, fennel or leek, potato

Table 5: Natural taste enhancers powders used for the development of the soup recipes (extra ingredients)

Natural taste enhancers	
Broth Exter UM9	Bay leaf
Culinairex VO001 PK- Sauteed Onions	Thyme
Culinairex HZ002PK- Umami mushrooms	Marjoram
Broth Bio-today w/o yeast extracts	Rosemary
Freeze dried cherry tomato powder	Chives
Shiitake	Oregano
Garlic	Dill
Onion	Tarragon
Salt	Jalapeño
Soy sauce	Cayenne pepper
White wine vinegar	Bombay spices
Balsamic vinegar	Basil
Red wine vinegar	Garam Masala
Tabasco	Cumin
Paprika	White pepper
Chili pepper	Cardamom
Black pepper	Ginger

Salt	Umami mix 3; ginger (3%), onion (22%), kombu (14%), shiitake (33%), garlic (6%), cherry tomato (22%)
Parsley	Umami mix 4; onion (23%), kombu (14%), shiitake (34%), garlic (6%), cherry tomatoes (23%)
Dates powder	

First of all, the base of the soups were developed using ingredients mentioned in table 4. Each time different amounts and ingredients were mixed to create a base which was rehydrated with boiling water (1 gram per 10mL) and tasted to evaluate the 'new' base. This was done until the most flavorsome base was developed. Once the base was developed additional ingredients such as type of broth, vinegar, soy sauce, and spices were added. The amounts of the extra ingredients variated keeping in mind to maintain a salt limit below 20% of the recommended daily intake. Every time the amount or ingredient was changed, it was rehydrated and tasted to find the best version of the developed soup. In cases that the soup recipes were too sour, an amount of date powder was added to suppress the sour flavor based on the information mentioned in chapter 2. Additionally, vinegar was used to enhance the salt perception and to give the soup more body, depending on the recipe either white, red or balsamic vinegar was used to complement the flavor profile. Other natural taste enhancers such as cherry tomato, kombu (seaweed), and shiitake were used in recipes to enhance umami perception due to their high content in umami compounds such as glutamate and ribonucleotides. These were mixed to synergistically enhance the umami perception of the soups. Additionally, the Exter products sauteed onions and Umami Mushrooms were used in some recipes due to their claim to enhancing umami taste perception. The spices used in each soup were carefully selected to complement the flavor profile of the soup and add visual decoration. After obtaining the final recipes, the recipes were added to the recipe robot and the price was calculated. In the event of the final recipe surpassing the cost margin, the recipes were tweaked to maintain cost below the cost margin. In chapter 4, the final recipes are shown and discussed.

The nutritional value of each ingredient was calculated using the NEVO database of the Dutch government: https://nevo-online.rivm.nl/Default.aspx the information found here was transferred to the recipe robot to obtain the nutritional value of the whole recipe with the corresponding amounts and ingredients.

3.3. Consumer Acceptability Test

As part of the final phase of the product development stage, a survey was conducted to give the company insight into how the product will be perceived by consumers. Consumer acceptance tests, measure the degree to which a food product is liked or disliked by the consumer *(Hein et al, 2008).* The respondents evaluated three new soup powders and had to answer questions on acceptance ratings. In addition, information on the importance of an all-natural ingredient list and the product being produced in a sustainable manner was gathered. To obtain insight into this matter three research questions were formulated: *How likely will the three new soups be liked by consumers?; How important is an all-natural ingredient list for consumers nowadays?; How likely will our products be recommended?.* To answer these questions, a tasting was carried out and a questionnaire was developed. For the evaluation, the soup powders were prepared in big bowls, and servings samples of 5g of soup powder per 50 mL of water were served. Samples were served in biodegradable cups and labeled with their corresponding name. Respondents were asked to drink water or eat a cracker in between tasting samples to prevent taste fatigue.

The first section of the survey included socio demographic questions such as age, country of origin, and gender, followed by soup consumption per week, and importance of all-natural ingredient list, sustainability aspect of the product, and functional health benefit. In order to get insight on where the potential market group lays, the age groups were classified as follows:

- Students: 15-25
- Young professionals: 26-35
- Adults: 36-59
- Seniors: 60 or above

The second, third, and fourth sections of the survey consisted of the evaluation of the three new soups, namely spicy tomato, onion potato, and pumpkin coco. The attributes measured were color, taste, mouthfeel, and smoothness of the soups. Considering that evaluation of food products, in terms of flavor perception is done in teamwork, where human senses are used as a measurement tool. During a sensory evaluation, flavor perception is evaluated through the eyes, nose, and mouth. If the odor is appealing, the color looks appealing and the taste is appealing the product tends to score higher than if one of these attributes is not appealing. Therefore, these attributes were selected to get an idea of how these attributes influence each other and the overall score of the soups. Each question was based on a specific attribute, where the respondent was asked to rate each attribute using a hedonic 10-point scale (e.g. from 1. color unappealing to 10. very appealing). The respondents filled out the questionnaire based on their perception of the product. Based on the number of attributes, the sample size (N) had to be 10 to 20 times the number of attributes. Therefore, a minimum sample size of N=40 was set. Preferably the number of observations should be 100 or more, the number of observations can be calculated using equation 2.

$$Observations = Respondents \times Products \qquad \textit{Eq. 2}$$

The survey was conducted with a group of 53 non-consumers/consumers which was above the minimum sample size set. Additionally, the number of observations obtained was 159, the sample calculation can be seen below.

$$159 = 53 \times 3$$

Additionally, the respondents were asked to give an NPS score for each soup, to have an overview of the likelihood that the respondents would recommend the new soup products. The final section of the questionnaire was intended for the respondents to fill in any comments, remarks, or feedback if necessary. The survey was written in English to increase the number of respondents and the tasting was done in two sessions, the first session was conducted at Plein Publiek in Antwerp and the second session at The Hague University of Applied Sciences in The Hague. Furthermore, the data collection was done through Qualtrics Surveys Software. The significance of the acceptance analysis was evaluated through the one-way analysis of variance (ANOVA). The questionnaire can be found in Appendix A.

4. Results and Discussion

4.1. Newly Developed Soups

During the development stage, several recipes were evaluated with different base ingredients and different natural taste enhancers. From this step, it was observed that steaming time (pre-treatment) had a big impact on the overall appearance, taste and texture of the freeze-dried product. It was observed that vegetables steamed for a longer period of time had a color that was less intense, the aromas were less dominant, however, the texture when rehydrated was smooth. For vegetables cooked between 6 to 10 minutes, the color was more vibrant, the aromas were more dominant but the texture of the dried product became more grainy upon rehydration. This is in accordance with the literature presented in chapter 2, that harsh pre-treatment conditions have a negative effect on the flavor, aroma, and color of the vegetable as these components are thermally sensitive and could be volatilized during this step from the food matrix *(Fabbri et al, 2015).* However, in this case, the texture of the vegetables steamed for a longer period of time was more desirable for the end product as it was more smooth than grainy. The soup powders made with vegetables steamed at 6 minutes upon rehydration had an undesirable grainy texture. Therefore, it was opted to steam all the vegetables for a longer period of time between 10-30 minutes until the vegetable structure was soft. This was done to prevent a grainy texture which would harm the overall likeliness of the final product. In figure 4, the effect of steaming time on the color of broccoli can be observed.

Figure 4: Effect of steaming time on the color of freeze-dried broccoli. On the left side, the freeze-dried broccoli steamed for 6 minutes is observed and on the right side, the broccoli is steamed for 12 minutes.

