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Swedish University of Agricultural Sciences

Faculty of Natural Resources and Agricultural Sciences
Department of Food Science

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Abstract

A rose hip soup manufacturing company has significant problems with a too low apparent viscosity of their product. Compiled historical data between the years 2007 and 2015 proves that the problem has been present for at least 8 years with many batches that does not live up to current quality standards. The compiled historical data followed a pattern with lower or higher apparent viscosity in periods, and not as single and irregular values. Packages of rose hip soup were analysed during two production occasions and no relations between apparent viscosity and brix, pH, total acid concentration or vitamin C concentration were found. A high content of solids in the soup appeared to contribute to a higher apparent viscosity. Since the rose hip raw material is not heat treated before the pasteurization step in the soup-process, apparent viscosity decrease was tested for possible content of active enzymes in the rose hip flour. The apparent viscosity decreased the longer the unpasteurized soup was allowed to rest before pasteurization. If the rose hip flour was added to a cooked and cooled soup-base, the apparent viscosity decreased over time from the point where the rose hip was added. Measuring the apparent viscosity with heat treated rose hip flour gave less decrease of the apparent viscosity. When only the soup-base without added rose hip flour was analysed, the apparent viscosity was stable over time. An external α-amylase analysis of rose hip flour detected activity of α-amylase in one of two tested flours. Actions to avoid unwanted enzymatic degradation could be to use rose hip flour that are free from enzymes, add the rose hip flour at a late stage in the production, or to heat treat the rose hip flour mixed with water before adding it to the mixing tank. To give a uniform content of solids, the stirring process could be increased in the sterile tank. The aims of this report were to identify the cause of the low apparent viscosity and to present solutions that could increase it. The aim was not to test the effectiveness of the presented solutions in large-scale production.

Keywords: rose hip soup, enzymes, rose hip flour, apparent viscosity degradation, enzyme inactivation, α-amylase, rosehip soup

Sammanfattning

Ett företag som producerar nyponsoppa har problem med att soppan har för låg skenbar viskositet som uppmäts vid regelbunden kvalitetssäkring. Genom att sammanställa data från år 2007 fram till år 2015 visar resultaten att problemen har funnits minst 8 år tillbaka och att många batcher inte lever upp till befintliga kvalitetsvärden. Data visar även på skillnader som följer trender dvs. låg och något högre viskositet kommer regelmässigt i perioder och inte som enstaka värden. Ett antal förpackningar nyponsoppa analyserades under två produktionstillfällen och inget samband påvisades mellan skenbar viskositet och brix, pH, totalt syrainnehåll eller koncentration av askorbinsyra. Ett högre innehåll av partiklar i soppan visades ge högre skenbar viskositet. Eftersom råvaran nyponmjöl inte värmebehandlas innan pastöriseringssteget i tillverkningen av nyponsoppa, testades om nedbrytning av skenbar viskositet orsakas av nyponmjölet och troligt innehåll av aktiva enzymer. Den skenbara viskositeten sjönk desto längre tid den opastöriserade soppan fick stå obehandlad. Tillsattes nyponmjöl i uppvärmd och avsvalnad sopp-bas sjönk den skenbara viskositeten i relation med tid från det att nyponmjöl tillsattes. Om samma mängd uppvärmt nyponmjöl istället tillsattes, resulterade det i lägre minskning av den skenbara viskositet. Mättes enbart uppvärmd och svalnad sopp-bas utan tillsatt nyponmjöl förblev blandningens skenbara viskositet stabil över tid. En extern analys av nyponmjöl påvisade α-amylasaktivitet i en av två testade nyponmjölbatcher. Åtgärder för att undvika ofrivilligt lägre skenbar viskositet orsakat av enzymer kan vara att använda enzymfri nyponråvara, tillsätta nyponmjöl så sent som möjligt i processen eller att värma upp nyponmjölet blandat med vatten innan det tillsätts i blandningstanken. För att ge ett jämnt partikelinnehåll inom batcherna kan omrörningen i steriltanken ökas. Syftet med rapporten har varit att analysera orsaken samt att presentera lösningar för den låga skenbara viskositeten, inte att vidare testa effektiviteten i de presenterade lösningarna i storskalig produktion.

