



THE PRODUCTION AND CHARACTERISTICS OF AN ORANGE FLESHED SWEET POTATO YOGURT

Master Thesis, Food Technology and Nutrition (M. Sc.)



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Abstract

Yogurt is an ancient food, used for a better preservation of milk. Milk gets fermented by *Streptococcus thermophilicus* and *Lactobacillus bulgaricus* (lactic acid bacteria, LAB) which converts the lactose present in the milk to lactic acid. These probiotics support the microbial population balance of the gastrointestinal tract. Sweet potato, *Ipomoea batatas*, is an important security crop in developing countries. The variety Orange fleshed sweet potatoes (OFSP) is gaining attention due to its β -carotene and non-pro-vitamin A carotenoid. The aim of this report is to study the fermentations of four different OFSP, containing 30-, 40-, 50- and 60 % OFSP. Then the consumer liking in Ghana was evaluated by performing a hedonic test. The yogurts, including a control yogurt containing no OFSP, were all analysed for ten days (ph, brix, viscosity and acid number). The pH was the highest for the control yogurt and as for the yogurts containing OFSP the pH got lower with an increase of the OFSP percentage. OFSP has a high concentration of starch, which can be used as a carbon source for the LAB. The Brix and acid number results supported this. The carotenoids caused a red/yellow/orange color for the OFSP yogurts. Lastly, the hedonic test showed that the 40 % OFSP was preferred among the participants from the taste, however several comments of the lack of sweetness were made. The difference in the hedonic test was small enough for a decision to be made based on the economic value of the product, as replacing milk powder with OFSP is much cheaper. Hence, the 60 % OFSP is the best option. It was concluded that the addition of OFSP contributed to the LAB activity. An interview conducted with a market researcher in Ghana showed that the product would mainly be for the population in the middle class, and to those who are health conscious. It would sell best in the bigger cities. The health benefits of this product are important, hence it needs to be accessible for everyone. With plain/sour yogurts becoming bigger in Ghana, so will crop and unsweetened yogurts eventually.

Popular Abstract

The yogurt market in Ghana is so dominated by sugary, fruit yogurts, with familiar flavors such as vanilla and strawberry. But how would a healthy, unsweetened sweet potato yogurt fit in? What would the customer choose: A familiar, sugary fruity yogurt or a new, neutral/almost sour crop yogurt filled with great health benefits? When a new product gets introduced to the market where there is a similar product in the same category, which exists in every corner store and at a cheap price, there can be some challenges. This new product I am talking about is a fermented yogurt with an addition of orange fleshed sweet potatoes, with absolutely no sugar!

The importance of consumption for orange fleshed sweet potatoes has had a raised awareness recently, due to their high content of β -carotene which converts to Vitamin A when consumed (one of many great health benefits!). It would be great to consume this as an easy, to-go product! The addition of sweet potato in yogurt resulted in an increase of formed lactic acid. Yogurt is already a product of good health benefits because of its probiotics, which supply our bodies with good bacteria. Interestingly, the high content of starch in sweet potato became a great carbon source for the lactic acid bacteria, *Streptococcus thermophilus* and *Lactobacillus bulgaricus*. The bacteria got more substrate to convert into lactic acid, which resulted in a lower pH as more sweet potato was added.

This work could contribute to a shift in the yogurt market in Ghana, which would reduce the intake of sugar and add sweet potato to the consumers daily or weekly diet. Vitamin A deficiency is common in developing countries. This can lead to a special type of blindness when the deficiency is severe, by adding sweet potato to one's diet it may help prevent the condition. The deficiency is quite common in Ghana, especially amongst children, so it is important to start today! The sensory evaluation performed in this project showed that most Ghanaians wanted sugar added to it, since it was too sour. The product might not have a smooth and fast journey into the Ghanaian market, another reason why we should start today! This is most likely because of the perception that a yogurt is supposed to have a sweet taste. The local farmers would also obtain great benefits from this shift as the farming is highly efficient and profitable, it's a win-win!

Surprisingly, the sensory evaluation showed participants coming from Europe found the sweet potato yogurt good, despite the sourness. This is due to a familiarity from their home countries. Hey! This means the sensory results could be completely different somewhere else.. It would be interesting to see how different nationalities enjoy this product.

In this study four different sweet potatoes were produced, 30-, 40-, 50- and 60 % sweet potato in the yogurts, alongside one containing no sweet potato. The best product was determined to be the most accessible one, which is the cheapest and contains the most sweet potato. Throughout a storage of 10 days in a refrigerator different physical and chemical analyses were performed to see the bacterias activity.

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This project has been a great learning experience for me, and my interest in food technology has grown immensely. I have learnt how to work independently, and to work in an efficient way.

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1. Introduction

1.1 Background

Yogurt is considered by most to be a fermented milk product, where lactose is digested, as well as specifically defined viable bacteria which most commonly are *Streptococcus thermophilicus* and *Lactobacillus bulgaricus*. The fermented product is a source of essential nutrients, such as protein, calcium, potassium and vitamin B₂ and B₁₂. Yogurt is an ancient food, and the human diet is believed to have had milk incorporated around 10000- 5000 BC. However, there was some difficulty in using milk due to it being spoiled easily. Around that time herdsman in the Middle East had bags which carried the milk, and they were made out of intestinal gut. During this contact with the intestinal juices the milk started to curdle and sour, which preserved and allowed for conservation of a dairy product with a longer shelf life. There is belief of the word “yogurt” coming from the Turkish word “yoğurtmak”, this meaning to thicken, coagulate, or curdle. The Turkish people were also the first to evaluate yogurts medicinal use, to treat diarrhea and cramps for example (Fisberg & Machado, 2015). The term probiotic was first introduced by a German scientist in 1953. Over the years there have been different definitions, in 1992 a more specific one was introduced by Fuller “a live microbial feed supplement which beneficially affects the host animal by improving its intestinal microbial balance” (Gasbarrini, et.al., 2016). There has been an abundance of evidence which implies that specific bacterial species, used for dairy product fermentation, which have been selected from the healthy gut microflora have important qualities, such as anti-pathogenic and anti-inflammatory. When yogurt is fermented by *L. bulgaricus* and *S. thermophilus* lactic acid is produced, this gives a low pH and high acidity of the product. Today there are many modern societies which have fermented dairy products in their daily food consumption (Adolfsson, et. al., 2004). Yogurt is consumed daily as a component in different foods, for example in different Indian dishes. Fruits in yogurts are very common today, but there have been different studies with the usage of crops instead.

Sweet potato, *Ipomoea batatas*, is in terms of food production the seventh most important crop in the world. They are mostly grown in developing countries, which account for more than 95 % of the world's output. The production of sweet potatoes is mostly done on a small level. Per hectare, sweet potato produces more biomass and nutrients than any other crop in the world. It survives well in fertile tropical soils, and produces tubers well without fertilizers. In East Africa thousands of villages depend on the crop for food security, and even in Japan it is used when typhoons demolish rice fields (Loebenstein, et.al., 2003). The production of sweet potatoes in the world had a drop between 1993 and 2004, but in the past decade it has been stable. The roots, stems and leaves of the crop are all edible parts with different composition of nutrients, non-nutrients, anti-nutrients and bioactives (Wang, et.al., 2016). The leaves are used as greens, while the tubers for their high carbohydrate and β -carotene source (Loebenstein, et. al., 2003). The chemical composition not only depends on the genetic diversity, but also the pre- and post-storage condition, extraction and analytic methods applied. With the crops unique

physicochemical properties, it is particularly valued as a functional food ingredient. Regarding yellow- and orange-fleshed they contain phenolic acids, as well as a relatively high level of carotenoids. Due to an awareness being raised in the relationship between sweet potato and human health there has been a rise in the efforts to increase the levels of certain bioactive constituents in the crop. To increase the antioxidant and specific nutrient concentrations molecular breeding holds great potential. In the food industry sweet potatoes are a versatile ingredient. Often the leaves are consumed as green leafy vegetables with their nutrient-dense and health-promoting qualities. The roots can be used and cooked in different ways, as in baking, boiling, dehydrating and frying. Of late there has been innovating new products containing sweet potato, such as pasta, pickled vegetables, beverages and yogurts (Wang, et.al., 2016).

As mentioned previously there has been recent studies of sweet potato yogurts. Because of sweet potato being a food security crop and so highly produced worldwide, this innovation could be very beneficial, especially in developing countries where it can be locally produced with a cheaper price. Yogurt and sweet potato both have different health benefits; hence the fermentation of sweet potato yogurt is of interest today. It is a relatively new food innovation and altogether two different flavours which have not been combined before. Therefore, the position in the market is important to evaluate as well, by doing market research.

1.2 Objectives

In this study four different fermentations of yogurt with sweet potato will be studied. The yogurt will contain different percentages of an orange-fleshed sweet potato (OFSP) variety, Apomuden. The different percentages are; 30, 40, 50 and 60 % in dry matter where the milk powder and OFSP will vary according to the percentage of sweet potato. These yogurts will then be analysed and compared regarding the change in pH, color, brix value, relative viscosity and acid number. The results will be obtained during a storage period of 10 days. There will also be a sensory evaluation of the different sweet potato yogurt, by the usage of a hedonic evaluation. The overall aim is therefore to, with the laboratory results in terms of physical change and hedonic evaluation, decide which percentage of sweet potato in yogurt is preferred and the effect OFSP has on the fermentation process.

The following are the research questions of this study:

1. How will different proportions of sweet potato affect the fermentation process of yogurt?
2. How will the sweet potato variety Apomuden affect the fermentation process of yogurt?
3. How will the characteristics of the yogurt be affected with the different proportions of sweet potato in the yogurt? This will be in the aspects of viscosity, brix value, pH, acid number and sensory evaluation.
4. How will the consumers in Ghana respond to the different sweet potato yogurts fermented in this project?

2. Theoretical background

2.1 Yogurt

One of the best-known foods that contain probiotics is yogurt. By definition of *Codex Alimentarius* of 1992 the product is described as coagulated milk that results from the fermentation of lactic acid which comes from *Lactobacillus bulgaricus* and *Streptococcus thermophilus*. There are also other lactic acid bacteria (LAB) which are used to give unique characteristics to the final product (Adolfsson, et.al., 2004). Due to this acid the sensory and rheological qualities of milk changes, as well as gives the fermented product a better storage properties. Yogurt is utilised as an energy source, it provides 3.6 kcal/g (Alm, 1982). The LAB species, coming from a starter culture for the production, works in a symbiotic way during their growth in the milk medium. There must be a careful selection of the LAB mixture to complement each other and have a remarkable efficiency in the production of acid (Adolfsson, et.al., 2004).

2.1.1 Fermentation

In milk there is lactose present, this is a major source of energy and carbon for the growth of lactic acid bacteria. Milk has a refractive index of 10 % (CDR FoodLab). These bacteria convert lactose into lactic acid, hence why yogurt has its characteristic acidic taste. There are two main categories of fermentation, homofermentation and heterofermentation, which depend on the variations in the metabolic products. The first mentioned generates lactic acid as the main end-product, whereas the latter results in several other end-products, such as ethanol, carbon dioxide or acetic acid (Chen, et.al., 2017). The lactic acid bacteria which are used as commercial starter cultures for yogurt production are composed of a synbiotic mix of *S. thermophilus* and *L. bulgaricus*. These two are responsible for the formation of the typical flavour and texture of yogurt. Both LABs can work independently, but the rate of the acid production is substantially higher when used together. A ratio of 1:1 is generally used, with a milk temperature of 42 °C. The temperature is a compromise of the optimum temperature of the two bacteria, *S. thermophilus* has 37 °C and *L. bulgaricus* has 45 °C. After the starter cultures are added *S. thermophilus* grows the fastest until it accounts for approximately 90 % of the total bacterial cells. 2 hours later *L. bulgaricus* is stimulated to grow faster by *S. thermophilus* due to the release of lactic acid, carbon dioxide, and formic acid. Due to the pH decrease to approximately 4, the yogurt mixture coagulates (Gurakan & Altay, 2010).

There are many volatile organic compounds in yogurt, however only a few have a high concentration which gives yogurt its characteristic aroma. There is a β -galactosidase system in both bacteria which hydrolyses lactose to glucose and galactose. The glucose is firstly metabolized into pyruvate which then is converted to lactic acid by lactate dehydrogenase enzymes. Galactose is partly metabolized by *L. delbrueckii* subsp. *bulgaricus* strains, and *S. thermophilus* different strains mostly do not have enzymes for metabolizing galactose. This causes for galactose and lactic acid to leave the cell, which then are accumulated in the yogurt medium. After the lactose has been hydrolysed, lactic acid, acetaldehyde, acetic acid and

diacetyl also contribute to the yogurt flavour. Due to lactic acid and its decreased pH many other microorganism's presences get inhibited in the same environment. Lactose gets metabolized to 1.2-1.4 % lactic acid, which has a pH of 4.2-4.3. The acidic nature causes milk proteins to get coagulated to form a firm gel. Acetaldehyde is the main cause of the flavour of yogurt. This metabolite has many ways it can be produced, such as from glucose directly via pyruvate and from threonine. Acetic acid, a flavour compound, is produced from pyruvate by *S. thermophilus*. Both bacteria have been detected to have acetic acid in their pure culture, however it was found that *L. bulgaricus* has the highest concentration of the acid out of the two. The product's harshness comes from acetic acid, and if there are high levels it can give a "vinegary" taste which causes consumers to dislike the product more. Diacetyl is a major aroma for butter. It is formed from citrate which is converted to diacetyl via pyruvate metabolism (Gurakan & Altay, 2010).

The temperature range for a proper fermentation is quite small, from 42°C to 44 °C. When the temperature during fermentation is up to 44 °C the rate of the metabolism is higher, which causes the yogurt to be sweeter. A fast growth also causes the yogurt to set faster. When the yogurt has reached its desired acidity, it is cooled to stop any further fermentation and metabolic activity (Gurakan & Altay, 2010).