During the Kitchen trials, it was observed that the addition of vinegar to the soup recipes created a more salty flavor. As was described by Keast (2002) at low salt concentrations in the mixture, the addition of a compound with a sour flavor profile in this case vinegar enhances the salt perception. Furthermore, during the kitchen trial, two different broths were used and it was observed that the Bio-today broth did not provide enough savory perception compared to the Exter Broth UM9. Therefore, the Exter Broth UM9 was selected and used in the newly developed recipes. Both broths did not contain any synthetic taste enhancers, E-numbers, or yeast extracts. Moreover, during the kitchen trials, it was observed that products containing too much sugar, in this case pear, when freeze-dried, was very sticky and not usable. This is because components with low molar mass like sugars, tend to become very sticky above the glass transition temperature. This results in powder particles sticking with each other resulting in a phenomenon known as caking. Therefore, the recipe using pear was disregarded. Apart from this, another observation was that the recipe for the mushroom soup had a nice flavor and savory profile, however the color was a dark grey-brown. For this reason, this recipe was disregarded, as the color would be unappealing for consumers. Since the commercially available mushroom flavored instant soup powder tend to have a white cream color instead of a dark grey-brown color, this is because these soups contain 2-4% w.w of mushrooms which is much lower than the amount of mushrooms in this recipe.

The newly developed recipes are listed in Tables 6 to 9, with the cost per serving. The cost margin was established to be between €0.60- €0.90 per serving for low production values. All recipes developed had a cost of production within this margin. Additionally, It should be noted that the utilization of the natural taste enhancers allowed for a 23-31% reduction in salt levels compared to existing recipes without reducing the quality and taste of the soups. Additionally, the new recipes contained salt amounts below the established limit set for this research project which was 20% (1.2gr) of the recommended daily intake which is 6gr/per day *(Kilcast et al, 2007)*.

Table 6: New spicy-tomato soup recipe

Ingredients	**Amounts (gr)**
Base ingredients	
Tomatoes	4
Onion	2,4
Red bell pepper	4
Sweet potato	3
Leek	1
Potato	2
Natural taste enhancers	
Exter Broth UM9	1,6
White vinegar	0,1
Soy powder	1
Cherry tomato	0,2
Spices	
Salt	0,2
Black pepper	0,04
Tabasco	0,044
Garlic	0,034
Paprika	0,092
Parsley	0,12
Total amount of gr per serving	***19,83***
Total salt amount	***0,92***
Cost of a recipe per serving	***€0,912***

The first developed recipe was the spicy tomato recipe, it was observed during the making of this recipe, the addition of cherry tomato as a natural taste enhancer provided the soup with a fuller mouthfeel and a higher savory intensity than without. This is because cherry tomatoes have one of the highest amounts of glutamic acid which is responsible for the umami sensation in the mouth. Soy powder was also used due to it being rich in amino acids glutamic and aspartic acid which both provide a higher umami sensation. The vegetables used for this recipe, the majority (white potato, tomatoes, and red bell peppers) are part of the *Solanaceous* family. These vegetables are known to be rich in a number of phytonutrients such as carotenoids, vitamin A, C, K, rich in essential amino acids such as lysine and other metabolites *(Dias, 2012).* These phytonutrients are important to maintain overall good health and reduce the risk of chronic diseases *(Mirmiran et al, 2009).* For the onion-potato soup soy powder and Exter broth UM9 were used to enhance the savory perception. The natural taste enhancer Culinairex VO001 PK- Sauteed Onions was also used but did not provide any enhancement in savory perception, it only provided a bitter after taste which did not suit the flavor profile of this recipe and therefore was disregarded. This recipe is rich in vegetables from the *Alliaceae* family and *Solanaceous* family. It is known that the Alliaceae family (leek, onion, and garlic) is rich in thiosulfates which have been linked to reducing various chronic diseases *(Dias, 2012).* Additionally, onions and garlic are excellent sources of manganese, calcium, potassium providing 10% of the daily intake requirements of these elements.

Table 7: Onion-potato soup recipe

Ingredients	**Amounts (gr)**
Base ingredients	
Onion	11
Potato	6
Natural taste enhancers	
Exter Broth UM9	1,4

White vinegar	0,14
Soy powder	1
Spices	
Salt	0,254
Black pepper	0,096
Bay leaf	0,024
Thyme	0,012
Chives	0,012
Garlic	0,05
Rosemary	0,028
Total amount per serving (gr)	***20***
Total salt amount (gr)	***0,9***
Cost of a recipe per serving	***€0,649***

The savory perception of the pumpkin coco soup was enhanced using Exter broth UM9, white vinegar, soy powder, and the umami mix 3. From the kitchen trial, it was observed that the addition of the umami mix 3 provided an enhancement in savory perception and also a fuller mouthfeel. This correlates with the literature research which states that glutamate and ribonucleotides act in a synergistic manner providing an enhancement in umami perception. For this mix, shiitake powder was used which is rich in the nucleotide GMP, and cherry tomatoes and kombu which are sources rich in glutamate. The combination of these ingredients demonstrated that the interaction between these ingredients indeed acted in a synergistic manner which enhanced the umami perception of this soup and maintained the salt levels below the proposed target. Finally, the vegetables used in this recipe are also rich in phytonutrients. Pumpkin is part of the *Cucurbitaceae* family, which are rich in vitamin C, carotenoids, and tocopherols. Carotenoids and tocopherols are known to act as antioxidants for humans. Additionally, vitamin C plays a key role in the immune system of humans.

Table 8: Pumpkin coco soup recipe

Ingredients	**Amounts (gr)**
Base ingredients	
Pumpkin	10
Leek	0,4
Onion	2,3
Potato	1,4
Coconut milk (the coconut company)	1,8
Natural taste enhancers	
Exter Broth UM9	1,4
White vinegar	0,3
Soy powder	0,9
Umami mix 3	1,8
Spices	
Salt	0,2
Black pepper	0,02
Total amount per serving (gr)	***20,52***
Total salt amount (gr)	***0,833***
Cost of a recipe per serving	***€0,656***

Finally, the last recipe developed was the broccoli soup, which used the same natural taste enhancers as the pumpkin soup except for the umami mix 4 which was different from umami mix 3. The same enhancement in mouthfeel and savory perception was observed during the kitchen trials. The difference between umami mix 3 and 4 is one ingredient which is ginger, umami mix 3 contains ginger while umami mix 4 does not. It was observed that ginger complemented the flavor profile of pumpkin soup but did not compliment the flavor profile of the broccoli soup and was therefore removed from the original mix. Furthermore, this recipe is also rich in ingredients with phytonutrients. Broccoli is part of the *Cruciferous* family which is an excellent vegetable source for folate and vitamins. The World Cancer Research Fund USA concluded that crucifers are likely to protect humans against colon, rectum, and thyroid cancer, and when consumed together with vegetables rich in phyto nutraceuticals they can protect against cancer in other organs.

Table 9: Broccoli soup recipe

Ingredients	**Amounts (gr)**
Base ingredients	
Broccoli	9

Leek	1
Onion	5
Potato	1,2
Natural taste enhancers	
Exter Broth UM9	1,4
White vinegar	0,4
Soy powder	1
Umami mix 4	1,8
Spices	
Salt	0,2
Black pepper	0,02
Chives	0,060
Total amount per serving (gr)	***21,1***
Total salt amount (gr)	***0,85***
Cost of a recipe per serving	***€0,906***

Furthermore, it could also be observed from the four newly developed recipes that the pumpkin-coco soup and the broccoli soup had lower amounts of salt. This corroborates the literature information provided in chapter 2, which states that ingredients rich in umami compounds glutamate and ribonucleotides could be used to control the total salt levels used in food to acceptable or low while still providing an enhancement in salt perception. The newly developed soups were evaluated in a consumer acceptance test, however, due to time constraints, it was not possible to assess the broccoli soup. The results of the test are shown in chapter 4.2. Furthermore, the nutritional values of each of the 4 newly developed recipes can be found in Appendix B.