Nyckelord: nyponsoppa, enzym, nyponmjöl, nedbrytning av skenbar viskositet, inaktivering av enzym, α-amylas

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Abbreviations

AC = Acid concentration
ALP= Alkaline phosphatase
a_w = Water activity
cP = Centipoise
DCIP: 2.6-Dichloroindophenol sodium salt dehydrate
HELP = High electric field pulses
HPP= High pressure process
LOX = Lipoxygenase
LPER= Lactoperoxidase
Masl= meters above sea level
PME= Pectinmethylesterase
POD= Peroxidase
PPO = Polyphenoloxidase
QA = Quality assurance

1 Introduction

Rose hip soup has a long historical place in the Swedish kitchen as a dessert soup and as a hot or cold beverage. The soup has been served for more than 100 years and industrially manufactured for more than 5 decades. (Uggla, 2004; Werlemark & Nybom, 2005). Before extensive international trading, the soup was an important source of vitamin C during the winter season in Sweden (Werlemark & Nybom, 2005). This study is about finding the reason for a too low apparent viscosity in a commercial rose hip soup together with the manufacturing company.

1.1 Summary of an earlier investigation

In a former investigation of the food quality performed by the manufacture itself in 2013, it was concluded that a seasonal variation of the soups apparent viscosity was present. The investigation focused on possible variations of the modified starch, but no final conclusions were made. The supplier of modified starch asserted that no changes in the modification or raw material had been made, and recommended an investigation of the concentration of acid present in the soup, as well as an investigation of pressure during processing. An experiment lowering the pressure during the process resulted in a slightly higher average apparent viscosity of the product, but not close to approved limits. The investigation of the impact of acid was not conducted when the apparent viscosity of the soup suddenly increased to approved levels and the entire investigation was put on hold.

1.2 Apparent viscosity

Apparent viscosity describes the resistance of a liquid to start to flow exposed to a certain force. Shear stress in relation to shear force form a graph of the flowing properties of liquids. A fluid can behave Newtonian or non-Newtonian depending on the relation between shear stress and shear rate. Newtonian fluids, like water, are in constant proportion between shear stress and shear rate, which defines the term *viscosity*. For non-Newtonian fluids the term *apparent viscosity* is used. Non-Newtonian fluids could be shear-thinning, like ketchup, or shear-thickening products like starch slurries where particles start to aggregate which will increase the resistance to flow. A Brookfield viscometer determines the apparent viscosity of the fluid at a controlled temperature by exposing and measure the foods shear force at different magnitudes. Even though the texture objectively can be measured, quality assurances (QA) must include sensory tests since no objective tests can measure the overall acceptance of food being consumed. (Vaclavik & Christian, 2008a).

1.3 Food quality

Food quality is a complex area, which even though it is regularly objectively measured in food manufacturing companies, depends on consumers' acceptability, which in turn is person dependent and influenced by place and time (Cardello, 1995). Many factors can be included in the term *food quality*, for example safety requirements, nutritional requirements or sensory requirements to mention only a few. A sensory requirement is individually perceived and causes an interaction between the foods itself and the consumer. The human brain transforms the sensation to a perception in connection with other brain functions like memory, culture or emotions. A summary of all the brain connections will form the sensory reaction of the food being consumed. (Peri, 2006).

Every time a food is consumed, our senses evaluate it. Consumers expect a certain food to behave in a certain way when eaten. For example potato chips, in combination with a good taste, is also expected to have a crunchy sound when eaten. A soup is expected to have a certain mouthfeel meeting the consumers' expectations for how it should appear on the tongue and flow in the mouth without being too thick or too runny. (Vaclavik & Christian, 2008a). This makes the term *food quality* complex and it could be defined as: "…the requirements necessary to satisfy the needs and expectations of the consumer" (Peri, 2006).

1.4 Starch anatomy

The starch reserve in plant tissues are found in the starch granules inside the plastids. Two glucose polymers, amylose and amylopectin, are formed in the plastids. (Tetlow, 2011). Biosynthesis of starch is initiated in the hilum and the granule is growing outwards from the hilum caused by addition of carbohydrate material at the growing surface (Delcour & Hoseney, 2010).