2.1.2 Probiotics

Probiotics, as a concept, was introduced back in 1908 when it was suggested that Bulgarian peasants' long life was due to fermented milk products. Probiotics refers to viable microorganisms which promote or support the native microbial population's balance of the gastrointestinal tract. Humans have a close association with vast numbers of microorganisms, present on the skin, in the mouth and in the gastro-intestinal tract. There are many important bacterial species in the different floras of our body, with important health functions such as stimulating the immune system (Gupta & Garg, 2009). LAB are considered the major representatives of probiotics, this is the case in both the food and pharmaceutical market. These LABs are associated with different habitats, especially those rich in nutrients where it's possible for the bacteria to ferment or spoil. Particular LAB strains inhabit the human oral cavity, the intestinal tract, and vagina where they beneficially influence these human ecosystems. Due to this, they are great candidates for usage in probiotics. Fermented food commodities or products in lyophilised form, as supplements and pharmaceutical preparations is mostly how viable probiotic strains are supplied in the market. With the intake of probiotics comes several beneficial functions. To name a few ther; nutritional benefits, vitamin production, important digestive enzymes are produced, infectious diarrhoea, stimulation of the immune system and cholesterol lowering effects (Holzapfel & Schillinger, 2002).

2.2 Sweet potato

In developing countries root and tuber crops play an important role in agriculture, which facilitates food security. Amongst all roots and tubers that are a part of the majority of the global production, sweet potato (*Ipomoea batatas*) is very important after potato regarding the basis of production and consumption. Sweet potato is in the Convolvulaceae family and is ranked as the worlds' seventh most important food crop. Sweet potato is cultivated in more

than 115 nations, and is considered as the secondary staple food which possesses a significant role in the diets of the populations in many underdeveloped countries. The crop is also reported to have good sensory acceptability due to the rich colors and sweet taste (See Figure 1) (Neela & Fanta, 2019).

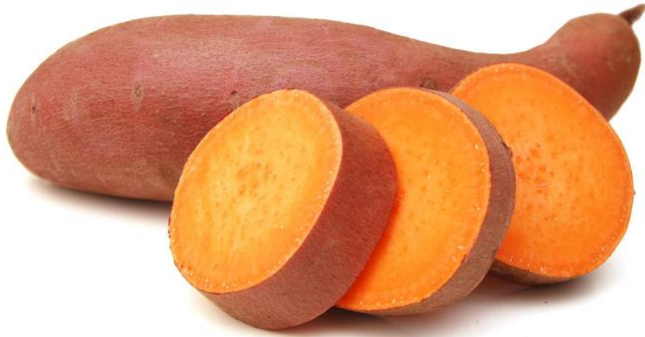


Figure 1. A picture of an oranges fleshed sweet potato which shows its rich, intense orange color (Uprety, 2018).

2.2.1 Nutritional composition

Sweet potato is a good carbohydrates source, as it contains 20% dry weight, despite this the World Health Food Organization has declared the root crop with antidiabetic activity. In vivo studies have shown that the carbohydrates stabilise sugar levels in blood, as well as decreasing the resistance to insulin. It has also been reported that sweet potato provides substantial quantities of selected vitamins (vitamin C), specific minerals and a mixture of bioactive compounds (phenolic acids and anthocyanins). In the different fleshed sweet potatoes, there is also a difference, for example purple- and orange fleshed cultivars possess higher quantities of anthocyanins and carotens when compared to white-fleshed varieties. Currently there is an increased attention and demand to OFSP due to the high concentration of β -carotene and non-pro-vitamin A carotenoid.

It is a good source of nondigestible dietary fibre, minerals, vitamins, and antioxidants. The nutrient composition can be viewed in Table 1. Scientists have accredited it to its rich nutritional components with anticarcinogenic and cardiovascular disease-preventing attributes. There is a high concentration of starch in OFSPs, approximately 65 % dry weight of the total carbohydrate content. Amongst all energy sources for consumers, starch is one of the most important energy sources. The sugar content in the OFSP is approximately 9.1 % dry weight (Šlosár, et.al., 2019). Sucrose is the main sugar component (Chan, et. al., 2014). The different minerals in the crop are calcium, magnesium, phosphorus, potassium, iron, zinc and sodium. They all play important roles in the human body. Calcium plays a major role in muscle function, formation and strengthening of bones and teeth. Magnesium is an essential mineral and has metabolic functions and possesses a role in optimal blood pressure. Phosphorus is important regarding energy metabolism. Potassium maintains a normal heart rhythm and is accountable for nerve signal functions. Iron is crucial for respiration and energy metabolism processes. Zinc is acquired for good immune systems, cell growth and insulin functions. Lastly, sodium has an

important role in terms of sodium-level adjustments. Carotenoids are a natural pigment in OFSPs. They are responsible for yellow, orange and red colors in different plant products, flavors and aromatic scents. The most common dietary carotenoid is β -Cryptoxanthin which is found in fruits and vegetables. Carotenoids easily convert into retinol in the human body. If there is a retinol deficiency it can cause night blindness, susceptibility to infections and respiratory infections, malaria and diarrhoea, for example. Lastly, the pH of OFSP, which influences the taste and overall sensory acceptability of foods, is 6.52, hence a neutral product (Neela & Fanta, 2019).

Table 1. The nutrient composition for raw, orange-fleshed sweet potato per 100 g (USDA).

| | |
|--------------------------------|-------------|
| Weight standard (g) | 100 |
| Water (g) | 79.5 |
| Energy (kcal) | 79.0 |
| Nitrogen (g) | 0.3 |
| Protein (g) | 1.6 |
| Total lipid (fat) (g) | 0.4 |
| Ash (g) | 1.2 |
| Carbohydrate, Total (g) | 17.3 |
| Starch (g) | 11 |
| Dietary Fibre, Total | 4.4 |
| Sugars, Total (g) | 6.1 |
| Sucrose (g) | 3.1 |
| Glucose (g) | 1.0 |
| Fructose (g) | 0.9 |
| Lactose (g) | <0.25 |
| Maltose (g) | 1.1 |
| Minerals, Total (g) | 0.6 |
| Vitamins, Total (g) | 0.02 |

2.3 Sweet potato yogurt

Different sweet potato yogurts have been developed for the commercial market as well as for studies. There is still a shortage of sweet potato yogurts on the market, despite all the benefits consumers get when consumed. A purple-fleshed sweet potato yogurt has been developed (Afiati, et.al., 2018) to study the improvement of functional food, which is yogurt, when enriched with different concentrations of sweet potato. However, in their case the sweet potato was added in the form of flour. The different concentrations had no effect on viability of the LAB, moisture content and crude fibre. But in regard to the fat, protein, carbohydrate and ash content the different concentrations affected these parameters (Afiati, et.al., 2018). Studies were made on a yogurt from milk and sweet potato or pumpkin. It showed an increase in lactic acid formation, however no significance on the different mixtures (Shin, 1993). An OFSP yogurt that reached the market came from a student at Kwame Nkrumah University of Science

& Technology. “Sweetpot yogurt” became a start-up brand which produced its yogurt enriched with highly nutritious OFSP. This company addressed the issues with vitamin A deficiency syndrome, which is especially prevalent in developing countries. At first the company's aim was to promote the consumption of OFSP and provide a market for OFSP farmers in Ghana. This former student received several awards, showing the yogurt has a prosperous future (Manful, n.d.).

2.4 Yogurt and sugar consumption in Ghana

Milk is an essential source of good, quality protein as well as key micronutrients, as calcium and vitamin A & B. The milk consumption per capita in Ghana is one of the lowest ones in the world. It is mostly consumed by preparing it through milk powder. In Table 2 whole milk powder nutritional data can be viewed. Per capita the consumption of milk is 8 kg, which makes the country among one of the lowest in Africa as well as globally (Kunadu, et. al., 2019). Yogurt is involved in this number. In Ghana the most common yogurts available, especially at small shops, are fruity, sugared yogurts, usually with vanilla and strawberry flavoring. These can be consumed by most people, as they are affordable, accessible and available in most stores. Greek Yogurt and non-sweetened, plain yogurts are mostly found at the big grocery stores which are more expensive, hence not as accessible to the entire Ghanaian population. The first Ghanaian Greek Yogurt was introduced in 2012 by Zeno’s, however there are more sour yogurts which are imported.

Table 2. The nutrient composition for whole milk powder standard for 100 g (Frida fooddata), (FoodDB).

| | |
|----------------------------|-------------|
| Weight standard (g) | 100 |
| Moisture (g) | 3.6 |
| Energy (kcal) | 493 |
| Nitrogen (g) | 3.8 |
| Protein (g) | 23.9 |
| Total lipid (fat) (g) | 26 |
| Ash (g) | 5.8 |
| Sugars, Total (g) | 37 |
| Sucrose (g) | 0 |
| Glucose (g) | 0 |
| Fructose (g) | 0 |
| Lactose (g) | 37 |
| Maltose (g) | 0 |
| Minerals, Total (g) | 2.5 |
| Vitamins, Total (g) | 0.03 |

The annual sugar intake per capita reached 11.2 kg in 2019, it was 10.9 % more compared to the previous year. In 2019 Ghana was ranked 132nd in a group of 161 countries, when looking at the interest rate on sugar consumption per capita (HelgiLibrary). There have been studies of the daily sugar intake in Ghanaians (Blay, et. al., 2000) which have been used to compare the

intake in urban and rural areas. The consumption of sugary drinks, cakes/biscuits and chocolate/sweets were researched on. It was found that intake of sugary snacks and drinks were low to intermediate proportions in both urban and rural areas. However, the sugared coffee and tea consumption were higher in both areas. The study showed women and the highly educated ones in the country had a bigger intake of snacks. Younger children who frequently consume sugary drinks and sweets are mainly a problem in urban areas. Other studies have shown otherwise, with the highest prevalence of sugar consumption observed among males and subjects of the lower social classes. Hence, a reasonable economic explanation is the sugar consumption being most common among those who can afford such products. The rapid, increasing urbanization in most developing countries leads to food rich in fat and sugar, this has become socially important and has tended to be more favoured than some traditional food (Blay, et. al., 2000).

2.5 Analyses

2.5.1 pH

pH is a quantitative measurement of the acidity or basicity of a liquid solution. The hydrogen ion concentration in the solution is measured which translates to a value between 0 and 14, this comes from the hydrogen ion concentration ordinarily ranges between about 1 and 10^{-14} gram-equivalents per litre (Britannica, 2020).

2.5.2 Color

It is of importance for the color of a product or sample to match the standard, since this comes with customer satisfaction which otherwise could be compromised leading to an amount of rework and an increase in cost. Therefore, the color needs to be identified early in the production process. The measurement of a liquid, for example, color is evaluated by a color measurement instrument. L*a*b* coordinates are common when identifying colors, these coordinates are defined by the Commission Internationale de l'Eclairage (CIE). The color system was modelled after concluding that two colors cannot be red and green at the same time, as well as yellow and blue at the same time. L indicates lightness, + is lighter whereas – is darker. a indicates the red/green coordinate, + is redder, and – is greener. Lastly, b indicates the yellow/blue coordinate, + is yellower and – being bluer (See Figure 2) (Konica Minolta).

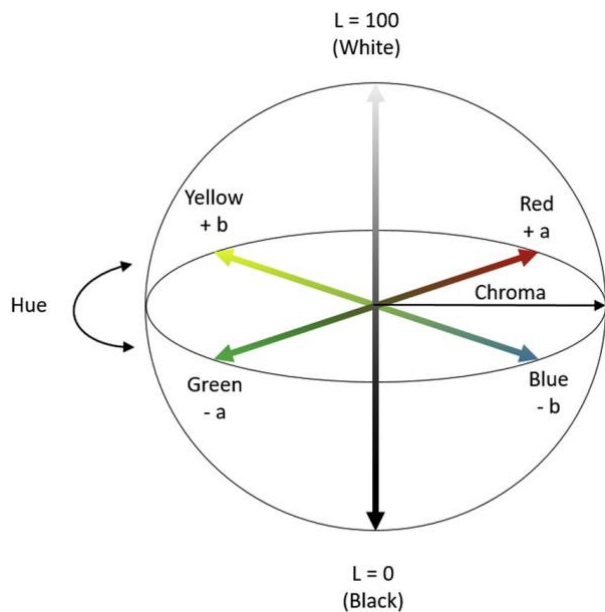


Figure 2. An image of the CIELAB color space diagram. The three axes, l , a and b , are all demonstrated (Del Bino, 2020).

2.5.3 Brix

Brix measurements can be performed by both refractive index and density. When there is pure sucrose content in water, both techniques will give the same result. To measure the sugar content of a solution brix refractometers are common. When the sugar level increases, so does the refractive index. When light passes through a sample and measures the refraction, the amount of light bending, the sugar content is measured. The refractometer is calibrated with the brix scale, one degree brix ($^{\circ}\text{Bx}$) is equal to 1% sucrose by mass. Other types of dissolved solids can also affect the refractive index; therefore, the scale only provides an approximate measurement of the sugar content (R&D World).

2.5.4 Viscosity

Viscosity is the resistance of a fluid, for it to change in shape, as well as the movement of neighbouring portions relative to one another. It denotes the opposition to flow. By comparing molasses and water, the first mentioned has a greater viscosity. The liquid that is forced to move will to some extent carry along some adjacent parts, therefore viscosity can be thought of as internal friction between the molecules (Britannica, 2022).

2.5.5 Acid number

Acid number is the measurement of the acidic concentration in a solution. It is defined as the amount of potassium hydroxide, in milligrams, that is required to neutralize 1 g of a chemical substance. The acid number measures the amount of carboxylic acid groups in a chemical compound, for example free fatty acids (ChemEurope).

3. Material and method

3.1 Method development

The initial phase of this study was to develop the method of the yogurt. This was done for the control yogurt, which did not have any sweet potato added. Different combinations of parameters were altered and combined. The parameters which could be altered were the LacPatrick milk powder to water ratio, the type of starter culture added, the quantity of starter culture added and the fermentation time.

3.1.2 LP milk powder: Water

The milk was formulated from a milk powder, specifically LP milk powder, which was whisked together with treated drinking water. The milk powder is a spray dried whole milk powder by LacPatrick Diaries NI, produced in Coleraine, Northern Ireland. For each trial water used was 1000 ml, hence only the LP milk powder was altered. Firstly, a ratio of 1/10 was used. This meant 100 g of milk powder was added to 1000 ml water. Following, a ratio of 1/3 was used, meaning 333 g of LP milk powder was added to 1000 ml water. Lastly, a ratio of 1/5 was used. This led to 200 g of LP milk powder being added to 1000 ml water.