4.2. Consumer Acceptance Test results

4.2.1 Sample Description

The consumers group consisted of 49% male respondents, age (15-25 years: 27%, 26-35 years: 50%, 36-59 years: 19%, 60 years or above: 4%) and 51% female respondents, age (15-25 years: 52%, 26-35 years: 37%, 36-59 years: 11%, 60 years or above: 0%). Additionally, the group consisted of 60% Belgians, 21% Dutch, and 19% other countries including Australia, Germany, Turkey, Indonesia, Iraq, and France. Most of the respondents were Belgians and this can be explained by the fact that there were more respondents in the tasting conducted at Plein Publiek in Antwerp in comparison to the number of respondents at The Hague University of Applied Sciences in The Hague. Additionally, since Future Kitchens is currently only focusing on the Belgian and Dutch market, the results of this tasting provides a good representation of how the soup powders will be judged by the population of the target markets.

Furthermore, the consumers were asked about their soup consumption per week, based on the results, there is a strong statically significant relationship between the number of times per week they consume soup and age group. The p-value indicated that the two variables had a relationship statistically significant, since the p-value was 0.006, meaning that it is unlikely for this to be a coincidence ($P \geq 0.05$: no statistical difference, $P<0.05$: statistical difference). Figure 5 displays the results of soup consumption per week. The y-axis represents the number of respondents and the x-axis represents the age group.

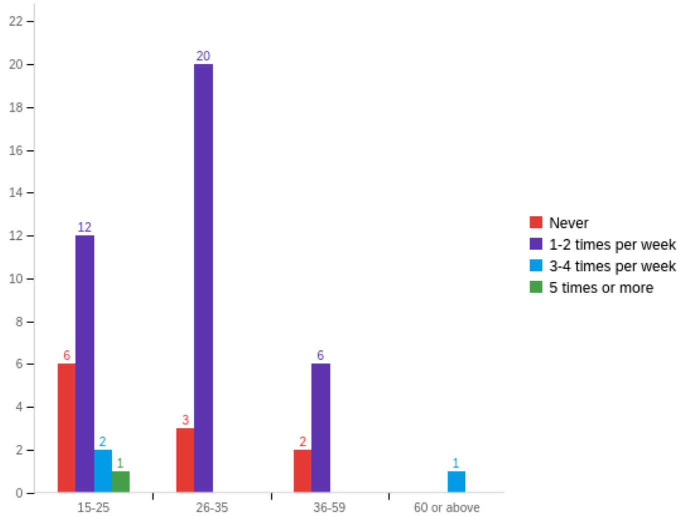

Figure 5: Amount of times per week soup is consumed by individual plotted against age group

From the results, it was observed that 57% of the respondents in the age group 15-25 years answered that they consume soup between 1-2 times per week. Additionally, 87% of the respondents between the age of 26-35 years consume soup 1-2 times per week. As for the respondents in the age group of 36-59 years, 75% indicated that they consume soup 1-2 times a week. There was only 1 respondent above the age of 60, and he indicated that he ate 3-4 times a week, but only 10% of the respondents aged 15-25 years ate 3-4 times a week, and 5% within this age group ate soup 5 times or more. Based on these results it could be assumed that our target groups could be in the age group of 26-35 years old but no conclusion can be made for the age group above 60 years old as the number of respondents does not accurately represent a portion of the 60+ population.

Moreover, consumers were asked how often they checked the ingredient list of a food product, only 22 % of the respondents answered always, while 24% said most of the time, 35% said sometimes, and 19% respondents never checked the ingredient list. There was no significant statistical relationship between this question and age or gender. So, age and gender did not influence how consumers would answer this question. It is thus assumed from these results that the ingredient list is an important factor when consumers are buying a product. Additionally, respondents were asked how important was it for a food product to only contain natural ingredients, so, no e-numbers or synthetic ingredients, 11% said it was extremely important, 28% of the respondents answered that it was very important for them that the ingredient list only consisted of natural ingredients, 26% said moderately important, 26% answered slightly important, while only 8% of the respondents said not at all important. It could thus be concluded that consumers value and find it important that food products contain only natural ingredients. More than 50% of the respondents thought it was somewhat important for the food product to contain only natural ingredients. However, it can also be concluded that this is an important factor when buying a food product for some consumers but not a determining factor on their decision when buying a food product. Regardless of their age group or gender, there was no statistical relationship found between these variables. Furthermore, the importance of having a health claim was also assessed, 2% answered extremely important, 36% found it to be very important, 34% said it was moderately important, while 17% said it slightly important, and 9% found it to be not at all important. There was no statistical relationship found between age group, gender, and having a health claim. Thus, having a health claim on the food product could have an impact on the consumer purchase behavior, as 72% of the respondent group found it to be important to some extent. It might increase the chances for a consumer to buy the food product. The respondents were also asked how important was it for the food product to be produced in a sustainable manner, 8% found it to be extremely important, 42% said it was very important, 26% answered moderately important, while 23% found it slightly important, and 2% did not find it important. Based on these answers, it can be assumed that the majority of the respondents find it important that the product is produced in a sustainable manner independently from their age group or gender. Making sustainability an important factor to take into consideration when manufacturing and marketing a product. Additionally, the importance of the price when buying a food product was also asked, 11% said it was extremely important, 32% said very important, while 38% thought it was moderately important, 13% said slightly important, and only 6% said it was not at all important. The importance of the quantity of the product was also examined, 8% said it was extremely important, 40% said it very important, 38 % found it to be moderately important, 6% thought it was slightly important, and 10% said it was not at all important. There was a strong statistical relationship found between price and quantity of a product, a p-value of 0.009. It was observed that 50% of the respondents that answered that quantity was important also thought price was important, and 52% found both very important. It can thus be concluded that consumers expect a price that is reasonable to the quantity of the product when buying a product. Lastly, the importance for a product to contain a functional health claim was also evaluated, 10% of the respondents said that it was extremely important for a food product to have a functional health claim, while 34% thought it was very important, 26% said it was moderately important, and 28% said it was slightly important, while 2% found it not at all important. It can thus be concluded that having a functional health claim could impact the decision for a consumer to buy the product, a product containing a function could be preferred over a product without a function, as consumers are more conscious of their eating habits nowadays.

4.2.2 Evaluation of consumer acceptability on the three new soups

As aforementioned, the second, third and fourth sections of the survey consisted of the evaluation of consumers' acceptance of the three new soups developed. The acceptance test will provide an indication of the degree of liking of the new soup recipes. For each soup, the respondents were asked to indicate their level of liking on the 10-point hedonic scale. All three samples were prepared directly before serving to prevent serving cold soup as that could also influence the taste perception.

Spicy tomato soup evaluation
In the first questions of section two of the survey, the respondents were asked to rate the following attributes, color (1. very unappealing – 10. very appealing), taste (1. very bland – 10. very intense), mouthfeel (1. low thickness – 10. high thickness, and smoothness (1. very gritty – 10. very smooth). Figure 6 shows the results from the survey, each attribute is represented by a color which is seen in the legend. The y-axis represents the number of respondents and on the x-axis the score each attribute was given. Additionally, Figure 7 provides information on how the respondents scored the selected attributes.