Amylose is mainly a linear polymer built of α-D-glucose units linked by 1,4 bonds. The length of the amylose polymer could be up to several hundred glucose units. Amylopectin is a branched polymer mainly build of α-D-glucose units linked by 1,4 bonds, and 4-5 % of the units are linked in 1,6 bonds. The amylopectin is a larger molecule compared to amylose and the chain is regularly branched with 1,6 bonds. (Delcour & Hoseney, 2010; Bahaji *et al.*, 2014). Due to its branching structure, amylopectin has a high molecular weight and is one of the largest molecules found in nature (Delcour & Hoseney, 2010). The structure of starch is complex and many different models have been presented explaining the organization of amylopectin inside the granules (Tetlow, 2011). The cluster model has been emerged to be the most likely model where amylopectin consist of three kinds of chains, A, B and C chain. The A-chains consist of glucose units linked by 1,4 bonds and does not carry any chains further. B-chains carry branches as well as the C-chain that also has one reducing group. (Delcour & Hoseney, 2010; Tetlow, 2011). The exact proportion between amylose and amylopectin varies between the crops and also within the same plant between its different parts (Bahaji *et al.*, 2014).

1.5 Gelatinisation- and retrogradation process

The character of many food products is decided by the changes that starch undergoes during preparation (Delcour & Hoseney, 2010). Uncooked starch mixed in water will form a temporary suspension of particles in a surrounding medium, which by time will settle to the bottom (Vaclavik & Christian, 2008b). The starch granule will, during heating, lose the molecular order when birefringence with start at the hilum disappears, and this will continue over the entire granule. This occurrence is defined as the point of gelatinisation. (Delcour & Hoseney, 2010).

Starches from different origins have different temperature points where gelatinizations occur. About 50 % of oat starch is gelatinized at a temperature of 50 °C while 50 % of rice starch is gelatinized at 70 °C in excess water. Parallel to the gelatinization process, which destroys the molecular order, all structural levels will be affected, for example melting of crystallites, absorption of water and swelling of granules takes place along with solubilisation of starch. The changes the starch undergoes will increase the apparent viscosity of the heated product. This process increases the apparent viscosity and is referred to as pasting. The starch will during pasting take up water, swell and soluble starch, mainly amylose, will leak from the granules to the surrounding medium. (Delcour & Hoseney, 2010).

During storage of food, gelatinized starch will undergo retrogradation when amylopectin goes back to crystalline form. Amylose will also undergo crystallization, which is a fast process that occurs during cooking rather than during storage. The combination of starch concentration and temperature combined with the applied shear force, determines the structure of the starch product. (Delcour & Hoseney, 2010). Amylose crystallization determines the hardness of the initial gel in a product while retrogradation determines the gel development and crystallinity in a long-term. In an ageing gel, starch chains will interact with each other, which will force water to leak out of the gel system. (Delcour & Hoseney, 2010).

1.6 Impact on gelatinization

1.6.1 Acid

Acid present during the gelatinisation process will affect the texture of the food product (Delcour & Hoseney, 2010). The starch will undergo hydrolysis of the glycosidic bonds in contact with acid resulting in fragmentation of the starch to short chain polymers (Delcour & Hoseney, 2010; Vaclavik & Christian, 2008b). This will affect the water uptake of the starch granule resulting in a less viscous final product (Vaclavik & Christian, 2008b). In one study, acid hydrolysed corn starch showed lower apparent viscosity if the pH was adjusted by vitamin C or citric acid lower than 3.6 or above than 5.5. Between pH 3.6 and 5.5 the apparent viscosity appeared higher than the controlling sample. Small amounts of acids gave in the study higher apparent viscosity due to the starch chains ability to entangle. Large amount of acids on the other hand caused a collapse of the starch granule and a decreased apparent viscosity. (Hirashima *et al.*, 2005).

1.6.2 Agitation

Stirring or agitation allows starch granules to swell freely and independent of each other resulting in a uniform mixture. But excessively stirring after the gelatinisation will cause a collapse of the granules resulting in a less viscous product. (Vaclavik & Christian, 2008b).

1.6.3 Sugar

The addition of moderate levels of sugar, especially disaccharides, competes with the starch for the water. This causes less water to be taken up in the granules, resulting in a lower degree of swelling. Sugar does also raise the temperature required for the starch to undergo gelatinization. (Vaclavik & Christian, 2008b).