3.1.3 Starter Culture

The second parameter is the choice of starter culture. A starter culture is a mixture of yogurt bacteria which acts as an inoculant to produce yogurt. It needs to be added in a small quantity to the milk solution for the fermentation of the yogurt to happen. Without this addition of bacteria added there would be no yogurt produced. The starter culture added, containing *S. thermophilus* and *L. bulgaricus*, needs to be of good quality. The first trial, a yogurt starter culture which was in powdered form containing *S. thermophilus* and *L. bulgaricus* was used (See Table 3). This was added to the milk solution. This was a yogurt starter culture from Yógourmet, produced in France. It was kept in the freezer during storage to prevent it from other bacteria growth. Afterwards, liquid yogurts from the market were added to the milk. The first one was YoFresh (no nutritional information is found), this contained *S. thermophilus* and *L. bulgaricus*, milk, sugar and vanilla flavouring. Following this, another yogurt was used in the trials, this was Dolait. This yogurt had no flavouring added, and contained full cream milk, water and *S. thermophilus* and *L. bulgaricus*. Lastly, greek yogurt was tested as a starter culture. This was Zeno's Yogurt (Greek Yogurt) which contained whole milk, skimmed milk powder, *S. thermophilus* and *L. bulgaricus* (See Table 4). The 1/10 LP milk powder and water ratio was only used for the powdered yogurt starter culture. The 1/3 ratio was used for the YoFresh. For the Dolait and Zeno's Yogurt (Greek Yogurt) the 1/5 ratio was used. YoFresh, Dolait and Zeno's Yogurt were all kept in 4 °C during storage.

Table 3. The nutritional information of Yógourmet Starter Culture (Yógourmet).

| Values | Per 1 g |
|---------------|---------|
| Fat | 0 g |
| Protein | 0 g |
| Carbohydrates | 1 g |
| Sodium | 5 mg |

Table 4. The nutritional information of Zeno's Greek Yogurt (Zeno's).

| Values | Per 100 ml |
|---------------|------------|
| Fat | 4.3 |
| Protein | 9.0 |
| Carbohydrates | 7.2 |
| Energy | 104 |
| Calcium | 293 |

3.1.4 Quantity starter culture added

Initially a quantity of 2.0 g of the powdered yogurt starter culture was used. Later, 4.0 and 6.0 g were also used of the powdered yogurt starter. As for Yofresh, 2.0 g and 5.0 g of the starter culture were used. For Dolait, 4.0, 6.0 and 10.0 g were used. Lastly, for Zeno's Yogurt (Greek Yogurt) 5.0 and 7.0 g was used.

3.1.5 Fermentation time

Initially, the fermentation time was four hours. Afterwards, it was increased to six hours, which was later followed by eight hours. It is worth mentioning the four-hour fermentation time only was used for the powdered yogurt starter culture. For the YoFresh a fermentation time of six hours was used. Lastly, for the Dolait and Zeno's Yogurt (Greek Yogurt) six and eight fermentation hours were tested.

3.2 Yogurt fermentation

To start the yogurt production, all equipment used during the process were sterilised by placing them in boiling water. For the control yogurt, LP milk powder (see quantity in Table 5) was added to 1000 ml. This was then whisked together to become homogeneous, with no clumps. The milk was then heated to 80 °C to kill all bacteria. Afterwards, the temperature was brought down to 43 °C which is the temperature *S. thermophilus* and *L. bulgaricus* grow best in. 5.0 g of starter culture, Zeno's Yogurt (Greek Yogurt) (See Figure 3), was added to the milk. Everything was then poured into a jar and left to ferment in a 43 °C environment for eight hours. It was then placed in a refrigerator of 4 °C. For the sweet potato yogurts, the process is the same as the control yogurt except for the addition of sweet potato. The sweet potato yogurt had the percentages of 30-, 40-, 50- and 60 %. In these cases, the sweet potato (see quantity in Table 5) was added after the LP milk powder and water had been whisked together, this was then made into a homogenous solution with a blender. This obtained each yogurt a calculated

amount of nutrients (Table 6). The sweet potato was in a paste form. It had been blended raw and then placed in a freezer. A small portion was thawed each time before being added to the milk.



Figure 3. An image of Zeno's Greek Yogurt which was used as the starter culture containing *S. thermophilus* and *L. bulgaricus* for the yogurt fermentation (Zeno's).

Table 5. The quantity of the LP milk powder, sweet potato, purified water and greek yogurt added to each yogurt.

| Yogurt sample | LP milk powder (g) | Sweet potato (g) | Purified water (ml) | Greek Yogurt (g) |
|---------------|--------------------|------------------|---------------------|------------------|
| Control | 200 | 0 | 1000 | 5.0 |
| 30 % | 140 | 60 | 1000 | 5.0 |
| 40 % | 120 | 80 | 1000 | 5.0 |
| 50 % | 100 | 100 | 1000 | 5.0 |
| 60 % | 80 | 120 | 1000 | 5.0 |

The composition in each product is presented in Table 6, where each nutrient is calculated regarding the proportions of sweet potato and milk powder added.

Table 6. The nutrient compositions in the yogurt products in 1000 ml purified water.

| Weight standard (g) | Control | 30 % SP Yogurt | 40 % SP Yogurt | 50 % SP Yogurt | 60 % SP Yogurt |
|----------------------------|----------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Energy (kcal) | 986 | 738 | 654 | 572 | 489 |
| Nitrogen (g) | 7.6 | 5.5 | 4.8 | 4.1 | 3.4 |
| Protein (g) | 48 | 34 | 30 | 26 | 21 |
| Total lipid (fat) (g) | 52 | 37 | 32 | 26 | 21 |
| Starch | 0 | 6.6 | 8.8 | 11 | 13.2 |
| Sugars, Total (g) | 74 | 56 | 50 | 43 | 37 |
| Sucrose (g) | 0 | 1.9 | 2.5 | 3.1 | 3.7 |
| Glucose (g) | 0 | 0.6 | 0.8 | 1 | 1.2 |
| Fructose (g) | 0 | 0.5 | 0.7 | 0.9 | 1.1 |
| Lactose (g) | 74 | 52 | 45 | 37 | 30 |
| Maltose (g) | 0 | 0.7 | 0.9 | 1.1 | 1.3 |
| Minerals, Total (g) | 5 | 3.9 | 3.5 | 3.1 | 2.7 |
| Vitamins, Total (g) | 0.06 | 0.05 | 0.05 | 0.05 | 0.05 |

3.3 Observations

3.3.1 Consistency

In this observation the consistency was looked at. This was done every two hours by opening the jar. The yogurt was stirred 5 times to become creamy, the wanted consistency. Yogurt was put on a sterilised spoon and raised in the air. It was then observed if there was a yogurt thread or not following the spoon being raised.

3.3.2 Adhesiveness

The adhesiveness of the yogurt was checked by moving around the closed jar of yogurt. The wall of the jar was then observed to see how much had stuck to it. The more that was left on the wall, the more adhesive it was considered. This was done every two hours.

3.3.3 Thickness

The thickness of the yogurt was observed by using a sterilised spoon and stirring the yogurt. The yogurt was stirred the same number of times, 5 times. The thickness was then observed by how much strength was needed to stir. This was done every two hours.

3.4 Analyses

3.4.1 pH measurement

Before the pH meter could be used to measure the samples, it had to be calibrated. This was done with calibration solutions with the pH of 7.0, 4.0 and 9.0. When the electrode had been calibrated each sample was poured into a beaker. The sample's pH was measured during stirring.

3.4.2 Color measurement

To measure the color of the samples a colorimeter (HuntersLab) was used. The sample was poured onto an agar plate, enough to cover the total place. The plate was then placed on a white sheet, which is needed for the background. The lid of the agar plate was then placed on top, and the instrument was placed on top. This gave each sample a L, a and b value.

3.4.3 Brix measurement

For the Brix measurement the samples had to be clearer, unlike they were in their yogurt state. This was done by using a cloth and pouring a small amount of sample into it which later was squeezed into a beaker. One drop from the clear solution was placed on the Brix Refractometer glass. The brix value was then able to be seen by looking inside the refractometer while facing it to a light source. The brix value gives a measure of the dissolved sugar content in a liquid solution. In this case it will show the lactose, sucrose and glucose as a sum, from the milk powder and sweet potato.

3.4.4 Viscosity approximation

To measure the viscosity a relative viscosity method was used. This compared the viscosity of each sample to each other. A funnel was used, and a metal wire was bended according to Figure 4. The funnel was held over a beaker throughout the process. Firstly, a finger was placed at the bottom of the funnel to be able to fill up the funnel, the yogurt was then poured all the way up. When the finger was removed to allow the yogurt to pass through the funnel, a timer was started. When the yogurts surface level was at the straight line of the wire the timer was stopped. This was performed two times for each sample to get an average time. The viscosity gives a measurement of the yogurt's resistance to flow. A higher value corresponds to higher resistance, meaning a thicker yogurt.



Figure 4. The funnel and wire construction used to measure the viscosity of the yogurt samples. It is constructed by a funnel and a wire bended according to the image. The yogurt went through the funnel and the bottom of the “U”-shape of the wire was used as the end point.

3.4.5 Acid number measurement and determination

Firstly, the sample was weighed to 5.0 g. This corresponded to 4.85 ml yogurt. Then it was diluted with 25 ml purified water. A pH electrode was later used in the sample while stirring. 0.01 M NaOH was added slowly to the solution until the pH reached 7.02. When the wanted pH was reached the volume of 0.01 M NaOH was noted. 1 ml of 0.01 M NaOH corresponded to 0.90 mg lactic acid.

3.4.6 Hedonic Test

A hedonic test was performed two days after producing the yogurts. The four OFSP yogurt samples, of 30-, 40-, 50- and 60 %, were all included. The samples were poured into small plastic cups, and they all were assigned to a code, which was a randomised three-digit number. There were 22 participants. These participants had different genders, backgrounds, and ages. Each participant was served the four samples containing 8 cl, these cups were placed in a randomised order to each participant. The samples were taken straight from the fridge, meaning the temperature was 4 °C. The participants were given a form created in Word and printed out for each participant (see A3.1). Each of the 22 participants were asked to rank their liking of different parameters on a scale of 1 to 9, 1 meant “Dislike Extremely” and 9 “Like Extremely”. There were eight parameters for the participants to rank their liking for, these were appearance, taste, texture, smell, sweetness, sourness, thickness, and smoothness. With each sample the participants were also given the choice to leave a general comment about their opinion of each sample. Between each sample the participants were told to drink water and eat white bread, as palate cleansers. During this test the participants were not allowed to talk to each other.

3.4.7 Interview

An interview was conducted with Sir Agyakwa Addo. He works at Kantar which is a market research company as an Associate Director in market research. Kantar currently works with Danone in Ghana. Danone has bought FanMilk which is one of the biggest yogurt companies

in the country. Kantar works in 80 countries globally. The interview was conducted online on Microsoft Teams. The questions in 4.3.7. were all asked in an unbiased way. The aim of this was to gain an understanding and knowledge of the Ghanaian populations view on the current yogurt on the market. But also, how they would react to a sweet potato yogurt, with no sugar. Sir Addo was believed to be a good fit for this due to his work with market studies and evaluations of yogurt, and since he works with one of the biggest yogurt companies in Ghana.

4. Results

4.1 Method development

4.1.1 LP milk powder: Water

The ratios used for the LP milk powder to water were 1:10, 1:5 and 1:3. Initially the ratio of 1:10 was used. The milk powder and water whisked together obtained a milk like solution, however when it was fermented for eight hours the yogurt had separated in an undesirable way. At the bottom of the jar there was bacteria activity, since it had become slightly thick and due to the density difference, it had fallen to the bottom (See Figure 5). However, the top layer had become a water like solution and obtained a yellow color.



Figure 5. The yogurt which had fermented for eight hours, with a LP milk powder: water ratio of 1:10. There are clearly two layers, the bottom layer containing the bacteria whereas the top layer is mostly water.

The second ratio used was 1:3. This was a drastic change to see if the failed fermentation was due to the milk powder to water ratio. In this case, a smaller volume, 300 ml, of the yogurt was produced. The sweet potato was also added to see its effect on the fermentation, the percentage of the OFSP was 60 %. After eight hours there were two layers, the bottom consisted of the heavier sweet potato. The yogurt had set firmly (See figure 6). When a spoon was used to stir it became a creamy yogurt with a light orange color.



Figure 6. The yogurt which had fermented for eight hours, with a LP milk powder: water ratio of 1:3. The percentage of sweet potatoes was 60 %. There are two layers, the bottom layer containing the sweet potato, this was stirred for a creamy consistency.

The last ratio was 1:5, this gave a similar result as the 1:3 ratio previously. Similarly, a smaller volume was used for the fermentation. Sweet potatoes were added, with a percentage of 30 % this time. After eight hours there were two layers, where the bottom layer contained the sweet potatoes (See figure 7). The yogurt had the desired firmness and consistency, when stirred with a spoon. The color obtained was also pleasing.



Figure 7. The yogurt which had fermented for eight hours, with a LP milk powder: water ratio of 1:5. The percentage of sweet potatoes was 30 %. There are two layers, the bottom layer containing the sweet potato, which when stirred obtained a creamy consistency.

4.1.2 Starter Culture

The first starter culture which was used was in a powdered form containing *S. thermophilus* and *L. bulgaricus*. This was used in the first trial with the LP milk powder and water ratio of 1:10 (See figure 5). As mentioned previously the yogurt after eight hours had two layers which were undesirable. The top layer looked like it had over fermented and caused it to be two layers. With the usage of both inoculums, YoFresh and Dolait, the yogurt had a slime-like texture after it had been fermented. The consistency was creamy, which is what was desired, but the yogurt was too stringy in both cases. The stringiness can be described as a long consistency. Lastly, the Zeno's Yogurt (Greek Yogurt) inoculum was used. This worked faster than the first ones used and gave a better creamy consistency to the yogurt. After four hours it was set, but eight hours was used for the final yogurt.

The quantity of the starter culture did not play such a big role with the powdered yogurt starter. After eight hours neither of them reached a desired consistency. YoFresh and Dolait showed results of a more stringy and thicker yogurt with an increased amount of them. YoFresh also had a vanilla flavor which was not desired to have with the sweet potato flavor. Out of the two YoFresh showed a shorter consistency, however for the wanted consistency no stringiness was aimed for. Lastly, Zeno's Yogurt (Greek Yogurt) was used. The Greek Yogurt showed great potential as a starter culture. Both 5.0 g and 7.0 g gave a fermented yogurt with a wanted firmness and short consistency. It worked fast and started to set after four hours. This also gave the yogurt a sourer taste.