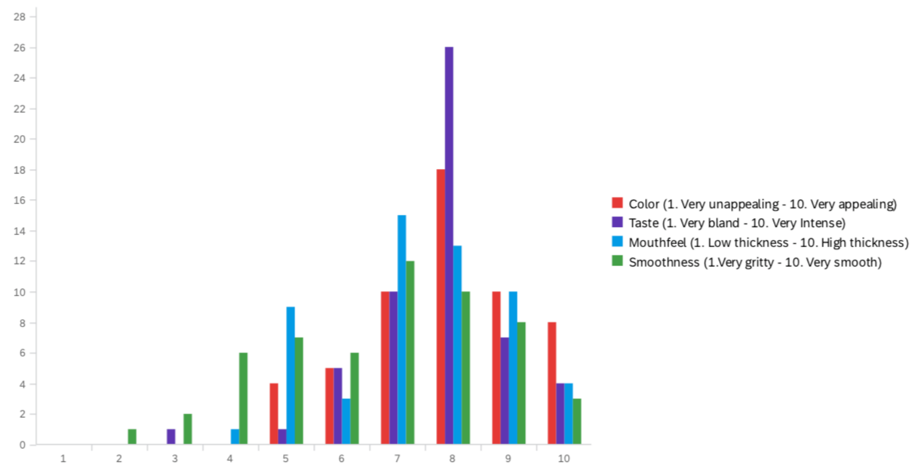

Figure 6: The selected attributes rated by the respondents based on their perception of the spicy tomato soup

#	Field	1	2	3	4	5	6	7	8	9	10
1	Color (1. Very unappealing - 10. Very appealing)	0.00% 0	0.00% 0	0.00% 0	0.00% 0	7.55% 4	9.43% 5	16.98% 9	33.96% 18	18.87% 10	13.21% 7
2	Taste (1. Very bland - 10. Very Intense)	0.00% 0	0.00% 0	1.92% 1	0.00% 0	1.92% 1	9.62% 5	19.23% 10	46.15% 24	13.46% 7	7.69% 4
3	Mouthfeel (1. Low thickness - 10. High thickness)	0.00% 0	0.00% 0	0.00% 0	1.89% 1	15.09% 8	5.66% 3	28.30% 15	22.64% 12	18.87% 10	7.55% 4
4	Smoothness (1.Very gritty - 10. Very smooth)	0.00% 0	1.89% 1	3.77% 2	11.32% 6	13.21% 7	11.32% 6	22.64% 12	18.87% 10	11.32% 6	5.66% 3

Figure 7: Indication of how the respondents scored each attribute given in percentage and amount of respondents that gave it the corresponding score on the 10-point hedonic scale.

Regarding color, the mean was 8.79 and a standard deviation of 1.56, which is an indication that the color was appealing for the respondents. Only 8% of the respondents gave it 5 (neither like or dislike) and 9% gave it a 6, while 83% of the respondent gave it a score of 7 or higher, with the largest portion of respondents (34%) giving it a score of 8 seen from the graph shown in figure 6. Regarding the liking of the taste, the average score was of 8.72 and a standard deviation of 1.39, indicating that the respondents found the taste intense. From the results, it was observed, that only 2% of the respondents gave a score of 3 for the taste, 2% a score of 5, and 10% a score of 6. The remaining 86% gave it a score of 7 or higher, 8 being the score most selected by respondents (46%) which is a good indication that the taste was intense. It can thus be concluded, that the overall liking of the taste intensity was very good as anything above 7 is considered to be good or a strong taste intensity. Regarding mouthfeel spicy tomato had a mean score of 8.20 and a standard deviation of 1.82, suggesting that this soup was very thick. From figure 7, it can be observed that 2% of the respondents thought that the thickness of the soup was on the low side, while 15% gave it a score of 5, 11% a score of 6 suggesting a medium thickness, and 78% of the respondents indicated that the thickness was high giving a score of 7 or above with 7 being the most selected score as shown in the graph. Thus, it can be concluded that the overall thickness of spicy tomato was more on the high side based on the results. However, having a high thickness does not mean that it is good or bad, as this factor is depending on the individual how they like their soups, some prefer a higher thickness while others a lower thickness. Regarding the smoothness of the soup, the mean score was 7.32 with a standard deviation of 2.33, suggesting that the soup had a smooth texture. From figure 7, it can be observed that 17% of the respondents gave a score of 5 or lower for the texture of the soup meaning it had a gritty texture, while 24% (score of 5-6) indicated that the texture was neutral, so not gritty nor smooth, and 59% of the respondents gave it a score of 7 or higher suggesting that the soup was smooth. The most selected option was 7, as 23% of the respondents gave this score. Additionally, based on the results it could be observed that for this attribute the data was more dispersed for this attribute. This can be the result of personal preference and each individual perceives texture in their mouth differently.

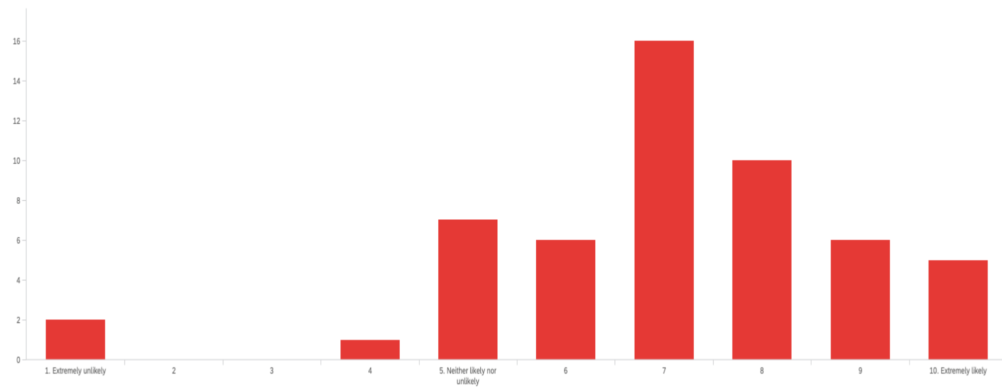

Figure 8: Net promoter score results given by respondents for the spicy tomato soup.

The respondents were asked if they would recommend spicy tomato to others, from the results it was observed that 30% of the respondents were detractors, as these gave a score of 6 or lower. While 49% were passive promoters as these gave a score of 7 or 8 and only 21% were promoters as they gave a score of 9 and 10. The mean score was 7.09 with a standard deviation of 1.91. The NPS score was calculated using eq. 2, a score of -9 was obtained, meaning that consumers are not going to be loyal to the brand, therefore the company should focus on turning detectors into promoters to improve the net promoter score. It should be noted that 49% of the respondents were passive consumers meaning that they were satisfied or liked the product but are vulnerable to competitive offerings. Furthermore, the statistical relationship between the selected attributes and the NPS score of the soup was also analyzed. The following hypothesis was made based on background information given in chapter 2, which states that the overall liking or taste perception of a food product is influenced by numerous factors including color, taste, texture, and mouthfeel thus not only taste.

H_0: There is no relationship between each selected attribute and the way the respondent will score the soup on the net promoter scale (NPS)

H_1: There is a relationship between each selected attribute and the way the respondent will score the soup on the net promoter scale (NPS)

Table 10: Statistical analysis on the relationship between selected attributes and net promoter score using one way ANOVA test (N=53).

Variables	***P*-value**
Color vs NPS	*0.04*
Taste vs NPS	*0.09*
Mouthfeel vs NPS	*0.39*
Texture vs NPS	*0.15*

In table 10, the results of the statistical test can be observed, since the p-value for the test with color is 0.04 < 0.05, the null hypothesis can be rejected and it can thus be concluded that there is a statistically significant relationship between color and how respondents score the spicy tomato soup on the net promoter score. As for taste, mouthfeel, and texture, there was no statistical relationship observed since the p-values of these attributes are >0.05. Indicating that the alternative hypothesis can be disregarded. This can be the result of how the question was formulated. The overall liking of a soup is hypothesized to be dependent on different factors mentioned in chapter 2, which include color, taste, mouthfeel, and texture. However, the question was formulated as; *How likely would you recommend spicy tomato soup to someone else?* Instead of; *Give an overall score for the spicy tomato*. For example, It is hypothesized that if someone gives a high score for taste, they would also give a high score for overall liking so there should be a strong statistical relationship between these two variables. This was not the case for these two variables as there was no statistical relationship observed between taste and the net promoter score. Some of the respondents were asked why they gave a high score in taste but a lower score on the net promoter scale and they explained that the soup was good but that did not necessarily mean they were too inclined to recommend the soup. For the next survey, an overall liking question should be included separately from the NPS question.

Onion potato soup evaluation

As mentioned above, the first questions of section three consisted of rating the selected attributes. Figure 9 displays the results obtained from the tasting, each attribute is represented by a particular color showed in the legend. Moreover, figure 10 shows how respondents scored the following attributes.