1.7 Enzymes

Nearly all known enzymes are proteins (Nasibov & Kandemir-Cavas, 2009). Enzymes are very specific catalysts in biological systems and mainly all substrate reactions take place on a particular site called the *active site* of the enzyme. The activity of many enzymes depends on the presence of coenzymes for example metals or small organic molecules often derived from vitamins. (Berg *et al.*, 2012). In fresh fruit and vegetables, enzymes and substrates are naturally separated. After treatment or processing of the crop, the natural separation is eliminated and enzymes and substrates are enabled to react (Chakraborty *et al.*, 2014). Some enzymatic reactions are desired in food processing while other reactions are undesired, for example reactions that negatively affect food quality (Vaclavik & Christian, 2008c).

The enzymatic activity of the raw material is affected by weather during the growing. A study made on rye, grown in the same area over 3 years, and product apparent viscosity indicated the more rain during the growing season the higher the activity of α-amylase and xylanase (Salmenkallio-Marttila & Hovinen, 2005). Higher apparent viscosity breakdown was observed with higher detected concentration of α-amylase and xylanase. The fibre content of the crop increased a rainy season parallel with a decreased size of the grains, which affect the concentration of enzymes.

1.7.1 Amylases

Amylase is a general name of starch degrading enzymes, which act on starch, derived polysaccharides, and glycogen by hydrolysing the 1,4-glycosidic bonds. There are several different types of amylases for instance α-amylase and β-amylase. (Whitaker, 1994).

α-Amylase is an endo-splitting enzyme that hydrolyses the 1,4-glycosidic bonds of starch. The enzymes hydrolyse the glycosidic bonds more or less randomly, into smaller oligosaccharides between two and six monomers. They are found in plant-, animal- and microbial kingdoms. β-Amylase is an exo-splitting enzyme that successively removes units of maltose from the non-reducing ends of the polysaccharide chains. The action of the enzyme stops when it comes to a 1,6-glycosidic bond of the starch. (Whitaker, 1994).

1.8 Inactivation of bioactive compounds

Enzymes have an optimal level of temperature and pH where the catalysing process is the most active. In order to inhibit undesirable enzyme activity, the conditions has to be outside of the area where the enzyme can react, for example a change in pH or a complete inactivation due to heat treatment. In fruits and vegetables enzymes are commonly inactivated by blanching, exposing the fruit or vegetable for boiling water a short time. (Vaclavik & Christian, 2008c). Heat treatment during drying of raw material is not necessarily enough to inactivate unwanted enzymes, in fact desired industrial enzymes are often handled in dry conditions due to stability reasons. Enzymes are differently sensitive to heat inactivation, but generally the inactivation is a function between temperature and moisture content. (Perdana *et al.*, 2012). Using a high temperature during drying will inactivate in a larger part, of the enzymes, compared with drying in low temperature (Luyben *et al.*, 1982). This means that even though the raw material is dried, residuals of enzymes can be present affecting the final quality and shelf-life of the product (Nijhuis *et al.*, 1998).

Thermal treatment at 80-95 °C is common for enzymatic inactivation in fruit purees and fruit juices. An alternative to avoid lower nutritional value and off flavour that thermal treatment can cause, is to inactivate microorganisms and enzymes by exposing the raw material to high pressure processing (HPP). (Chakraborty *et al.*, 2014). HPP works in three steps, pressurization, pressure holding time and depressurization and the inactivation of the enzymes might be due to immediate structural disruption during the depressurization combined with pressure holding time that exposes the enzyme for constant mechanical stress which affect the enzymes structure and form. HPP can be combined with thermal treatment. According to Chakraborty *et al.* (2014), different scientific papers describe different levels of pressure, and pressure combined with thermal treatment, that are required to inactivate the enzymes, for example polyphenoloxidase (PPO) inactivation in strawberry pulp. One paper describes the PPO to be totally inactivated at 800 MPa for 15 minutes and a similar paper describes the PPO in strawberry pulp to be 48 % inactivated at 600 MPa for 5 minutes at 25 °C. According to Chakraborty *et al.* (2014) some scientific studies have also reported that total inactivation of enzymes are not possible with only HPP and therefore a mild thermal treatment in combination with HPP is recommended. (Chakraborty *et al.*, 2014). High electric field pulses (HELP), exposing the food for short electric pulses in high intense electric fields under controlled and moderate temperatures, can be used to inactivate vegetative microorganisms (Bendicho *et al*., 2002; Van Loey *et al.*, 2001). But no degrading effects in enzyme activity of lipoxygenase (LOX), PPO, peroxidase (POD), pectinmethylesterase (PME), alkaline phosphatase (ALP) or lactoperoxidase (LPER) have been found in real food systems. (Van Loey *et al.*, 2001). Gamma irradiation at a dose of 10 kGy caused a decrease in α- and β-amylase activity in sorghum flour by 22 % and 32 %, respectively. In starch rich products, like sorghum porridge, irradiation of the flour can negatively affect the apparent viscosity of the ready porridge. This is caused by free radicals that cleave the glycosidic bonds in amylose and amylopectin chains resulting in lower molecular weight and reduced swelling capacity. (Mukisa *et al.*, 2012).