4.1.3 Fermentation time

The fermentation of four hours was not enough, it gave the yogurt a thinner consistency than wanted. As expected, a longer fermentation hour gave a thicker consistency, this however was not the case for the YoFresh and Dolait. As the fermentation time increased, the stringiness increased and not the firmness of the yogurt. However, for Zeno's Yogurt it became thicker as the fermentation time became longer.

4.2 Observations

Different observations could be made during the eight-hour fermentation for the control yogurt and the 30, 40, 50 and 60 % sweet potato yogurt. These observations were made visually.

4.2.1 Consistency

Throughout the fermentation process the consistency changed substantially. It started off as milk and ended up as a creamy yogurt after eight hours. For all five yogurts they obtained a firm consistency after eight hours. The yogurts were set and barely moved when gently moving around the jar. However, after using a sterilised spoon and stirring around the yogurt it became creamy. In this subsection the consistency will be described for each yogurt, in terms of a short or long consistency. A short consistency is described as a short snap, meaning there will be no thread when removing some of the yogurt from the rest. This can be viewed in Figure 8. A long consistency is on the other hand when there is a thread coming off, which eventually will snap off. This can be viewed in Figure 9.



Figure 8. An image representing a yogurt with short consistency. There is no thread following the yogurt.



Figure 9. An image representing a yogurt with long consistency. There is a thread following the yogurt, which does not easily snap off.

As for all yogurts throughout the fermentation process they are described in Table 7. As described previously, the control yogurt is 0 % sweet potato. The special about the design is the sweet potato and milk powder combined is 200 g/ 1000 ml liquid. The 30 % SP yogurt contains 30 % in weight of the total 200 g, etc. As can be observed from Table 7 there was no long consistency in neither of the yogurts. Before stirring the yogurts with the spoon it was especially thick, leaving no room for a long consistency. Even in the beginning of the fermentation process when the yogurts were not firm yet, they still did not have any long consistency properties.

Table 7: A table showing the consistency of the yogurts all throughout the fermentation process. This was observed every two hours.

| Yogurt/ Time | 2 hours | 4 hours | 6 hours | 8 hours |
|----------------|-------------------|-------------------|-------------------|-------------------|
| Control Yogurt | Short consistency | Short consistency | Short consistency | Short consistency |
| 30 % SP Yogurt | Short consistency | Short consistency | Short consistency | Short consistency |
| 40 % SP Yogurt | Short consistency | Short consistency | Short consistency | Short consistency |
| 50 % SP Yogurt | Short consistency | Short consistency | Short consistency | Short consistency |
| 60 % SP Yogurt | Short consistency | Short consistency | Short consistency | Short consistency |

4.2.2 Adhesiveness

The adhesiveness was observed for the control yogurt and the four different percentages of sweet potato yogurt. The adhesiveness of the different yogurts throughout the fermentation process is described in Table 8. As the adhesiveness got higher (from low to high) more yogurt got stuck on the walls. As can be observed the control yogurt had the lowest adhesiveness out of the five yogurts. It reached a medium state after eight hours, meaning it did not stick all too much on the wall of the jar. The 30 and 40 % yogurt sweet potato yogurt reached a high adhesiveness after six hours, the yogurt got stuck on the wall noticeably. However, the 50 and 60 % reached a high adhesiveness after four hours.

Table 8: A table showing the adhesiveness of the yogurts, all throughout the fermentation process. This was observed every two hours. The adhesiveness is described as low, medium and high.

| Yogurt/ Time | 2 hours | 4 hours | 6 hours | 8 hours |
|----------------|---------|---------|---------|---------|
| Control Yogurt | Low | Medium | Medium | Medium |
| 30 % SP Yogurt | Low | Medium | High | High |
| 40 % SP Yogurt | Low | Medium | High | High |
| 50 % SP Yogurt | Medium | High | High | High |
| 60 % SP Yogurt | Medium | High | High | High |

4.2.3 Thickness

The thickness was observed for all five yogurts. A spoon was used to check the thickness of them, by stirring it. High thickness means it had a high resistance to the spoon. Table 9 describes the thickness of them throughout the fermentation process. As can be seen the control yogurt remained a low thickness after two hours, while after four hours it reached a medium thickness, followed by a high thickness after six hours. All sweet potato yogurts reached a medium thickness after two hours and after four hours they all obtained a high thickness.

Table 9: A table showing the thickness of the yogurts, all throughout the fermentation process. This was observed every two hours. The thickness is described as low, medium and high.

| Yogurt/ Time | 2 hours | 4 hours | 6 hours | 8 hours |
|----------------|---------|---------|---------|---------|
| Control Yogurt | Low | Medium | High | High |
| 30 % SP Yogurt | Medium | High | High | High |
| 40 % SP Yogurt | Medium | High | High | High |
| 50 % SP Yogurt | Medium | High | High | High |
| 60 % SP Yogurt | Medium | High | High | High |

4.3 Analyses

Throughout the storage, which lasted 10 days, the pH, color, brix value, viscosity and acid number were measured. For all analyses they were done in a logarithmic way. This meant the samples were measured more frequently in the beginning, and towards the end the measurements were sparser. Day 1 all analyses were performed twice, one in the morning and one in the afternoon. The following day they were performed only once. Then the analyses continued day 4, 7 and 10.

4.3.1 pH measurement

Throughout the storage period the pH was taken (Figure 10). The control yogurt had the highest pH out of the five. It started off at 3.71 and increased to 3.92 in the afternoon. The following days there was not much activity of the bacteria as the pH increased slowly. On day 10 the final pH value was 3.90. The 30 % SP yogurt had an initial pH of 3.65. The biggest increase from the previous pH occurred in the afternoon on day 1, when it increased to 3.78. Following day 1 the pH was relatively stable, ending up at 3.79 on day 10. The 40 % SP yogurt started at 3.63 and increased to 3.77 in the afternoon. Similarly, to the yogurt containing 30 % SP the pH was stable on the following days. On day 10 the pH was 3.77. The 50 % SP yogurt started at the pH 3.54 and had its big increase in the afternoon to 3.81. From day 2 to 10 it decreased, increased, and decreased again. The final pH on day 10 was 3.73. Lastly, the yogurt containing 60 % sweet potato the pH was 3.49, it increased to 3.81 in the afternoon. It had a similar

behaviour as the 50 % SP yogurt from day 2 to 10. On day 10 the pH was 3.71. As can be seen in Figure 10 the control yogurt, 50 % SP yogurt and 60 % SP yogurt shared a similar behavior. The yogurts containing 30 % and 40 % sweet potato shared a similar behavior in terms of their pH up until day 2.

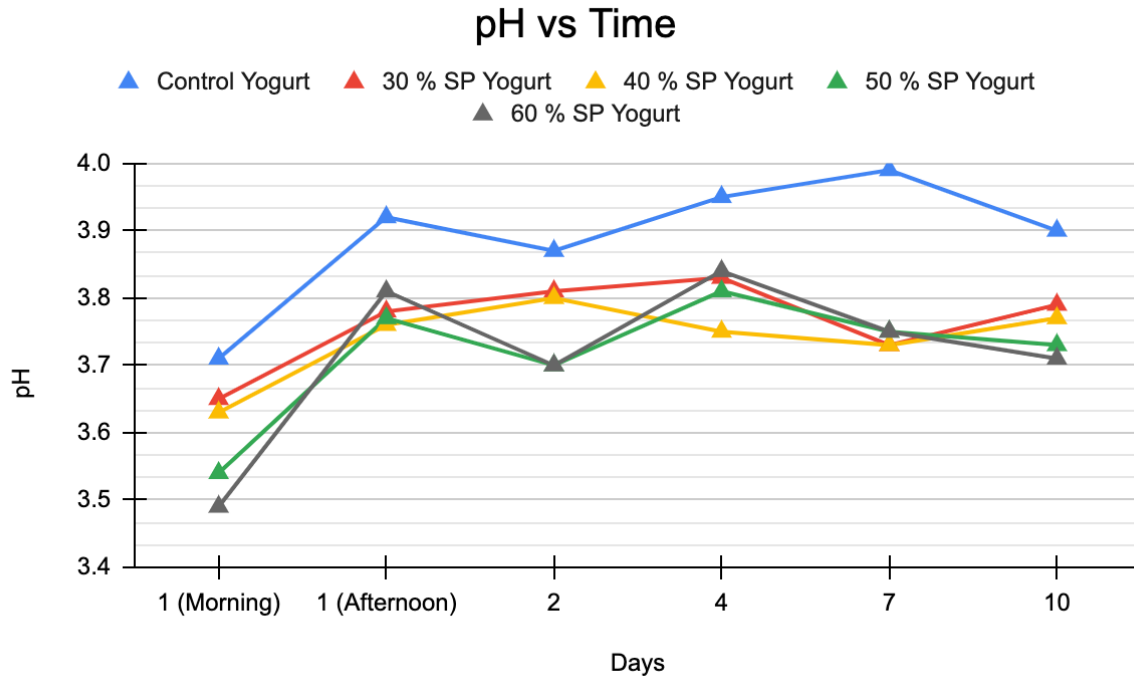


Figure 10. The change in pH for the control yogurt, 30-, 40-, 50- and 60 % sweet potato yogurt throughout the storage period of 10 days. The data for this can be seen in Table A1.

4.3.2 Color measurement

When measuring the colors of each sample Lab coordinates were used as mentioned previously. The L value, indicating lightness, can be viewed in Table 10. This ranges from 0 to 100. The control yogurt showed the highest L value throughout the storage period. It increased to 80.09 by day 10. Out of the sweet potato yogurts the L values were quite similar on day 1 in the morning, except for the 40 % sweet potato yogurt who had a slightly lower value. However, on day 10 the 60 % sweet potato yogurt had the highest L value. The 40 % SP yogurt had the lowest L value. Next, the a-value which indicates greenness/redness is also shown in Table 10. This ranges from -100 to +100. As can be seen the control yogurt has the most negative a-values, starting at -2.06 and by day 10 ending at -2.59. Out of the sweet potato yogurts the 30 % concentration had the lowest a-value throughout the entire storage period. On day 10 the a-value was 0.28. The 60 % sweet potato yogurt had the highest a-value throughout, by day 10 it had increased to 1.93. Lastly, the b-value indicates the blueness and yellowness. The control yogurt had the lowest b-value, which started at 10.61 and ended at 12.43. Out of the sweet potato yogurts, the 60 % yogurt had the highest value whereas the 30% one had the smallest value. With some exceptions the b-value increased for the yogurts throughout the storage period.

Table 10. The change in color for the control yogurt, 30-, 40-, 50- and 60 % sweet potato yogurt throughout the storage period of 10 days. The color change is indicated by L, a and b values. The data for this can be seen in Table A2.

| | | Storage period (days) | | | | | |
|----------|---------|-----------------------|--------|-------|-------|-------|-------|
| Color | Yogurt | 1 (am) | 1 (pm) | 2 | 4 | 7 | 10 |
| L | Control | 72.84 | 74.99 | 76.45 | 74.44 | 80.09 | 80.09 |
| | 30 % SP | 66.88 | 68.45 | 57.63 | 67.52 | 74.15 | 73.63 |
| | 40 % SP | 64.52 | 65.89 | 54.71 | 62.33 | 67.45 | 69.73 |
| | 50 % SP | 67.57 | 66.90 | 69.19 | 64.38 | 75.04 | 73.84 |
| | 60 % SP | 67.46 | 67.38 | 69.58 | 69.16 | 75.58 | 75.88 |
| a | Control | -2.06 | -2.02 | -2.00 | -1.85 | -2.56 | -2.59 |
| | 30 % SP | -0.15 | -0.54 | -0.75 | -0.34 | -0.25 | 0.28 |
| | 40 % SP | 0.02 | 0.14 | -0.29 | 0.45 | 0.61 | 0.70 |
| | 50 % SP | 0.84 | 0.30 | 1.35 | 1.46 | 1.38 | 1.32 |
| | 60 % SP | 1.40 | 0.87 | 1.76 | 1.78 | 2.00 | 1.93 |
| b | Control | 10.61 | 10.63 | 11.57 | 11.10 | 12.82 | 12.43 |
| | 30 % SP | 13.19 | 14.02 | 9.75 | 14.99 | 15.26 | 16.00 |
| | 40 % SP | 13.27 | 13.87 | 9.80 | 14.02 | 14.33 | 15.82 |
| | 50 % SP | 16.75 | 15.87 | 17.70 | 15.42 | 20.67 | 19.61 |
| | 60 % SP | 17.29 | 16.71 | 18.24 | 17.82 | 21.17 | 21.07 |

4.3.3 Brix measurement

The sugar content was measured in Brix % from a refractometer. The change of the sugar content can be seen in Figure 11. It can clearly be seen that the control yogurt contains the highest amount of sugar content throughout the storage period. The control yogurt starts at 8.9 % sugar content and slowly decreases to 8.5 % after 10 days. The control yogurt contains 200 mg/ 1000 ml, hence more sugar is inside. The composition (Table 6) shows the lactose being the highest in the control yogurt, and slowly decreasing when the sweet potato portion increases. The 30 % SP yogurt starts at 6.6 % sugar content, which is higher than the other SP yogurts. This as well, decreases slowly through the storage period. The 40 % and 60 % SP yogurt had a similar sugar content, however the yogurt containing more sweet potato ended up slightly higher after 10 days. The 50 % SP yogurt had the lowest sugar content, after 10 days it was 5.5 %. All yogurts had a similar slow decrease in sugar content, however there are some deviations. The 50 % SP yogurt had a larger increase on day 1 in the afternoon.