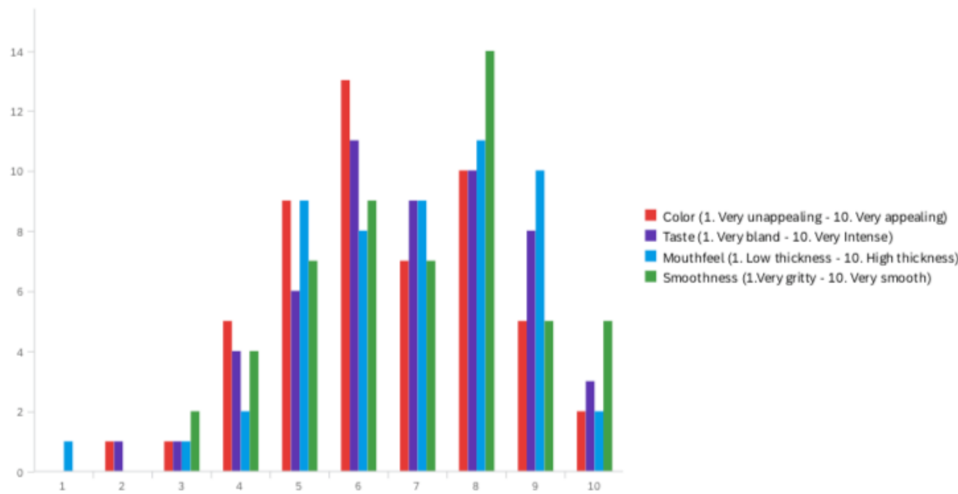

Figure 9: The selected attributes rated by the respondents based on their perception of the onion potato soup

#	Field	1	2	3	4	5	6	7	8	9	10
1	Color (1. Very unappealing - 10. Very appealing)	0.00% 0	1.96% 1	0.00% 0	9.80% 5	17.65% 9	25.49% 13	13.73% 7	17.65% 9	9.80% 5	3.92% 2
2	Taste (1. Very bland - 10. Very Intense)	0.00% 0	1.96% 1	0.00% 0	7.84% 4	11.76% 6	21.57% 11	17.65% 9	19.61% 10	13.73% 7	5.88% 3
3	Mouthfeel (1. Low thickness - 10. High thickness)	1.96% 1	0.00% 0	1.96% 1	3.92% 2	15.69% 8	15.69% 8	17.65% 9	21.57% 11	17.65% 9	3.92% 2
4	Smoothness (1.Very gritty - 10. Very smooth)	0.00% 0	0.00% 0	3.92% 2	7.84% 4	11.76% 6	17.65% 9	13.73% 7	27.45% 14	9.80% 5	7.84% 4

Figure 10: Indication of how the respondents scored each attribute given in percentage and amount of respondents that gave it the corresponding score on the 10-point hedonic scale.

The average score for color was 7.20 with a standard deviation of 2.10, which implies that the color was moderately appealing for the respondents. A score of 4 or lower (not appealing) was given by 12% of the respondents, while 44% gave it a score of 5 (neither like or dislike) and 6, being the score most selected (25% of the respondents) as seen in the figure 9. The remaining 44% of the respondents gave it a score of 7 or higher. Regarding taste, the mean was 7.65 with a standard deviation of 2.09. It was observed that 10% of the respondents thought that the taste was bland, giving it a score of 4 or lower, 33% of the respondents gave it a score of 5 and 6 (being the most selected) meaning that the taste was neutral, so not bland nor intense, 37% thought it was intense giving it a score of 7 and 8, and 20% thought it was very intense giving it a score of 9 or 10. Since taste perception varies per individual depending on several external factors, the difference in results can be explained as to why some respondents indicated that the taste was bland while others thought it was intense to very intense. However, the average score is a good indication that the taste was intense but it might need some additional flavor enhancers to further increase the average score. As the majority of the respondents thought it had a neutral/mild taste. The following attribute measured was mouthfeel which had a mean score of 7.67 and a standard deviation of 2.19, indicating that the soup was thick to very thick. From figure 10, it can be observed that 8% of the respondents thought the soup was low in thickness while 31% thought it was medium thickness giving it a score of 5 and 6, 39% thought the thickness was high giving it a score of 7 or 8 the majority rating it an 8 (22%) as seen in the figure 9. The remaining 22% indicated that the soup was very thick with a score of 9 and 10. The results indicate that the thickness of the onion potato was more on the high side even though some respondents thought the thickness was low. The final attribute measured was texture, which had an average score of 7.67 and a standard deviation of 2.18, suggesting that the soup had a smooth texture. The results illustrated that only 12% of the respondents gave it a score of 4 or lower, implying that the soup had a gritty texture, 29% (score of 5-6) said the texture was neither gritty nor smooth, 41% of the respondents pointed out that the texture was smooth giving it a score of 7-8 with 8 being the most selected by respondents as seen in figure 9. The rest of the respondents (18%) said that the soup was very smooth giving it a score of 9-10. The net promoter score for the product was also calculated, the respondents were asked to rate the likelihood they would recommend the onion potato soup the results can be observed in figure 11.

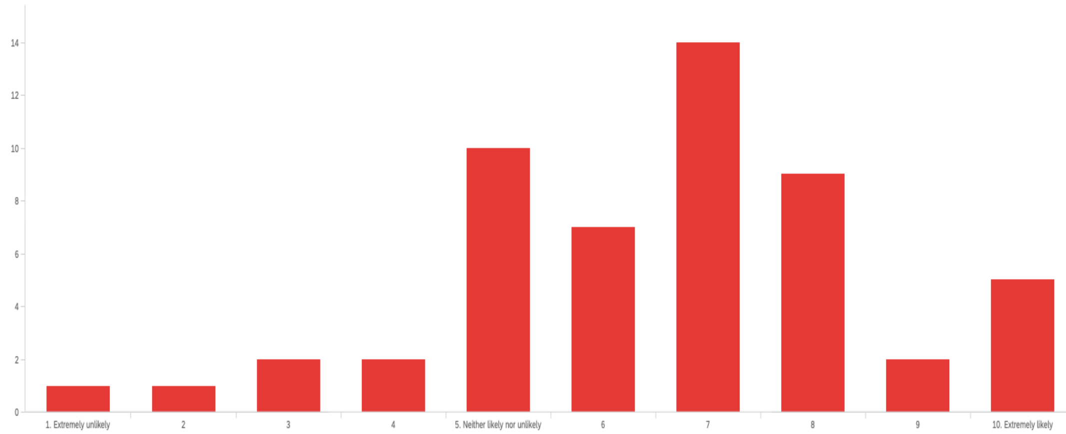

Figure 11: Net promoter score results given by respondents for the onion potato soup

From the results, the mean was calculated and had a value of 6.55 with a standard deviation of 1.99. The percentage of detractors was also calculated and 43% of the respondents gave it a score of 6 or lower, 43% were passive consumers giving it a score of 7 or 8, and only 13% were promoters (score of 9-10). The NPS score was calculated using eq X, a score of -30 was obtained, suggesting that the consumers were not satisfied with the product, and are more inclined to buy similar products from other companies. Even though 43% were passive consumers, this is not enough to guarantee that the consumers would only buy our onion-potato soup or promote it to others. As mentioned above, the company should focus on turning detectors into promoters to improve the NPS, this can be done by further improving this soup based on the feedback/results obtained from this survey and conduct a follow-up tasting with the improved version. Moreover, the statistical relationship between the measured attributes and the NPS results was also evaluated. The same hypothesizes were made for the onion potato soup as seen above, table 11 displays the results of the statistical tests.

Table 11: Statistical analysis on the relationship between selected attributes and net promoter score using one-way ANOVA test (N=53).