1.9 Ingredients in rose hip soup

The ingredient list in the commercial rose hip soup presented in falling order: water, sugar, rose hip flour, modified starch, guar gum, citric acid and vitamin C.

1.9.1 Rose hip

Rose hip is the fruit of a plant in the *Rosaceae* family with the genus *Rosa* that include over 100 species with large variations in quality aspects such as taste, aroma, size, ripening time, colour etc. (Andersson, 2009; Uggla, 2004). Rose hip is also known as witches briar, wild briar, hip fruit and dog rose among other names (Türkben, 2009). The *Rosa* species are today widely spread over the world and 25 % of all *Rosa* species are native to Turkey, which makes the country a germplasm centre for many of the species (Ercişli & Güleryüz, 2005).

Rose hips are normally cultivated in the wild in temperate or subtropical areas (Andersson, 2009). Chile is one of the largest world exporters of rose hips, with an annual export of 3600-4500 tonnes dehydrated rose hips to Europe. The cultivation area in Chile for rose hips is distributed between 33°S Santiago to 45°S Aisén from sea level to 2000 masl. (Joublan *et al*., 1996; Joublan & Rios, 2005). The harvesting of rose hips, which mainly is made by hand, normally begins in March and continues into April. The fruit that matches the quality parameters of humidity, shows no signs of fermentation and has low amount of damage and low content of external matters is transported to processing factories. The fruit is crushed and dried before the flesh is separated from the seed. (Joublan & Rios, 2005). The hairs have to be removed, as they otherwise would cause irritation when the food product is consumed. It is possible to deep-freeze the rose hips waiting for dehydration or puree manufacturing, but it may negatively affect quality aspects. (Rumpunen & Andersson, 2012). The typical and expected aroma in rose hip soup has mainly been found in the species section *Rosa Caninae* (Uggla, 2004; Werlemark & Nybom, 2005). The rose hip raw material used in the current study is imported from South America.

During the mid-eighties a program to domesticate wild roses for rose hip production was initiated in the south of Sweden to ensure raw material. Due to high costs and relatively low global prices of unprocessed rose hips, mechanical harvesting had to be performed which required uniform fields, uniform maturation, uniform plant material and a good resistance to damage due to mechanical handling. The harvesting season in Sweden is from the end of September to the beginning of October and the hips have to be harvested as soon as possible to avoid frost damage. In 1993, about 130 ha of rose hip cultivation was established in Sweden, but since year 2000 the production in Sweden has decreased considerably. (Uggla & Martinsson, 2005).

In recent years the Swedish rose hip research has instead focused on rose hips as an ingredient in functional food and medicinal purposes due to the high nutritional aspects (Nybom *et al*., 2014). Rose hips have a relatively high content of folate, is very rich in vitamin C and also has a high contents of carotenoids and phenolics (Strålsjö *et al.,* 2003). The content of bioactive compounds in rose hip can negatively be affected if processing does not inactivate all the enzymes in the final product (Rumpunen & Andersson, 2012). Beyond rose hip soup, the hips are used as an ingredient in many commercial food products, like juice or marmalade (Nybom *et al*., 2014). The rose hip seeds are commonly used in oil manufacturing to cosmetic products. (Rumpunen & Andersson, 2012).

1.9.2 Sugar

The taste of sugar is something many people enjoy. Armelagos (2014) describes the omnivores dilemma with the human brain craving for energy-dense food, like sugar- and fat rich food, for a large part of the evolution. But sugar does not only improve the taste of food products by making it sweet, it can also enhance or lessen certain flavours and create a balance between sweet and sour in fruit-based food (Goldfein & Slavin, 2015). Adding sugar to food decreases the water activity (a_w) and increases the osmotic pressure, which has an important preservative effect reducing the activity of microorganisms and mould formations. If the sugar content lowers in a food product, the preservative effect would decrease. (Davis, 1995).