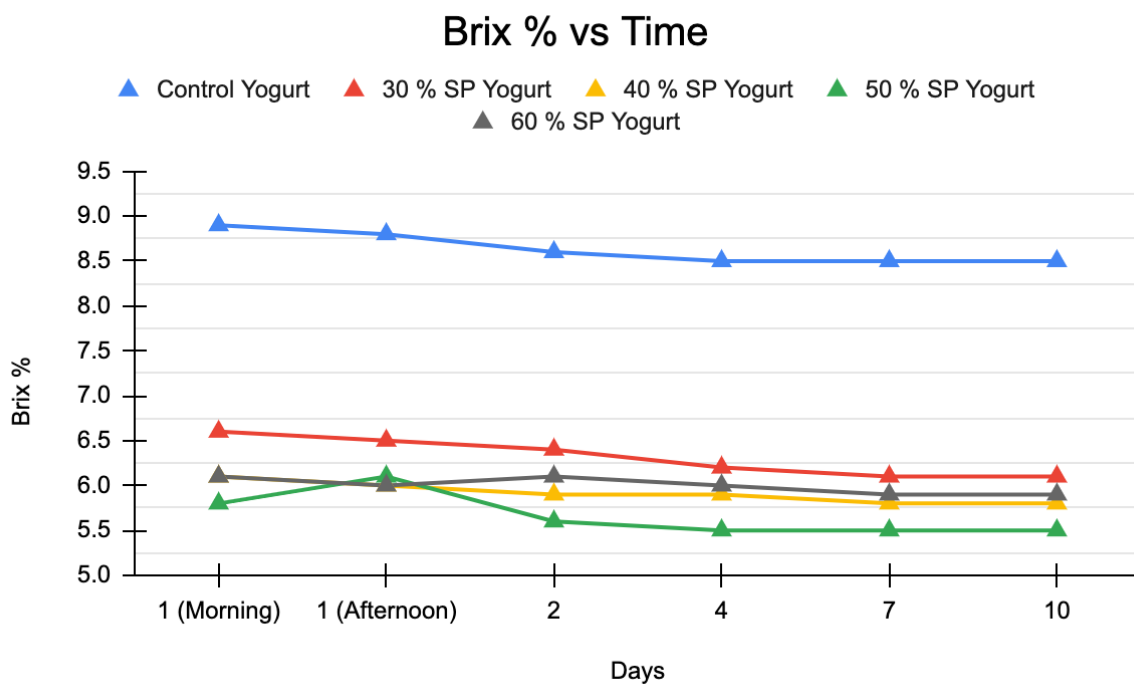


Figure 11. The change in the Brix % for the control yogurt, 30-, 40-, 50- and 60 % sweet potato yogurt throughout the storage period of 10 days. The data for this can be seen in Table A3.

As mentioned before, milk has a refractive index of 10 % and OFSP has 9.1 %. This means each of the yogurts has an initial refractive index, before fermentation, which can be viewed in Table 11. The calculations can be viewed in A2.1.

Table 11. The Brix % of the different yogurt before the fermentation process.

| Yogurt | Brix % before fermentation |
|------------------|----------------------------|
| Control Yogurt | 10 % |
| 30 % OFSP Yogurt | 9.7 % |
| 40 % OFSP Yogurt | 9.6 % |
| 50 % OFSP Yogurt | 9.55 % |
| 60 % OFSP Yogurt | 9.46 % |

4.3.4 Viscosity approximation

In this section the relative viscosity will be shown. This will be illustrated in time (seconds). As can be seen in Figure 12 the control yogurt had the longest time going through the funnel. As the sweet potato concentration in the yogurt increases the time to go through the funnel gets shorter. This applies for all yogurts except for the 60 % SP yogurt. In this case it has a longer time than the 50 % SP yogurt. The control yogurt has the biggest difference in viscosity, as it has the steepest graph. After 10 days the control and 30 % yogurt have a similar time, while the 40-, 50- and 60 % SP yogurt have a lower, but similar time.

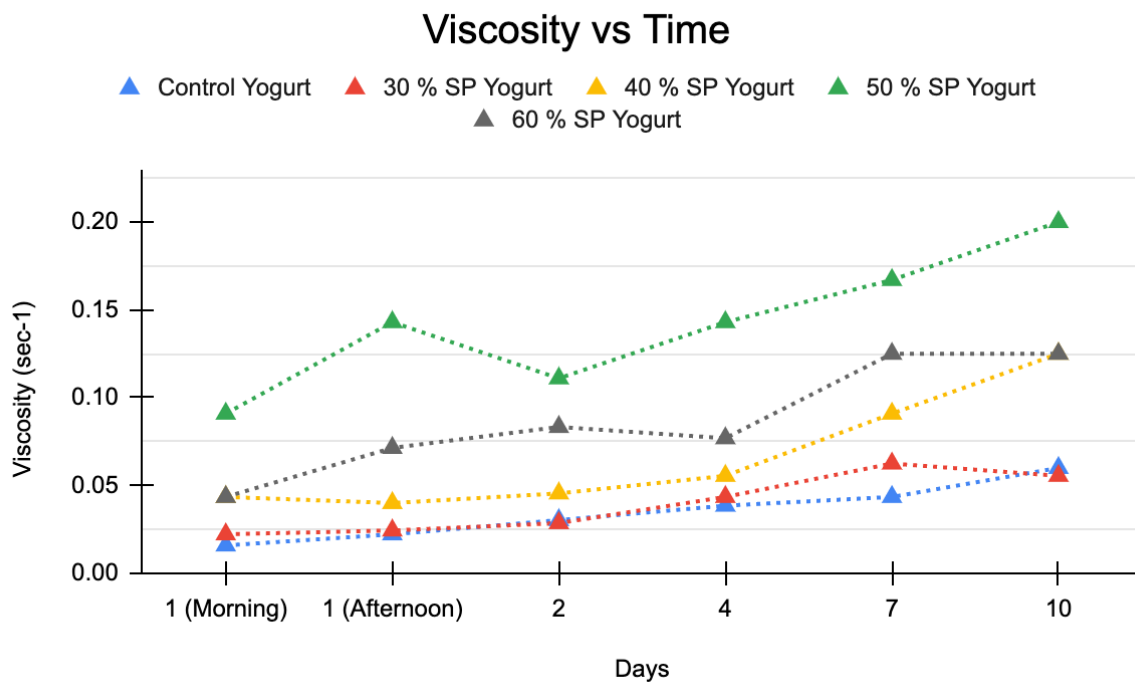


Figure 12. The change in the viscosity (seconds) for the control yogurt, 30-, 40-, 50- and 60 % sweet potato yogurt throughout the storage period of 10 days. The data for this can be seen in Table A4 where a mean value was calculated from.

4.3.5 Acid number measurement and determination

The acid number was determined for the sweet potato yogurts and the control yogurt. The results are shown in Figure 13. The figure presents how much lactic acid (g/l) has been formed per litre milk/yogurt. The assumption is that all acid produced is lactic acid. The calculations and results can be viewed in A2.2. As can be viewed in Figure 13 it is possible to see the control yogurt having the least amount of lactic acid formed. It started off at 10.7 g/l and after 10 days the lactic acid formation was 9.8 g/l. The 60 % sweet potato yogurt showed the highest amount of lactic acid formed after 10 days, it was 12.7 g/l. The 50 % sweet potato yogurt had 12.4 g/l after 10 days. The 30- and 40 % sweet potato yogurt had an increased lactic acid formation as time went and ended up around the same amount after 10 days, 11.8 and 11.9 g/l lactic acid.

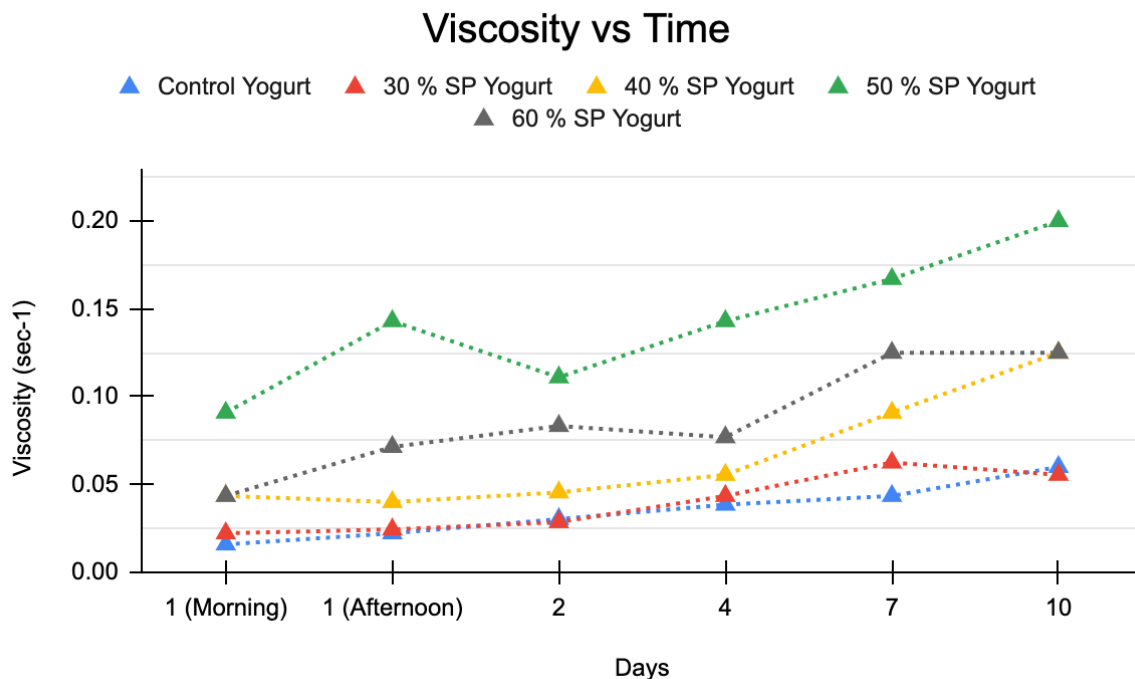


Figure 13. Formation of lactic acid in the five yogurts during the storage period. The calculation can be viewed in A2.

4.3.6 Sensory Evaluation

The results from the hedonic test are shown in Figure 14 where the average score for each parameter is presented. The mean value was taken from the Appendix (A5, A6, A7 and A8). From the results it is possible to see the yogurt containing 40 % sweet potato has a higher mean score compared to the other yogurts. This was the case for all parameters except for the thickness and sourness. As for the appearance and smell there were not many differences on the results for the different yogurts. The 30 % sweet potato yogurt showed best liking regarding the thickness, whereas the remaining three had similar results in the category. The texture showed the 30- and 40 % had a higher liking. By observing the chart, the parameters with the lowest mean scores for all yogurts are the Taste, Sweetness and Sourness.

The participants were also asked to leave comments for each yogurt. In most cases where a lower score was given to the taste and sourness a comment was made about the addition of sugar to balance out the sour, fermented taste. Among the other comments made by the participants, some expressed they thought a thicker consistency was fine as long as it was creamy (fit as a drinking yogurt). Two different participants made a comment regarding a sharp biting feeling in the mouth, one commented on the 30 % sweet potato yogurt and the other one on the 40 % sweet potato yogurt. Generally, most comments concerned the sourness as 17 out of 22 mentioned it for the yogurts. There were 22 participants.

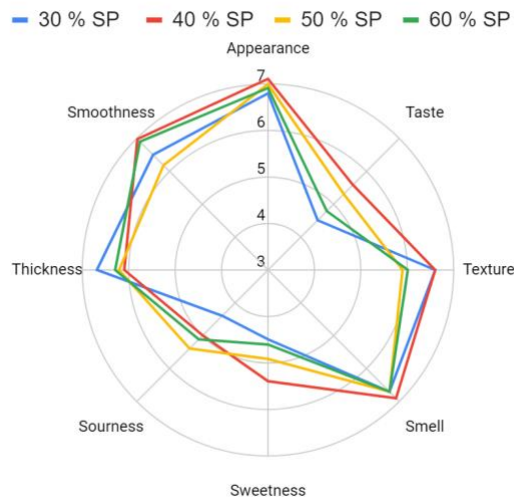


Figure 14. A spider plot showing the average score for all parameters for each yogurt. A higher score indicates a higher liking of the parameter. These values represent the mean value, n=22.

4.3.7 Interview with Sir Agyakwa Addo

I have done some research and seen that the milk consumption in Ghana is 8 kg per capita, which is quite low. I wanted to ask how much of this you think is yogurt. And then to further discuss the yogurt consumption market in Ghana.

In Ghana the daily consumption of milk is mostly evaporated milk, and in second place comes powdered milk. Most households consume evaporated milk, despite the economic class. In regard to yogurt, FanYogo is the most consumed yogurt in Ghana. This is sold on the street, usually by someone on a bike, making it an accessible product. Pure, plain yogurts are low in terms of consumption of people.

Is yogurt considered an important product and prioritised in someone's daily life and their budget?

Yogurt is considered a treat in Ghana, and not an essential food product in most Ghanaian homes. Typically, you will not find yogurt on the table. It is treated as a dessert after a meal.

Do people know about the health benefits in yogurts?

Yes, for those who consume, they know about it. The nutritional benefits are a driving factor, for those who buy. However, the taste is more key to consumers than the nutritional benefits. Most people appreciate the nutritional benefits, but it is not as important as taste being the key driver in dairy products.

According to the African Development Bank, 46 % of Ghanaians are now classified as middle class. Do you think the yogurt consumption will grow as the middle class percentage in the country grows?

The consumption is lower for middle and lower consumption. Yes, it will grow, as the ability to buy. Mainly taste drives the consumption of yogurt, but cost is obviously a key driver. It can be a challenge to preserve yogurt since it needs to be in a fridge. This is a barrier for some of the population, it can be someone not owning one or electricity shortage. As the economy is growing, due to the middle class growing, it would increase. The middle class in Ghana is the most exposed in the market, and has a more international taste. The growth of the middle class will increase people's ability to buy. So, yes, there is potential for yogurt to grow. Especially when the cost is removed, and availability is increased for all.

Is the consumption mostly in Accra, and the bigger cities or even in the rural areas?

It is mainly in the bigger cities, for example greek yogurts are mainly in Shoprite (and other big supermarkets). Prominently, pure yogurts (like the plain and unsweetened ones) are in big cities, with a higher population in the middle class. Therefore, the consumption is in the urban cities. There are also yogurt buses in the big cities, which I know have a good sales market.

How do you see the future of yogurt in Ghana, is there a noticeable trend?

There is opportunity for growth. Over the years being in this industry I have seen growth. It might not be a sharp growth but looking at the performance of some popular brands, they have had stability as it is not declining. Other yogurts brands are coming up, with new innovative yogurts. Key barriers are mainly around cost, once they are removed the growth will be higher. Yogurt buses might also become bigger around the bigger cities in the country, now they are only in Accra. Taste is before nutrition, as mentioned. The growth might be slow, but an opportunity.

Currently I have noticed fruit yogurts, such as vanilla and strawberry are popular, but do you see any other becoming more popular?