Variables	***P*-value**
Color vs NPS	*0.88*
Taste vs NPS	*0.41*
Mouthfeel vs NPS	*0.31*
Texture vs NPS	*0.29*

From table 11, it is observed that all the p-values for all the attributes are above 0.05, meaning that there is no statistical relationship between the attributes and how the respondents score the onion potato soup on the net promoter score. Thus the alternative hypothesis (H1) can be rejected. As explained above, color, taste, mouthfeel, and texture are factors that should have an impact on the overall liking of a product, however, due to the way the question was formulated it is difficult to get a statistical relationship between these variables. Based on feedback obtained from some of the respondents and seen from the results, all the attributes had a higher average score compared to the average from the NPS, indicating that a person could very much like or be satisfied with the product but does not imply that they would recommend it to others. Therefore, it is important to also include a question where the overall liking of the product is measured. This would provide a more adequate interpretation of the likeliness of a product and provide a better understanding of if there is a statistical relationship between the selected attributes and the overall score of a product.

Pumpkin coco soup evaluation

The respondents also evaluated the selected attributes of the pumpkin soup on a 10 point hedonic scale. In figure 12, the results obtained are demonstrated. Additionally, figure 13 provides information on how each respondent scored each of the attributes.

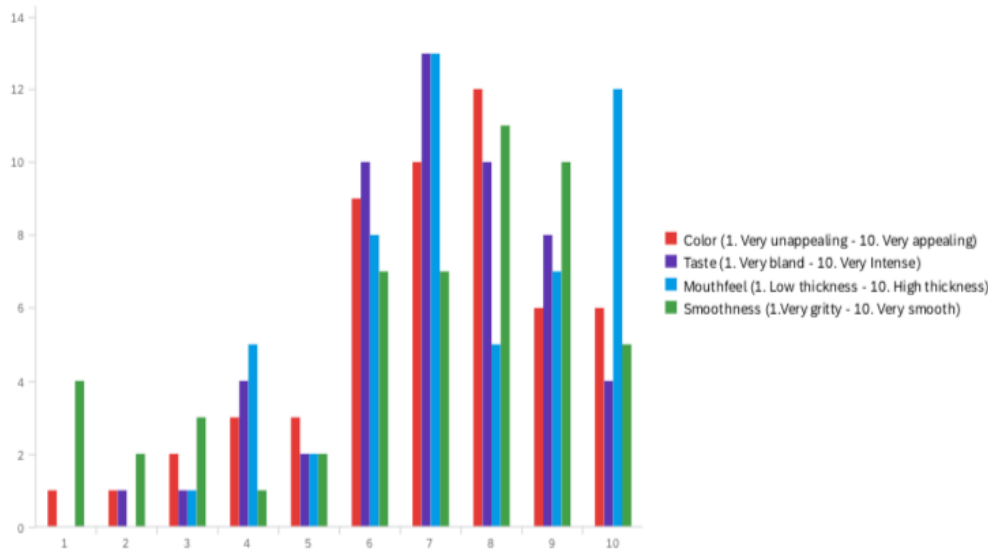

Figure 12: The selected attributes rated by the respondents based on their perception of the pumpkin coco soup

#	Field	1	2	3	4	5	6	7	8	9	10
1	Color (1. Very unappealing - 10. Very appealing)	0.00% 0	1.96% 1	3.92% 2	5.88% 3	5.88% 3	17.65% 9	19.61% 10	23.53% 12	11.76% 6	9.80% 5
2	Taste (1. Very bland - 10. Very Intense)	0.00% 0	1.96% 1	1.96% 1	5.88% 3	3.92% 2	19.61% 10	25.49% 13	19.61% 10	13.73% 7	7.84% 4
3	Mouthfeel (1. Low thickness - 10. High thickness)	0.00% 0	0.00% 0	1.96% 1	9.80% 5	3.92% 2	15.69% 8	23.53% 12	9.80% 5	13.73% 7	21.57% 11
4	Smoothness (1.Very gritty - 10. Very smooth)	4.00% 2	4.00% 2	6.00% 3	2.00% 1	4.00% 2	14.00% 7	14.00% 7	22.00% 11	20.00% 10	10.00% 5

Figure 13: Indication of how the respondents scored each attribute given in percentage and amount of respondents that gave it the corresponding score on the 10-point hedonic scale.

Regarding color, the mean was computed and a value of 7.86 was obtained with a standard deviation of 2.21, the average indicated that the color was appealing. From figure 13, it can be seen that 12% of the tasting group gave the color a score of 4 or lower expressing that the color was not appealing for them, while 24% said the color was neither appealing nor unappealing giving it a score of 5 and 6, the remaining 64% thought the color was appealing to very appealing giving it a score of 7 or higher with most of the respondents (24%) rating it an 8 also observed in figure 12. The results point out that the color was appealing to very appealing for more than half (64%) of the respondents (N=53), giving a good indication that the majority of the respondents liked the color of the product. As for the likeliness degree of taste, the average score was 7.94 with a standard deviation of 2.03, indicating that the taste was intense. The results pointed out that only 10% of the respondents thought the taste was bland to very bland giving it a score of 4 or lower, 24% gave it a score of 5 and 6, and 66% gave it a score of 7 or higher with 7 being the most selected as seen in figure 12. Thus it can be concluded that the majority of the respondents thought that the taste was intense to very intense. This is a very good indication that the pumpkin coco soup has a good taste intensity. Regarding mouthfeel, the pumpkin coco soup had a mean score of 8.25 with a standard deviation of 2.26. As seen from figure 13, 12% of the group, thought the soup was low in thickness, while 20% said it had a moderate thickness giving it a score of 5 and 6, while 68% of the respondents thought the soup was thick to very thick giving it a score of 7 or higher. It was observed from figure 12, that 7 was the most selected score with 10 being the second most selected, having a high thickness does not necessarily mean that it is good, this depends on personal preference on how they like their soups to be. A possible solution for consumers that do not like their soups to be very thick is to add some extra water to reduce thickness, this, however, could have an impact on the taste intensity of the soup, as there is more 'free' water for water-soluble flavor compound such as free amino acids to dissolve in the water simultaneously reducing the perceived taste intensity (Pérez-Palacios et al, 2017). Lastly, the texture of the soup was also measured, the mean was 7.76 with a standard deviation of 2.75. The results are displayed in figure 13, it can be seen that 16% of the respondents rated the texture a 4 or lower indicating that it had a gritty to very gritty texture, while 18% thought the texture was neither gritty nor smooth giving it a score of 5 or 6, and the remaining 66% thought the soup had a smooth to very smooth texture rating it a score of 7 or higher, 8 being the most selected score. From the results and the standard deviation, it can be observed that the data was more dispersed for this attribute. A possible reason for this is that texture is perceived differently by individuals and it comes to personal preference and to what type of soup texture they are used to. Furthermore, the net promoter score for the pumpkin coco soup was also measured, the results can be observed from figure 14

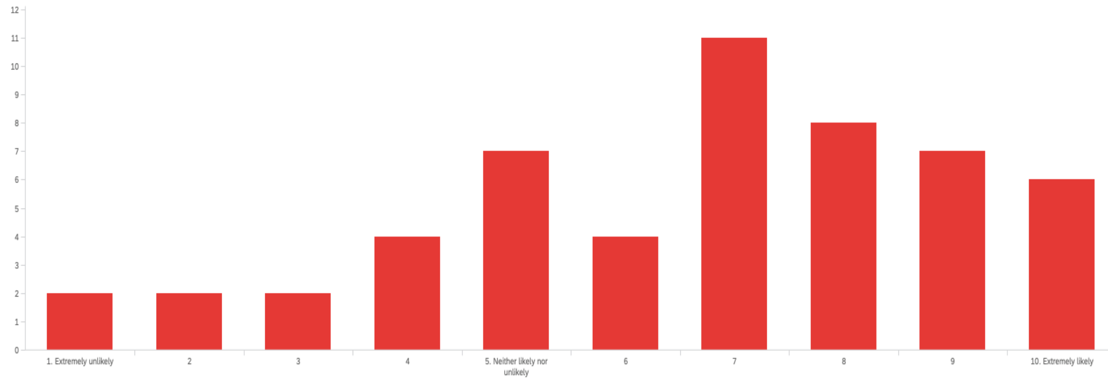

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Figure 14: Net promoter score results given by respondents for the pumpkin coco soup

The mean of the results was calculated and a value of 6.62 was obtained with a standard deviation of 2.40. The detractor's percentage was 39%, these are the respondents that gave it a score of 6 or lower, 36% of the respondents were passive promoters, the remaining 25% were promoters which gave a score of 9 or 10. The net promoter score was also calculated using eq X, and a value of -14 was obtained, indicating that consumers were not satisfied with the product or company, and are more inclined to buy products from other companies. It should be noted that different factors can have an impact on the net promoter score, these factors were not measured during the survey, therefore the score could be lower than in reality. Some of these factors are mentioned in chapter 2, an example is the brand reputation or website performance, these factors were not measured, and could have resulted in a higher score. Additionally, net promoter scores should be evaluated with a group of existing consumers which was not the case in this survey, to properly assess the influencing factors. Therefore, another survey should be conducted taking into account factors that influence the NPS to be able to measure those to obtain a more accurate score. Furthermore, the statistical relationship between the measured attributes and the NPS results was also analyzed, the results are displayed in table 12.