Apparent viscosity of a product can vary depending on the sugar content, the higher the concentration of sugar the higher the apparent viscosity (Davis, 1995). Sugar gives a more viscous product and contributes with mouthfeel when consuming the product (Vaclavik & Christian, 2008 p. 42). If the concentration of sugar is reduced, a decrease in apparent viscosity will appear. Sugar added in food will also increase the boiling point, decrease the freezing point and affect the degree of gelatinization when less water will be available for the starch to gelatinize. Sugar is involved in nonenzymatic browning, and combined with high temperature it causes caramelization and together with other molecules it enables the Maillard reaction to take place, which will give a brown colour and add characteristic flavour to the food. (Davis, 1995). The total content of sugar in food products is commonly measured by brix determination (Kawahigashi *et al.*, 2013).

But even though sugar has many positive effects on food, organizations and scientists promote a lower daily intake of sugar in beverages and foods due to health and dental aspects (Nordic Council of Ministers, 2012; WHO, 2015).

1.9.3 Modified starch

Starch is one of the most abundant organic compounds found in nature. Native, starches are water insoluble and can easily form unstable pastes or gels, which are unwanted effects in the food industry. To enhance the wanted effects of starch as an ingredient in food, the starch can undergo modification. There are four different kinds of modification, chemical, physical, genetical and enzymatic. Recent years, focus has been to develop chemical or physical modification of starches. (Ashogbon & Akintayo, 2013).

Modification does change the starch granules in order to meet desired functionalities of apparent viscosity, freeze-thaw stability and paste clarity (Delcour & Hoseney, 2010. Examples of physical starch modification could be heat treatment, osmotic pressure treatment, pulsed electric field treatment or pre-gelatinized starch resulting in improved water solubility or reduced particle size. (Ashogbon & Akintayo, 2013).

Chemically modified starches involve changes of the functional groups in native starch, which markedly will cause changed properties. Improvements involve changes in gelatinization properties, pasting properties or retrogradation properties. The changes of the starch during the modification are for instance determined by the source of the native starch, pH, reaction time or reactant concentration. The physical changes that chemical modification causes on the native starch include cross-linking, acid hydrolysis, acetylation, cationization or oxidation. One of the oldest methods of starch modification is chemically acid-modified starch, which is commonly used in the food industry. Due to environmental issues and consumers' safety, the techniques of chemically modified starch are limited. (Ashogbon & Akintayo, 2013).

1.9.4 Guar gum

Guar gum is extracted from the guar bean commercially grown in Pakistan, India and southwest of United States. Guar gum is widely used in the food industry due to its thickening property and it is commonly used as a stabilizer in fruit beverages. The thickening property makes the gum to a good viscosifying ingredient, also in very low amounts. (Joshi *et al.,* 2015).

1.9.5 Citric acid

Citric acid is naturally present in many foods and is also naturally produced in the human body. It is added to food as an acidic regulator that amplifies the effect of antioxidants due to its ability to bind metals like iron or copper, which accelerates rancidity and browning. (National Food Agency of Sweden, 2015).

1.9.6 Vitamin C

Vitamin C is present in high concentration in fruits and vegetables and work as an antioxidant (Hirashima, 2005). Naturally, fresh rose hips have a high concentration of vitamin C, among other antioxidants, and therefore it have been used as a vitamin supplement in Europe (Strålsjö *et al.*, 2003). Vitamin C is a very labile vitamin and is therefore commonly used as a marker of the nutrient quality of food (Uddin *et al.*, 2001). Degradation of vitamin C can work as an indicator of applied thermal treatment (Bai *et al.*, 2013). Factors that can affect the degradation of vitamin C include storage temperature, pH, a_w, oxygen and metal ion catalysts. (Uddin *et al.*, 2001). Vitamin C can be degraded both in aerobic or anaerobic conditions but the degradation is greatly favoured if oxygen is present. Ascorbate oxidase is an enzyme mostly responsible for enzymatic degradation of vitamin C. (Lee & Kader, 2000).