The familiar ones will continue to stay popular. Strawberry is the most popular when it comes to flavor. Plain yogurts might become more popular for the ones who are health conscious. People are getting more health conscious today. It's becoming bigger amongst Ghanaians. Especially during and after covid, they now want to remain healthier. Can expect the consumption of yogurt to increase. Innovation is important, once something is meeting the consumers with taste and nutrition it might break through and compete with the common, popular flavors. But the sugared, strawberry yogurts will still be strong. But sweet and plain yogurt have a brighter future than flavored, unsweetened ones.

Where do you see the future of sour yogurts in Ghana, for example greek yogurt? Do you think there is a market for crop yogurts, like sweet potato yogurts?

Sour yogurts may fit for the health-conscious segment of the population, however that is also a small population. It would be a challenge breaking through the market with sour yogurt. Drinkable yogurts are more dominant, where most are also flavored. This crop, unsweetened

yogurt is a very niche kind of yogurt, and should target the health-conscious segment. Those who are close to 40 and above.

I do not know much about sweet potato yogurts. A sweet potato yogurt would compete more with sour and greek yogurts. And it still has the position of a healthy option, since there is no sugar added. It will meet the target of 40+ year olds. However, the young, millennials have the sweet tooth and are the main consumers today. It would fit the upper middle class. Consuming this product would be more of a lifestyle, when you are looking for something that is healthy. It would most likely be a small market for the crop yogurt.

It would be best to start in the bigger cities, Accra, and Kumasi. Accra has more consumer power and is more cosmopolitan. With an expansion drive to Kumasi or Takoradi. More health-conscious people with purchasing power are in Accra. There are also more expatriates and international schools there. These people are more used to it, as it might be familiar from home. It should be in bigger supermarkets or bigger neighborhood shops because of the preservation in the fridge.

5. Discussion

5.1 Method development

When developing the method for producing the yogurt four different factors were looked at; the LP milk powder: water, starter culture, amount of starter culture and fermentation time. The ratio of 1:5 was chosen as the best option. This, since it gave good amounts of nutrients from the milk powder. However, when deciding the Dolait yogurt was used as a starter culture, this is what caused the long consistency of the yogurt. This means the quality of the bacteria in the Dolait was not good at the time of usage. The bacteria's activity will become less active when further away from the manufacture date. When 1:5 was used the Zeno's Yogurt (Greek Yogurt) was used, hence a more reproducible result was obtained. To be able to do the method development trials all factor combinations must be tested together, which was not performed in this study. Using a ratio of 1:10 or 1:3 would not have caused a long consistency yogurt with a proper starter culture, in this case Zeno's Yogurt. By using 1:10 the yogurt production would have benefited economically, since less milk powder is needed.

A common pH for yogurt is 4.3-4.4. The fermentation time of eight hours caused the yogurt to have a pH ranging from 3.49-3.99. This is due to Zeno's Yogurt, which acted as an efficient starter culture and formed lactic acid fast. When lactic acid is formed eventually the lactose, the energy and carbon source, will not be enough for the bacteria to convert it into the acid. By continuing with the fermentation after this maximum there will be no change in the pH. By having a shorter fermentation time, the fermentation process could be ended before it reaches a pH that is too low. A lower pH caused the yogurt to have a sour taste, which can be viewed differently around the globe. In this case the best option would have been to aim for a pH that was higher than the ones obtained in this study. A pH of 4.3-4.4 is what consumers are more used to, especially when there is no sugar added.

5.2 Observations

It is of great importance for a food product to be appealing to the eye. A yogurt with high consistency is often viewed in a negative way. In a more everyday term, most people would describe it as “slimey”, which is not a desirable quality in a yogurt. When altering the different factors in the method development the long consistency was looked at considerably. There are different reasons for a long consistency in a yogurt, poor temperature control, stringy starter batch, poor quality milk or yeast involvement. During the yogurt fermentation as mentioned above the jars of yogurt were placed in an ice chest with 43 °C, but since this is not an incubator with a set temperature the temperature most likely decreased. Hot water was filled regularly to prevent it from decreasing too much, the temperature span was 40-43 °C, meaning there is still room for error. However, when the temperature is outside the limits the fermentation can become stringy, the bacteria which causes the long consistency becomes stringy around 37°C and is then the dominant bacteria. In this study the Dolait was always involved when the yogurt had a long consistency as soon as it was replaced by Zeno’s Yogurt the yogurt obtained a short consistency. It can therefore be concluded that Dolait contains a mixture of bacteria, which when reaches a lower temperature the dominant bacteria cause for a stringiness. Another reason worth mentioning is that, in the same kitchen the yogurt was made, other students baked bread for their projects hours before. The kitchen bench and all equipment were properly washed and sterilized, however there could still be yeast involvement in the fermentation process. The yeast could have still been in the air which then disrupts the LAB.

In terms of the adhesiveness, the yogurt had a lower adhesiveness. The 30- and 40 % sweet potato yogurt had the same result, which was a slow increase from low to medium, whereas the 50- and 60 % sweet potato yogurt reached a high adhesiveness after four hours. This can be linked to the thickness of the yogurts. As the yogurt got thicker the adhesiveness got higher. The two highest percentages of sweet potato yogurts obtained the thickest consistency the fastest. This means by adding sweet potato causes for a faster fermentation process which causes a change of consistency. A high adhesiveness means the consistency is short, however it can be viewed negatively as more products can remain in the packaging walls as it is empty.

5.3 Analyses

The analyses were all done in a logarithmic way. The day after the yogurt fermentation the analyses were performed twice, one time on day 2, then one time on day 4, 7 and 10. The reason is because the bacteria would most likely have more activity in the beginning and not as much towards the end.

By observing the pH of the yogurts, the control yogurt obtained the highest pH all throughout the storage time. It increased and decreased, however after ten days it ended at a pH higher than the initial one. This is most likely due to a systematic error from the pH meter. Throughout the storage time the pH is expected to remain the same, as it was placed in a refrigerator with a temperature of 4°C, at this temperature the bacteria are not active and does not produce any lactic acid. If any pH changes were to happen it would have been a decrease, as the bacteria could have used the substrate and produced the lactic acid when it was out of the refrigerator

during the analyses. In similar studies the pH either remained the same or had a slight decrease. As for the sweet potato yogurts the pH did not show a significant difference, this was also the result in another study (Shin, 1993). The systematic error most likely happened due to the calibration solutions. When measuring the pH, the pH meter was always calibrated before, depending on who used it in the laboratory the first time that specific day. If someone did not calibrate it well or used solutions that could have been expired the results obtained in the analysis would be incorrect. It is clear to see that the first measurements on day 1 in the morning had a wrongful calibration most likely, as they deviated substantially from the rest of the pH measurements. The following measurements, for all yogurts, showed a slight increase and decrease in the pH with a value not more than 0.1. This means the pH at day 10 is better to be trusted than the first pH measured.

Looking at all yogurts the pH decreases as the yogurts containing a higher percentage of sweet potato increases. The control yogurt deviates the most from the yogurts containing the sweet potato. On day 10 the difference in pH between the sweet potato yogurts is small. In previous studies, such as the purple-fleshed sweet potato yogurt there was no effect on the LAB depending on the different concentrations (Afiati, et. al., 2018). The difference in pH is very small, and since the pH meter had a systematic error on some days the result is not reliable. The four different yogurts could have had the same pH after 10 days. However, it is clear to see that the yogurts containing the sweet potato have a lower pH. During the lactic acid fermentation, the bacteria uses a carbon source to convert it into lactic acid, this could be glucose, sucrose or lactose for example. The lactose in this case comes from the milk powder. As mentioned previously OFSP has a high concentration of starch, approximately 11% of the total weight. Therefore the crop is of such importance, as it is a great energy source for its consumers. Starch is a polymeric carbohydrate, consisting of glucose units. For the starch to be used as a carbon source by the LAB it could be hydrolyzed in a first step into glucose. When this step is done the LAB will convert it into lactic acid. In this study there seems to have been a direct fermentation of the starch in the OFSP, since the LAB made the pH decrease more for the sweet potato yogurts. Meaning the reduction of lactose but the addition of the starch from the OFSP caused for a better carbon source, therefore a more effective fermentation. The sucrose in OFSP could have also been used as a carbon source during the fermentation. As mentioned, the main sugar in sweet potatoes is sucrose. With the starch and sucrose, the lactic acid fermentation therefore was more effective in the sweet potato yogurts. As mentioned, OFSPs have a pH of 6.52, meaning that already before the fermentation process the crop contributed to a decrease in the pH.

When observing the L-value, indicating lightness, of the yogurts they all had an increase throughout the storage time. For some of the results there was a decrease from the previous days, this most likely was due to a human error. The agar plate used could have been not thoroughly cleaned, meaning something was also measured by the colorimeter. It is clear to see the trend is increasing behaviour. This means the yogurts obtained a lighter color as the storage time was longer. In many studies the yogurt became darker, "browning" is common for food products during storage. There was not much difference between the sweet potato yogurts and the control yogurt considering the change of lightness. The a-value represents red/green.

As the sweet potato yogurt concentration increased, so did the a-value. This means the sweet potato accounted for a red color and got redder as time went on. The b-value represents yellow/blue. The results showed as the sweet potato concentration increased so did the b-value, meaning the yogurts got a deeper yellow color. It increased slightly for each yogurt after the ten days storage. As mentioned, OFSP contains carotenoids which is a natural pigment. These are responsible for the yellow, orange, and red color. By these results the carotenoid content seemed to have increased throughout the storage time. If there still was a fermentation process going on during the storage the lactic fermentation could favor carotenoids and its extraction. There have been studies showing lactic fermentation does not cause important losses of carotenoids, which supports the result in this study.

The brix %-value is the dissolved sugar in an aqueous solution, in this case the yogurt. The results show how there is more sugar, which is lactose, in the control yogurt. This corresponds with the pH-results as it did not drop as low as the sweet potato yogurts, where lactose and sucrose were the two major sugar components. Hence, not as much lactic acid was formed and therefore not as much lactose was consumed. This left more lactose in the yogurt as it was not involved in the fermentation process. The Brix % before the fermentation process was 10 %, meaning the decrease in sugar content was 15 % from the initial content. Sucrose and lactose have the same refractive index, and therefore the sum of the two is what was observed for the sweet potato yogurts. The 50% sweet potato yogurt had the lowest amount of sugar, this being a combination of lactose and glucose, in the yogurt. The sugar had decreased by 42 %. This means more lactose and glucose were involved in the fermentation process. The 60- and 40 % sweet potato yogurt had a similar Brix % after ten days, here the decrease was 37 % and 40 %. The 30 % had a slightly higher value, which corresponded to a decrease of 37 %. This means the 50 % sweet potato yogurt had the most effective substrate consumption. According to the pH results 60 % should have had the lowest value as it had the lowest pH. The sucrose, glucose, fructose, and maltose in the yogurts containing sweet potato were significantly lower compared to the lactose, which was the highest in the control yogurt. Even though the carbon source, mainly, lactose was higher in the control yogurt more was consumed in the sweet potato yogurts. This means the lactose were converted more efficiently with the sweet potato addition and caused a lower Brix value. There could have been a human error during this method however, as the Brix % was to be seen visually in the Brix Refractometer. From the results it can be concluded that the control yogurt had the least amount of substrate consumed during the fermentation process. In Table 6 the total sugar content is calculated for each sample. As the OFSP in the yogurt increases, the sugar decreases. The perceived sweetness from the hedonic test shows that the 40 % OFSP yogurt has the highest score in terms of Sweetness, but the 30 % yogurt has the lowest. This is contradictory when looking at Table 6 and reading the comments. Most participants in wanted more sugar in the yogurt, but the ones with the most sugar got the lowest score. Most likely due to the sugar from the milk powder and sweet potato did not reach the sugar content of the popular yogurts.

The viscosity results showed that in the beginning of the storage time, the control yogurt had the lowest viscosity. This means the addition of sweet potato made for a thinner yogurt.

However, for the sweet potato yogurts there was no strong correlation between the percentages of sweet potato yogurt and the viscosity. After ten days all the yogurts had increased in viscosity. For the 40-, 50- and 60 % yogurt there was not much change in the viscosity, as for the other two yogurts. The control yogurt showed the biggest increase in the viscosity throughout the storage time.

The acid number results gave a clear result showing the least amount of lactic acid was formed in the control yogurt. By observing the graphs individually there is not a clear trend, as the results decrease and increase. However, when comparing the results from day 1 (morning) and day 10 for the sweet potato yogurts there is a small increase for each yogurt. As mentioned before, in a regular milk fermentation to yogurt lactose gets metabolised to 1.2-1.4 %. The results from this study show the sweet potato yogurts range between these values, however the control yogurt is slightly lower. The results align with the pH results, as the pH dropped the least for the control yogurt. And then as the sweet potato concentration increased, the pH decreased. With the decrease of pH, more lactic acid is formed. When comparing with the Brix result, it mostly supports the Acid Number results. It is also possible to compare the acid number to the perceived acidity, which corresponds to the sourness in the hedonic test. The least amount of lactic acid was formed in the 30 % OFSP yogurt, however this yogurt had the lowest mean score for Sourness. This is quite interesting since the comments suggest that as more acid is formed, the product is less enjoyed. Therefore, it would have made more sense if this yogurt had the highest mean score. The 50 % OFSP has the highest mean score for Sourness, but more lactic acid was formed here. Since a human error most likely was done the results are not too reliable but it is clear to see the control yogurt's Brix % supports the acid number result.

The aim of the sensory evaluation by conducting a hedonic test was to find out if there is a general preference among the sweet potato yogurts. By observing the parameters of the combined results there is not a big difference between the four yogurts. However, the 40 % sweet potato yogurt shows slightly better palatability than the rest. The spider plot in Figure 14 shows the 40 % sweet potato yogurt has the highest result in most parameters, except for sourness and thickness. There was not a significant difference however when comparing with the three other yogurts. No statistical evaluations were performed, but only by observing the mean value. When observing the parameters, it is clear to see the taste, sweetness and sourness parameters have the lowest grades. The comments all suggested the pH being too low which caused the sourness to be too high. Some participants also mentioned a dislike to the sharpness of the yogurts, this comes from the acetic acid and the levels therefore being too high. With an addition of an appropriate amount of sugar most participants would have enjoyed the yogurts more. In this study most participants were from Ghana. However, two were from Germany and one from Austria. Their results were quite different from the rest, as they enjoyed the sourness substantially more. In Ghana the most common yogurts are the ones containing sugar, mostly with either vanilla or strawberry. These are sold everywhere and are the norm for yogurt. Most people choose taste over nutritional value, this could possibly be that there are other foods people value more as nutritious. Lately there have been new yogurts entering the market with a different flavour. The used starter culture in this study was Zeno's Yogurt, this is a Ghanaian

brand which produces greek yogurt (having a distinct sour taste and no sugar added). There is a slight shift in the yogurt market as Zeno's is becoming more and more popular, however it will most likely take a few more years to make it as common as the sweet yogurts. In Germany and Austria there are many fermented milk products with a distinct sour taste, hence why these three participants enjoyed it as it was familiar to them.