Table 12: Statistical analysis on the relationship between selected attributes and net promoter score using one-way ANOVA test (N=53).

Variables	***P*-value**
Color vs NPS	*0.18*
Taste vs NPS	*0.21*
Mouthfeel vs NPS	*0.06*
Texture vs NPS	*0.45*

There was no statistical relationship between the attributes and how respondents scored the pumpkin coco soup on the net promoter score. Therefore, the alternative hypothesis can be rejected as there was no relationship observed between variables because all the p-values were above 0.05. As aforementioned, the net promoter score is not a good indication of overall liking, as there are many other factors that consumers take into consideration before promoting a company or a product. These factors were not measured during this survey, thus a more suitable question should have been; *Rate the overall score of this soup*. This would allow for better interpretation of the data and a possible statistical relationship between variables, verifying that the selected attributes could have an impact on the overall liking of a product.

Furthermore, in the last section of the survey, the respondents were asked to rate the 3 soups of today's tasting, 1st place being their favorite and 3rd their least favorite. The results of this question are displayed in figure 15.

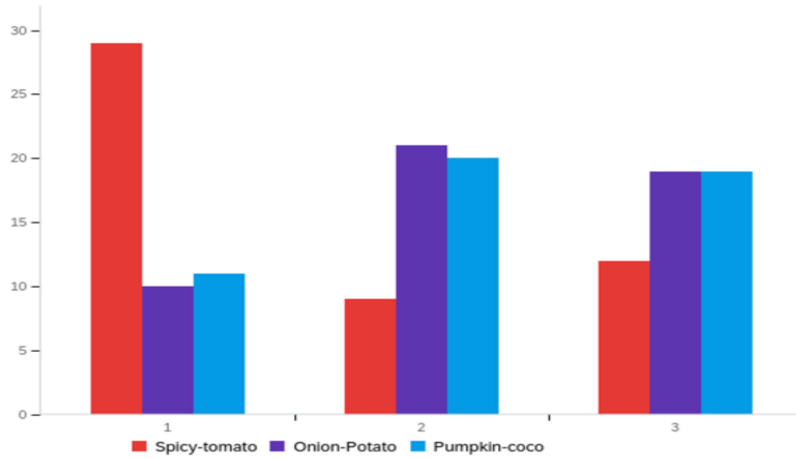

Figure 15: Ratings of the three soups based on respondents perception of favorite to least favorite

From the results, it was observed that 58% of the respondents selected the spicy tomato soup as their favorite soup of the tasting, while 18% said it was their second favorite, and 24% said it was their third favorite. As for the onion potato soup, 20% said it was their favorite, 42% selected it as their second favorite, and 38% said it was their third favorite. The pumpkin coco soup was placed in first place for 22% of the respondents, 40% said it was their second favorite, and 38% said it was their least favorite putting it in 3rd place. Even though the pumpkin coco soup had a higher average for the four attributes measured compared to onion potato, more respondents (42%) selected it as their second place compared to the 40% that selected pumpkin coco as their second place. This is because taste perception varies between individuals and as mentioned in chapter 2 there are many external factors that influence taste perception or overall liking of a food product such as environment, cultural background, personal preferences, first childhood memories, and other psychological factors (Visser, 2020).

5. Conclusion & Recommendations

Reducing food waste as a mitigation tool to combat food insecurity and help build a more sustainable food system should be the focus of related research. In this study, four different instant soup powders were developed that will be manufactured using vegetables from overproduction or side streams that were deemed as waste. The newly developed soups met the criteria proposed prior to starting the research which was maintaining salt levels below 20% of recommended daily intake, and maintaining the cost margin between €0.60-0.90 for low production volumes to guarantee economic feasibility of the product. General conclusions that can be made from the aim of this research are about the influence of process conditions on flavor, color, aroma, and texture of the final product, components that influence savory taste perception, and enhancement of savory perception using these components to reduce salt levels in food products.

From this research, it was established that enhancement of savory perception could be achieved using ingredients rich in umami compounds such as glutamate and ribonucleotides such as GMP. Additionally, an evaluation of taste interactions allowed for the combination of ingredients that could enhance the flavor profile of the soups. The addition of Shiitake, cherry tomatoes, kombu, soy sauce powder, vinegar, and 'clean label' broth resulted in a 23-30% reduction of salt levels in the new recipes compared to existing recipes without compromising the overall quality and sensory attributes in the new recipes. The combination of these ingredients not only reduced the salt levels but enhanced the savory perception of the soups and provided a fuller mouthfeel. After developing the new soup recipes, a consumer acceptability test was conducted using a non-trained panel of 53 non-consumers/consumers. For this test, only three recipes were evaluated namely, spicy tomato, onion-potato, and pumpkin coco soup. The soups were evaluated on four attributes: color, flavor, mouthfeel, and texture. From this test, it was concluded that consumers liked all three soups in terms of color, taste, mouthfeel, and texture as all attributes had an average score of 7 or higher. From the results, the spicy tomato was voted most liked, second place was onion potato and third place pumpkin coco. However, none of the soups obtained a high NPS, and this most likely due to the fact that NPS should be evaluated with a group of existing consumers which was not the case in this survey, and should include other influencing factors to properly assess the NPS. These were not taken into account during this survey. Therefore, it is recommended to conduct another survey with a consumer group taking into account the influencing factors for an NPS to obtain better and more accurate results. Furthermore, it is recommended to conduct a free amino analysis and nucleotide analysis to obtain an overview of the levels of these components in the soup products. This will indicate if the taste could be further enhanced by increasing the levels of these compounds. Another experiment that could be conducted to analyze the umami components content of the selected natural taste enhancers is an ion-exchange chromatography to be able to identify ingredients highest in these mentioned components. Additionally, it is recommended to conduct another consumer acceptability test to assess the broccoli soup which could not be assessed due to time constraints during this project.

Furthermore, from the kitchen trials, it can be concluded that process conditions can have an impact on the color, texture, aroma, and flavor of the freeze-dried vegetables. Vegetables that were pretreated for a longer period of time were less intense in terms of color, flavor, and aromas as compared to vegetables pretreated for a shorter time. However, a shorter pre-treatment resulted in an unwanted texture for the final product and was therefore established to proceed with longer steaming times. Therefore, it is recommended to further research the impact of the process conditions of pre-treatment on the final product to be able to identify methods to reduce the impact to a minimum without compromising the texture of the final product. An additional experiment such as HPLC can be conducted to analyze the micronutrient content of raw material and final product. This information can be used to back up function claims or to optimize the pre-treatment steps to be able to retain as much of the micronutrient as possible, high flavor intensity, intense color, and retain more aroma compounds.