The 40 % sweet potato yogurt is the best option to continue with to enter the market, when observing the hedonic test. But as I mentioned previously the difference between the four yogurts was not big. Therefore, one can view it as the best option is to choose the one which would be cheaper. The 60 % sweet potato yogurt would be substantially cheaper, as milk powder is much more expensive compared to the sweet potato. This would be better economically for the producers of the yogurt and would lead to a cheaper product which would then be accessible for more people. Compared to the control yogurt the 60 % sweet potato yogurt is almost half the price. This would lead to a product with less nutrients, however. Since vitamin A deficiency has been highlighted in this report, which comes from the OFSP, at least this important nutrient would increase. It would have been interesting to also add sugar to the yogurts and perform a hedonic test. However, the dilemma in this case is to add the sugar, knowing it would be preferable for the consumer but with the price of a less healthy product. For this product to enter the market the addition would be best, or the yogurt would need to have a shorter fermentation time which would reduce the sourness. It would be unfortunate to have to add sugar to the sweet potato yogurt as it has great health benefits from the probiotics, starch, and carotenoid for example. The retinol from the carotenoids would have a great effect on the population suffering from infections, malaria and diarrhoea, and work in a preventative way. As the sugar intake is relatively low in Ghana today, but with a slow increase due to influences around the world, it would be best if this product did not contribute to the increase of sugar intake.

The hedonic test in this project was performed to the best of its ability. It would have been interesting to explore the results if the background of the participants were more diverse. Most of the participants were students from Kwame Nkrumah University of Science and Technology. If there were participants coming from different socioeconomic backgrounds, as well other countries there would surely be a change in the results. It is more difficult to draw conclusions with different backgrounds. It would be good to have several groups with different backgrounds amongst the groups, but where the participants in each group have similar backgrounds. Also, in the form for the hedonic test there should have been a last parameter "Overall liking" which would have summed up each participant's results. By this it would have been easier to see which parameters are the most important for the yogurt to be considered palatable.

6. Conclusion

To conclude this report the results show the addition of sweet potato in a milk fermentation with *S. thermophilus* and *L. bulgaricus* has an effect on the fermentation process, which was one of the objectives. The orange fleshed sweet potato, Apomodan, affected the fermentation process as the ones containing it fermented faster. The starch coming from the OFSP acts as a carbon source to bacteria which makes the conversion to lactic acid more efficient. The difference between adding 30-, 40-, 50- and 60 % sweet potato yogurt to the milk did not show a huge difference in terms of the characteristics. The pH and acid number results showed the 60 % sweet potato yogurt fermented the most, and as the percentage of sweet potato increased the fermentation was less efficient. The method development concluded the importance of choosing a starter culture with good potential of active bacteria. The main parameter which affected the result during the method development was the selection of starter culture. As the hedonic test was performed it was concluded that a sour yogurt is not preferred among the participants, most likely because a sour yogurt is not common in Ghana. Another conclusion made was that the favors of exchanging the milk powder to OFSP is the cost. Milk powder can be more than 10 times more expensive than OFSP, meaning more people could access a yogurt product with a higher proportion of OFSP. For this yogurt to be picked from the shelf by consumers the sourness would have to be lowered, by increasing the pH. The importance of this food product as a daily/weekly consumption does not come from it being fermented, as Ghana has many fermented foods which are a part of their daily life. It comes from the additional health benefits from the OFSP, mainly by preventing the vitamin A deficiency which unfortunately is quite common in Ghana. Finally, how would consumers respond to this? This product would be best in bigger cities where the middle-class population is higher, and also where health-conscious people exist.

In the future it would be interesting to study the different combinations more when developing the method for the sweet potato yogurts. By first concluding which starter culture is the most efficient, the other parameters could be optimised. The pH should be observed throughout the fermentation process to find out after how many hours the pH becomes constants. This pH observation should also be performed for the chosen method in this study. It would also be interesting to see the liking of the sweet potato yogurts if the pH was higher, around 4.2-4.3, meaning a shorter fermentation time. A hedonic test should then be performed for the different OFSP yogurts with different pH to see which one is preferred. This would determine if the negative reviews concerning the sourness and taste is solely due to the low pH, or if it is also due to no sugar added. It would also be interesting to perform a hedonic study of the produced yogurt in this study, but with the addition of sugar. Lastly, the yogurt consumption is increasing in Ghana and therefore this field is highly relevant. The introduction of new, healthier crop yogurts with no sugar is worth continuing with. It is important to continue with sour yogurts too, as it is already on the Ghanaian market, but with a transition period which might take some time. As mentioned previously, the transition period possibly needs a mixture of the old and new, by disguising the fact that there is no sugar by finding an optimised pH. It is also of importance to make this product inexpensive for all Ghanaians to access it and gain its health benefits. Other potential new, innovative products with OFSP should also be investigated.

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8. Appendix

A1. Raw data

Table A1. The results of the pH change during the storage period of the control yogurt and the yogurts containing 30-, 40-, 50- and 60 % sweet potatoes. The data in this table is used for the graph in Figure 10.

| | Day 1 (morning) | Day 1 (afternoon) | Day 2 | Day 4 | Day 7 | Day 10 |
|-----------------------|----------------------------|------------------------------|--------------|--------------|--------------|---------------|
| Control Yogurt | 3.71 | 3.92 | 3.87 | 3.95 | 3.99 | 3.90 |
| 30 % SP | 3.65 | 3.78 | 3.81 | 3.83 | 3.73 | 3.79 |
| 40 % SP | 3.63 | 3.76 | 3.80 | 3.75 | 3.73 | 3.78 |
| 50 % SP | 3.54 | 3.77 | 3.70 | 3.81 | 3.84 | 3.77 |
| 60 % SP | 3.49 | 3.81 | 3.70 | 3.84 | 3.88 | 3.80 |

Table A2. The results of the color change, expressed in the CIELAB color space, during the storage period of the control yogurt and the yogurts containing 30-, 40-, 50- and 60 % sweet potatoes. The data in this table is used for the graph in Table 10.

| | Day 1 (morning) | Day 1 (afternoon) | Day 2 | Day 4 | Day 7 | Day 10 |
|---------------------------|----------------------------|-----------------------------------|--------------|--------------|--------------|---------------|
| Control Yogurt | | | | | | |
| L | 72.84 | 74.99 | 76.45 | 74.44 | 80.09 | 80.09 |
| a | -2.06 | -2.02 | -2.00 | -1.85 | -2.56 | -2.59 |
| b | 10.61 | 10.63 | 11.57 | 11.10 | 12.82 | 12.43 |
| 30% | | | | | | |
| L | 66.88 | 68.45 | 57.63 | 67.52 | 74.15 | 73.63 |
| a | -0.15 | -0.54 | -0.75 | -0.34 | -0.25 | 0.28 |
| b | 13.19 | 14.02 | 9.75 | 14.99 | 15.26 | 16.00 |
| 40% | | | | | | |
| L | 64.52 | 65.89 | 54.71 | 62.33 | 67.45 | 69.73 |
| a | 0.02 | 0.14 | -0.29 | 0.45 | 0.61 | 0.70 |
| b | 13.27 | 13.87 | 9.80 | 14.02 | 14.33 | 15.82 |
| 50% | | | | | | |
| L | 67.57 | 66.90 | 69.19 | 64.38 | 75.04 | 73.84 |
| a | 0.84 | 0.30 | 1.35 | 1.46 | 1.38 | 1.32 |
| b | 16.75 | 15.87 | 17.70 | 15.42 | 20.67 | 19.61 |
| 60% | | | | | | |
| L | 67.46 | 67.38 | 69.58 | 69.16 | 75.58 | 75.88 |
| a | 1.40 | 0.87 | 1.76 | 1.78 | 2.00 | 1.93 |
| b | 17.29 | 16.71 | 18.24 | 17.82 | 21.17 | 21.07 |

Table A3. The results of the brix change during the storage period of the control yogurt and the yogurts containing 30-, 40-, 50- and 60 % sweet potatoes. The data in this table is used for the graph in Figure 11.

| | Day 1 (morning) | Day 1 (afternoon) | Day 2 | Day 4 | Day 7 | Day 10 |
|-----------------------|----------------------------|------------------------------|--------------|--------------|--------------|---------------|
| Control Yogurt | 8.9 % | 8.8 % | 8.6 % | 8.5 % | 8.5 % | 8.5 % |
| 30 % SP | 6.6 % | 6.5 % | 6.4 % | 6.2 % | 6.1 % | 6.1 % |
| 40 % SP | 6.1 % | 6.0 % | 5.9 % | 5.9 % | 5.8 % | 5.8 % |
| 50 % SP | 5.8 % | 6.1 % | 5.6 % | 5.5 % | 5.5 % | 5.5 % |
| 60 % SP | 6.1 % | 6.0 % | 6.1 % | 6.0 % | 5.9 % | 5.9 % |

Table A4. The results of the viscosity change during the storage period of the control yogurt and the yogurts containing 30-, 40-, 50- and 60 % sweet potatoes. The viscosity is presented in time (seconds) and the analysis was performed twice to obtain a mean value. The data in this table is used for the graph in Figure 12.

| | Day 1 (morning) | Day 1 (afternoon) | Day 2 | Day 4 | Day 7 | Day 10 |
|---------------------------|----------------------------|------------------------------|--------------|--------------|--------------|---------------|
| Control Yogurt | | | | | | |
| Time 1: | 1:07:97 | 0:41:16 | 0:35:37 | 0:27:57 | 0:24:06 | 0:21:19 |
| Time 2: | 0:59:75 | 0:48:84 | 0:29:94 | 0:25:35 | 0:21:97 | 0:18:94 |
| Average time: | 1:03:86 | 0:44:50 | 0:32:66 | 0:26:46 | 0:22:64 | 0:19:76 |
| 30% | | | | | | |
| Time 1: | 0:48:97 | 0:43:54 | 0:38:37 | 0:25:28 | 0:16:00 | 0:19:50 |
| Time 2: | 0:41:97 | 0:37:86 | 0:31:90 | 0:21:78 | 0:16:07 | 0:16:97 |
| Average time: | 0:45:47 | 0:40:70 | 0:34:89 | 0:23:53 | 0:16:04 | 0:17:99 |
| 40% | | | | | | |
| Time 1: | 0:23:78 | 0:25:86 | 0:23:22 | 0:19:25 | 0:11:31 | 0:08:50 |
| Time 2: | 0:22:41 | 0:23:56: | 0:21:17 | 0:15:56 | 0:11:31 | 0:08:00 |
| Average time: | 0:22:85 | 0:24:71 | 0:22:20 | 0:17:65 | 0:11:31 | 0:08:25 |
| 50% | | | | | | |
| Time 1: | 0:10:90 | 0:07:50 | 0:10:17 | 0:07:09 | 0:05:90 | 0:05:19 |
| Time 2: | 0:10:74 | 0:06:03 | 0:08:49 | 0:06:81 | 0:05:18 | 0:05:68 |
| Average time: | 0:10:82 | 0:06:51 | 0:09:33 | 0:06:70 | 0:05:54 | 0:05:43 |
| 60% | | | | | | |
| Time 1: | 0:26:84 | 0:16:85 | 0:12:09 | 0:13:28 | 0:08:72 | 0:07:94 |

| | | | | | | |
|---------------|---------|---------|---------|---------|---------|---------|
| Time 2: | 0:19:84 | 0:12:66 | 0:11:88 | 0:11:87 | 0:07:19 | 0:07:88 |
| Average time: | 0:23:09 | 0:14:75 | 0:11:73 | 0:12:57 | 0:07:65 | 0:07:91 |

Table A5. The results of the acid number change during the storage period of the control yogurt and the yogurts containing 30-, 40-, 50- and 60 % sweet potatoes. The acid number is presented in g/l lactic acid formed, the mass of yogurt (g) used is also shown and the volume NaOH added. The data in this table is used for the graph in Figure 13. This data was used in the calculation shown in A2.2.

| | Day 1 (morning) | Day 1 (afternoon) | Day 2 | Day 4 | Day 7 | Day 10 |
|---------------------------|----------------------------|-----------------------------------|--------------|--------------|--------------|---------------|
| Control Yogurt | | | | | | |
| v(ml, NaOH) | 65.2 | 59.5 | 60.4 | 57.1 | 53.2 | 60.5 |
| m (g, yogurt) | 5.03 | 4.99 | 5.08 | 5.09 | 5.08 | 5.08 |
| lactic acid (g/l) | 10.7 | 9.86 | 9.23 | 9.28 | 8.66 | 9.34 |
| 30% | | | | | | |
| v(ml, NaOH) | 56.8 | 65.3 | 67 | 73.7 | 73 | 71.2 |
| m (g, yogurt) | 5.03 | 5.00 | 5.11 | 5.05 | 5.05 | 5.00 |
| lactic acid (g/l) | 10.5 | 11.6 | 11.5 | 11.4 | 11.9 | 11.8 |
| 40% | | | | | | |
| v(ml, NaOH) | 52.4 | 59.8 | 64.0 | 65.4 | 66.3 | 64.9 |
| m (g, yogurt) | 5.04 | 5.15 | 5.01 | 5.02 | 5.01 | 5.07 |
| lactic acid (g/l) | 9.78 | 10.8 | 12.0 | 12.3 | 12.3 | 11.9 |
| 50% | | | | | | |
| v(ml, NaOH) | 54.5 | 49.8 | 52.1 | 48.6 | 46.0 | 53.3 |

| | | | | | | |
|-------------------|------|------|------|------|------|------|
| m (g, yogurt) | 5.08 | 5.02 | 5.02 | 5.01 | 5.04 | 5.06 |
| lactic acid (g/l) | 11.3 | 12.4 | 11.8 | 12.2 | 11.9 | 12.4 |
| 60% | | | | | | |
| v(ml, NaOH) | 68.8 | 63.1 | 68.3 | 65.7 | 64.6 | 68.3 |
| m (g, yogurt) | 5.06 | 4.99 | 5.01 | 5.03 | 5.04 | 4.99 |
| lactic acid (g/l) | 12.6 | 11.8 | 12.7 | 12.2 | 11.9 | 12.7 |

A2. Calculations

A2.1 Initial Brix %

The calculations for the the brix of each yogurt before the fermentation process was done according to the following:

$$30 \% \text{ OFSP: } 0.3 * 9.1\% + 0.7 * 10\% = 9.7 \%$$

$$40 \% \text{ OFSP: } 0.4 * 9.1\% + 0.6 * 10\% = 9.6 \%$$

$$50 \% \text{ OFSP: } 0.5 * 9.1\% + 0.5 * 10\% = 9.55 \%$$

$$60 \% \text{ OFSP: } 0.6 * 9.1\% + 0.4 * 10\% = 9.46 \%$$

A2.2 Acid Number

The calculations for the acid number was done according to the following:

$$n(lut) = c(lut) * v(lut) \quad [mmol] \quad (\text{Equation 1})$$

$$c(lut, 1) = n(lut)/m(yogurt) \quad [mmol/g] \quad (\text{Equation 2})$$

$$r(\text{milk/yogurt}): 1032 \text{ g/l}$$

$$c(lut, 2) = c1 * r \quad [mmol/l] \quad (\text{Equation 3})$$

$$M(\text{lactic acid}): 90.08 \text{ g/mol}$$

$$c(\text{lactic acid}) = c(lut, 2) * M \quad [g/l] \quad (\text{Equation 4})$$

A3. Sensory Evaluation

A3.1

The evaluation used for the hedonic test is shown below.