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Appendixes

Appendix A: Consumer Acceptability Test Questionnaire

Future Kitchens Survey

Start of Block: Social demographics

Q1 Country of Origin

○ Belgium (4)

○ The Netherlands (5)

○ Other (6) ____

Q2 What is your gender?

○ Male (1)

○ Female (2)

○ Non-binary / third gender (3)

○ Prefer not to say (4)

Q3 Select your age group?

○ 15-25 (1)

○ 26-35 (2)

○ 36-59 (3)

○ 60 or above (4)

End of Block: Social demographics

Start of Block: Tasting instructions

Q4
Please follow the instructions 1. Take a drink of water before tasting the soup samples
2. Taste the soup samples and answer the questions according to their name
3. Take a sip of water or eat a cracker between samples

5. Fill in the questionnaire, as honest as possible
And enjoy! :)

- Okay (1)

End of Block: Tasting instructions

Start of Block: General questions

Q5 Number of times per week you consume soup?

- Never (1)
- 1-2 times per week (2)
- 3-4 times per week (3)
- 5 times or more (4)

Q6 How often do you check the ingredient list of a food product?

- Always (1)
- Most of the time (2)
- Sometimes (3)
- Never (4)
- I dont know what that is (5)

Q7 What is most important for you when buying a food product? Please mark the most important points for you

	Not all important (1)	Slightly important (2)	Moderately important (3)	Very important (4)	Extremely important (5)
Contains only natural ingredients and natural taste enhancers. So, no E-numbers and synthetic ingredients (1)	○	○	○	○	○
It has a health claim (2)	○	○	○	○	○
Must be very flavourful even if it means containing synthetic additives (3)	○	○	○	○	○
Produced in a sustainable matter (4)	○	○	○	○	○
The price of the product (5)	○	○	○	○	○
The quantity of the product (6)	○	○	○	○	○
It has a functional health benefit. An example of a function: boost the immune system (8)	○	○	○	○	○

End of Block: General questions

Start of Block: This section is designated for the tasting of soup 1.

Q8 Rate spicy-tomato on the following attributes:

	1 (1)	2 (2)	3 (3)	4 (4)	5 (5)	6 (7)	7 (8)	8 (9)	9 (10)	10 (11)
Color (1. Very unappealing - 10. Very appealing) (1)	o	o	o	o	o	o	o	o	o	o
Taste (1. Very bland - 10. Very Intense) (2)	o	o	o	o	o	o	o	o	o	o
Mouthfeel (1. Low thickness - 10. High thickness) (7)	o	o	o	o	o	o	o	o	o	o
Smoothness (1.Very gritty - 10. Very smooth) (10)	o	o	o	o	o	o	o	o	o	o

Page Break

Q9 How likely would you recommend spicy-tomato to someone else?

- ◯ 1. Extremely unlikely (1)
- ◯ 2 (2)
- ◯ 3 (3)
- ◯ 4 (4)
- ◯ 5. Neither likely nor unlikely (5)
- ◯ 6 (6)
- ◯ 7 (7)
- ◯ 8 (8)
- ◯ 9 (9)
- ◯ 10. Extremely likely (10)

End of Block: This section is designated for the tasting of soup 1.

Start of Block: This section is designated for the tasting of soup 2.

Q10 Rate onion-potato on the following attributes:

	1 (1)	2 (2)	3 (3)	4 (4)	5 (5)	6 (7)	7 (8)	8 (9)	9 (10)	10 (11)
Color (1. Very unappealing - 10. Very appealing) (1)	○	○	○	○	○	○	○	○	○	○
Taste (1. Very bland - 10. Very Intense) (2)	○	○	○	○	○	○	○	○	○	○
Mouthfeel (1. Low thickness - 10. High thickness) (7)	○	○	○	○	○	○	○	○	○	○
Smoothness (1.Very gritty - 10. Very smooth) (10)	○	○	○	○	○	○	○	○	○	○

Q11 How likely would you recommend onion-potato to someone else?

○ 1. Extremely unlikely (1)

○ 2 (2)

○ 3 (3)

○ 4 (4)

○ 5. Neither likely nor unlikely (5)

○ 6 (6)

○ 7 (7)

○ 8 (8)

○ 9 (9)

○ 10. Extremely likely (10)

End of Block: This section is designated for the tasting of soup 2.

Start of Block: This section is designated for the tasting of soup 3.

Q12 Rate soup pumpkin-coco on the following attributes:

	1 (1)	2 (2)	3 (3)	4 (4)	5 (5)	6 (7)	7 (8)	8 (9)	9 (10)	10 (11)
Color (1. Very unappealing - 10. Very appealing) (1)	o	o	o	o	o	o	o	o	o	o
Taste (1. Very bland - 10. Very Intense) (2)	o	o	o	o	o	o	o	o	o	o
Mouthfeel (1. Low thickness - 10. High thickness) (7)	o	o	o	o	o	o	o	o	o	o
Smoothness (1.Very gritty - 10. Very smooth) (10)	o	o	o	o	o	o	o	o	o	o

Q13 How likely would you recommend pumpkin-coco to someone else?

- ◯ 1. Extremely unlikely (1)
- ◯ 2 (2)
- ◯ 3 (3)
- ◯ 4 (4)
- ◯ 5. Neither likely nor unlikely (5)
- ◯ 6 (6)
- ◯ 7 (7)
- ◯ 8 (8)
- ◯ 9 (9)
- ◯ 10. Extremely likely (10)

End of Block: This section is designated for the tasting of soup 3.

Start of Block: Final section

Q14 In general, rate the 3 soups of today's tasting, 1 being your favourite and 3 your least favourite. (Drag your answer)
______ Spicy-tomato (1)
______ Onion-Potato (2)
______ Pumpkin-coco (3)

Q15 Do you have any additional feedback?

____

End of Block: Final section

Appendix B: Nutritional Values of the Newly Developed Soups

In Figure B1- B4, the nutritional values of the newly developed soups are shown which where calculating using the Recipe Robot.

Total mass (g): 19.82
Total price (euro): 0.912
Total protein (g): 2.7
Total carbs (g): 11.2
Total fats (g): 1
Total natrium (mg): 323.935
Total energy (kcal): 69
Total vitamin b1 (mg): 0.07638423999999999
Total vitamin b2 (mg): 0.0608822
Total vitamin b6 (mg): 0.28109710000000004
Total vitamin c (mg): 74.05810193999999
Total vitamin e (mg): 2.86186228

Figure 1B: Nutritional value of the spicy tomato soup

Total mass (g): 20.016000000000002
Total price (euro): 0.649
Total protein (g): 2.5
Total carbs (g): 12.5
Total fats (g): 0
Total natrium (mg): 309.224
Total energy (kcal): 70
Total vitamin b1 (mg): 0.0745467
Total vitamin b2 (mg): 0.0176814
Total vitamin b6 (mg): 0.24402350000000003
Total vitamin c (mg): 8.419399499999999
Total vitamin e (mg): 0.1435786

Figure 2B: Nutritional value of the onion potato soup

Total mass (g): 20.068
Total price (euro): 0.656
Total protein (g): 2.6
Total carbs (g): 7.9
Total fats (g): 2
Total natrium (mg): 296.643
Total energy (kcal): 67
Total vitamin b1 (mg): 0.29867857999999997
Total vitamin b2 (mg): 0.00749756
Total vitamin b6 (mg): 0.1405192
Total vitamin c (mg): 17.434567740000002
Total vitamin e (mg): 2.27400932

Figure 3B: Nutritional value of the pumpkin-coco soup

Total mass (g): 20.299999999999994
Total price (euro): 0.906
Total protein (g): 5.8
Total carbs (g): 6.9
Total fats (g): 1
Total natrium (mg): 227.048
Total energy (kcal): 66
Total vitamin b1 (mg): 0.08178414
Total vitamin b2 (mg): 0.08202628
Total vitamin b6 (mg): 0.1974754
Total vitamin c (mg): 42.98425531999999
Total vitamin e (mg): 2.69274336

Figure 4B: Nutritional value of the broccoli soup