Sensory Evaluation

Date:.....

Age:.....

Occupation:.....

Location:.....

This is a sensory evaluation where you will rate 4 different samples. In between each sample you should drink water and eat a small piece of bread to neutralize your mouth. Rate the following samples in the tables below according to:

1. Dislike extremely.
2. Dislike very much.
3. Dislike Moderately.
4. Dislike Slightly.
5. Neither Like or Dislike.
6. Like Slightly.
7. Like Moderately.
8. Like very much.
9. Like extremely

Sample:.....

| Appearance | Taste | Texture | Smell | Sweetness | Sourness | Thickness | Smoothness |
|------------|-------|---------|-------|-----------|----------|-----------|------------|
| | | | | | | | |

Comments:.....
.....
.....

Sample:.....

| Appearance | Taste | Texture | Smell | Sweetness | Sourness | Thickness | Smoothness |
|------------|-------|---------|-------|-----------|----------|-----------|------------|
| | | | | | | | |

Comments:.....
.....
.....

Sample:.....

| Appearance | Taste | Texture | Smell | Sweetness | Sourness | Thickness | Smoothness |
|------------|-------|---------|-------|-----------|----------|-----------|------------|
| | | | | | | | |

Comments:.....

Sample:.....

| Appearance | Taste | Texture | Smell | Sweetness | Sourness | Thickness | Smoothness |
|------------|-------|---------|-------|-----------|----------|-----------|------------|
| | | | | | | | |

Comments:.....

A3.2

Table A5. The results of the hedonic test on the 30 % sweet potato yogurt. The participants in this test were 22. The yogurt had a randomized number, 567. A low score indicates a dislike, whereas a higher score indicates a liking of the product. The data in this table obtained a mean value for each parameter, which is used for the graph in Figure 14.

| Participant | Appearance | Taste | Texture | Smell | Sweetness | Sourness | Thickness | Smoothness |
|-------------|------------|-------|---------|-------|-----------|----------|-----------|------------|
| 1 | 7 | 7 | 7 | 7 | 8 | 7 | 4 | 8 |
| 2 | 8 | 1 | 3 | 5 | 1 | 7 | 8 | 4 |
| 3 | 6 | 7 | 8 | 4 | 7 | 7 | 8 | 7 |
| 4 | 8 | 6 | 9 | 6 | 2 | 3 | 9 | 6 |
| 5 | 7 | 4 | 6 | 7 | 4 | 6 | 7 | 8 |
| 6 | 7 | 2 | 8 | 7 | 2 | 6 | 6 | 7 |
| 7 | 8 | 3 | 7 | 7 | 2 | 5 | 4 | 7 |
| 8 | 6 | 2 | 4 | 7 | 2 | 3 | 8 | 6 |
| 9 | 7 | 8 | 9 | 8 | 7 | 7 | 9 | 8 |
| 10 | 8 | 3 | 6 | 6 | 4 | 3 | 8 | 8 |
| 11 | 5 | 6 | 9 | 5 | 4 | 7 | 9 | 9 |
| 12 | 7 | 7 | 6 | 7 | 7 | 4 | 8 | 7 |
| 13 | 4 | 6 | 7 | 8 | 4 | 7 | 8 | 8 |
| 14 | 6 | 6 | 7 | 8 | 7 | 3 | 7 | 6 |
| 15 | 7 | 4 | 6 | 2 | 7 | 4 | 5 | 4 |
| 16 | 8 | 6 | 7 | 7 | 6 | 4 | 7 | 8 |
| 17 | 6 | 2 | 4 | 6 | 6 | 2 | 8 | 8 |
| 18 | 8 | 2 | 8 | 9 | 1 | 1 | 7 | 6 |
| 19 | 2 | | 6 | 6 | 2 | 2 | 6 | 3 |
| 20 | 9 | 1 | 3 | 8 | 1 | 1 | 2 | 4 |
| 21 | 7 | 4 | 6 | 8 | 9 | 2 | 1 | 3 |

| | | | | | | | | |
|----------------|-----|-----|-----|-----|-----|-----|-----|-----|
| 22 | 9 | 7 | 9 | 9 | 7 | 5 | 9 | 9 |
| Average | 6.8 | 4.5 | 6.6 | 6.7 | 4.5 | 4.4 | 6.7 | 6.5 |

Table A6. The results of the hedonic test on the 40 % sweet potato yogurt. The participants in this test were 22. The yogurt had a randomized number, 373. A low score indicates a dislike, whereas a higher score indicates a liking of the product. The data in this table obtained a mean value for each parameter, which is used for the graph in Figure 14.

| Participant | Appearance | Taste | Texture | Smell | Sweetness | Sourness | Thickness | Smoothness |
|-------------|------------|-------|---------|-------|-----------|----------|-----------|------------|
| 1 | 6 | 9 | 6 | 6 | 7 | 7 | 9 | 8 |
| 2 | 6 | 2 | 3 | 6 | 1 | 7 | 6 | 4 |
| 3 | 7 | 8 | 7 | 9 | 9 | 7 | 6 | 6 |
| 4 | 8 | 9 | 6 | 9 | 8 | 8 | 6 | 9 |
| 5 | 7 | 4 | 5 | 6 | 4 | 7 | 4 | 4 |
| 6 | 8 | 7 | 7 | 7 | 8 | 6 | 7 | 8 |
| 7 | 6 | 8 | 7 | 6 | 6 | 6 | 5 | 6 |
| 8 | 7 | 2 | 4 | 7 | 2 | 3 | 6 | 6 |
| 9 | 7 | 8 | 8 | 8 | 7 | 6 | 6 | 4 |
| 10 | 8 | 7 | 7 | 6 | 7 | 4 | 7 | 8 |
| 11 | 5 | 4 | 9 | 5 | 4 | 4 | 8 | 9 |
| 12 | 5 | 6 | 6 | 5 | 4 | 4 | 4 | 7 |
| 13 | 7 | 4 | 8 | 7 | 4 | 6 | 7 | 8 |
| 14 | 8 | 4 | 6 | 8 | 6 | 3 | 6 | 8 |
| 15 | 7 | 1 | 6 | 8 | 1 | 3 | 4 | 5 |
| 16 | 8 | 4 | 6 | 7 | 4 | 4 | 6 | 8 |
| 17 | 6 | 6 | 8 | 8 | 6 | 4 | 8 | 8 |
| 18 | 7 | 8 | 7 | 8 | 5 | 5 | 7 | 7 |
| 19 | 7 | 6 | 7 | 8 | 8 | 8 | 7 | 7 |
| 20 | 9 | 2 | 8 | 7 | 2 | 1 | 5 | 9 |
| 21 | 9 | 7 | 6 | 1 | 8 | 3 | 4 | 5 |

| | | | | | | | | |
|----------------|-----|-----|-----|-----|-----|-----|-----|-----|
| 22 | 9 | 7 | 8 | 9 | 7 | 5 | 7 | 9 |
| Average | 7.1 | 5.6 | 6.6 | 6.9 | 5.4 | 5.0 | 6.1 | 7.0 |

Table A7. The results of the hedonic test on the 50 % sweet potato yogurt. The participants in this test were 22. The yogurt had a randomized number, 294. A low score indicates a dislike, whereas a higher score indicates a liking of the product. The data in this table obtained a mean value for each parameter, which is used for the graph in Figure 14.

| Participant | Appearance | Taste | Texture | Smell | Sweetness | Sourness | Thickness | Smoothness |
|-------------|------------|-------|---------|-------|-----------|----------|-----------|------------|
| 1 | 8 | 8 | 8 | 4 | 7 | 8 | 6 | 8 |
| 2 | 5 | 1 | 2 | 4 | 1 | 7 | 6 | 3 |
| 3 | 7 | 6 | 7 | 4 | 6 | 5 | 8 | 8 |
| 4 | 8 | 6 | 8 | 8 | 6 | 6 | 6 | 8 |
| 5 | 8 | 4 | 6 | 6 | 4 | 7 | 7 | 7 |
| 6 | 8 | 7 | 7 | 8 | 6 | 8 | 8 | 7 |
| 7 | 5 | 7 | 2 | 6 | 7 | 3 | 3 | 3 |
| 8 | 7 | 2 | 4 | 6 | 2 | 3 | 6 | 6 |
| 9 | 6 | 7 | 7 | 8 | 6 | 7 | 7 | 8 |
| 10 | 8 | 5 | 5 | 6 | 5 | 4 | 5 | 8 |
| 11 | 5 | 8 | 9 | 5 | 4 | 8 | 9 | 9 |
| 12 | 5 | 7 | 7 | 8 | 5 | 6 | 5 | 1 |
| 13 | 8 | 6 | 6 | 8 | 4 | 7 | 7 | 8 |
| 14 | 6 | 3 | 4 | 7 | 2 | 6 | 6 | 5 |
| 15 | 7 | 2 | 5 | 7 | 2 | 3 | 6 | 5 |
| 16 | 8 | 8 | 7 | 8 | 8 | 6 | 7 | 6 |
| 17 | 6 | 5 | 6 | 6 | 5 | 2 | 8 | 8 |
| 18 | 8 | 4 | 7 | 8 | 5 | 6 | 7 | 6 |
| 19 | 6 | 6 | 6 | 8 | 6 | 8 | 6 | 6 |
| 20 | 9 | 1 | 7 | 8 | 1 | 1 | 2 | 5 |
| 21 | 8 | 7 | 1 | 6 | 9 | 4 | 5 | 3 |

| | | | | | | | | |
|----------------|-----|-----|-----|-----|-----|-----|-----|-----|
| 22 | 9 | 6 | 8 | 9 | 6 | 4 | 7 | 9 |
| Average | 7.0 | 5.3 | 5.9 | 6.7 | 4.9 | 5.4 | 6.2 | 6.2 |

Table A8. The results of the hedonic test on the 60% sweet potato yogurt. The participants in this test were 22. The yogurt had a randomized number, 482. A low score indicates a dislike, whereas a higher score indicates a liking of the product. The data in this table obtained a mean value for each parameter, which is used for the graph in Figure 14.

| Participant | Appearance | Taste | Texture | Smell | Sweetness | Sourness | Thickness | Smoothness |
|-------------|------------|-------|---------|-------|-----------|----------|-----------|------------|
| 1 | 7 | 6 | 4 | 6 | 4 | 6 | 4 | 4 |
| 2 | 4 | 1 | 3 | 5 | 1 | 6 | 6 | 4 |
| 3 | 8 | 8 | 7 | 7 | 7 | 6 | 6 | 7 |
| 4 | 8 | 6 | 4 | 8 | 4 | 2 | 4 | 8 |
| 5 | 7 | 4 | 6 | 7 | 5 | 6 | 6 | 4 |
| 6 | 8 | 3 | 8 | 9 | 4 | 8 | 7 | 9 |
| 7 | 7 | 2 | 5 | 7 | 1 | 4 | 1 | 4 |
| 8 | 8 | 2 | 4 | 7 | 2 | 3 | 7 | 6 |
| 9 | 8 | 8 | 7 | 7 | 7 | 7 | 7 | 7 |
| 10 | 6 | 4 | 5 | 6 | 3 | 2 | 5 | 8 |
| 11 | 6 | 8 | 9 | 5 | 8 | 7 | 8 | 9 |
| 12 | 4 | 4 | 6 | 6 | 3 | 7 | 5 | 7 |
| 13 | 8 | 3 | 7 | 8 | 3 | 6 | 8 | 7 |
| 14 | 8 | 6 | 7 | 9 | 7 | 6 | 9 | 6 |
| 15 | 8 | 4 | 5 | 3 | 4 | 5 | 5 | 3 |
| 16 | 6 | 8 | 7 | 7 | 8 | 7 | 8 | 7 |
| 17 | 6 | 4 | 8 | 6 | 6 | 4 | 8 | 8 |
| 18 | 8 | 7 | 6 | 8 | 6 | 6 | 7 | 6 |
| 19 | 7 | 3 | 6 | 8 | 3 | 2 | 8 | 8 |
| 20 | 9 | 2 | 8 | 7 | 1 | 1 | 6 | 9 |
| 21 | 1 | 6 | 2 | 3 | 8 | 5 | 7 | 9 |

| | | | | | | | | |
|----------------|-----|-----|-----|-----|-----|-----|-----|-----|
| 22 | 9 | 7 | 8 | 9 | 7 | 6 | 7 | 9 |
| Average | 6.9 | 4.8 | 6.0 | 6.7 | 4.6 | 5.1 | 6.3 | 6.9 |