1.10 Manufacturing process of rose hip soup

All ingredients are mixed in a mixing tank, where rose hip powder is added at an early stage. The guar gum is pre-blended with hot water before added to the mixing tank. The soup mixture is stirred in the mixing tank in room temperature before pasteurized and treated with an additional thermal holding time. The soup will be stored in a sterile tank until it undergoes the packing process. Each batch produced consists of a variable number of individual mixing batches.

During the process, there are two risks of stop (Figure 1). The first risk is caused if the packing process is troubled and the sterile tank has to act as a prolonged temporary storage tank. When the sterile tank is filled, no product from the mixing tank can undergo pasteurization and be transferred to the sterile tank. This leads to the second stop risk. A process stop in the mixing tank cause that unprocessed product will be stored in the mixing tank until the cause of the stop is solved. The storage time of unprocessed product is 10 hours before a QA has to be conducted. If additional storage time is needed, a new QA has to be conducted every 4th hour to ensure a good and safe quality of the product. The apparent viscosity quality test of rose hip soup is regularly analysed on the mid-produced package, which thickness should be between 400-700 cP.

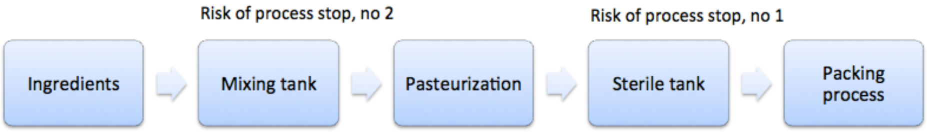

Figure 1. The figure shows a simplified flowchart of the manufacturing process of rose hip soup. The two stop risks in the mixing process are marked.

1.11 Problem description and aim of the report

A manufacturing company of rose hip soup has significant problems with the produced soup. The consistency of the ready-to-drink soup appears thin, which does not correspond to existing quality aspects. The measured apparent viscosity is uneven between the batches and often lower than what the current quality limit allows. The aim of this work was to investigate the soup and the manufacturing process in order to find the reason for the low apparent viscosity. The aim was also to present possible solutions that increase the apparent viscosity without making any changes in the original recipe.

1.12 Limitations

The study is limited in time to 20 weeks and investigations covering a longer time period are therefore not possible. Due to limitations of time, the project focus is to find possible solutions and not to further test the efficiency of the presented solutions. The budget is limited and therefore expensive equipment and tests are excluded from the study. One single person conducted the investigations and additional help from factory workers had to be included in time consuming tests covering several days. All the tests had to be performed side by side with regular QA in the company limiting full access to the instruments. The analysing instruments were also present in singular and parallel measurements were therefore not possible.

2 Methods

In order to find relevant theories about what could influence the apparent viscosity, a literature research was made on apparent viscosity and the ingredients in rose hip soup. Theories were based on information of the different production stages handed from the manufacturing company. Material from an earlier investigation was provided from the company and used as an information base. Historical data about apparent viscosity, brix and vitamin C from regular QA between January 2007 and November 2015 were studied. Laboratorial tests of brix, pH, apparent viscosity, acid- and vitamin C determination were made according to instructions for regular QA conducted in the company. All data were analysed using Microsoft Excel, The Unscrambler® X and Minitab Express™.

2.1 Literature research

Information regarding apparent viscosity, apparent viscosity degradation and rose hips were primarily found on the Internet using scientific databases. Mainly *Web of science*, *Google scholar* and *Scopus* were used. Complimentary research in the library at the Swedish University of Agricultural Science, Uppsala, was done to find relevant publications. Information regarding rain precipitations during rearing were collected from a website recommended through contact with the Swedish Metrological and Hydrological Institute (SMHI)[1]. All information related to the production of the rose hip soup and the methods of regular quality assurance were provided from the manufacturing company, complemented with observations made attending the production- and QA process.

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[1] Recommended by phone contact, 2015-12-03

2.2 Material

Chemicals:

Ascorbic acid 176.12 g/mol, Merck KGaA, Germany
Deionized water
Oxalic acid solution 0.1 M $(COOH)_2$ (0.2 N) Fluka, Sigma Aldrich, Germany
Calibration buffer solution pH 4,7,10 Labservice AB, Sweden
Titration base NaOH 0.1 mol/L Labservice AB, Sweden
2.6-dichloroindophenol sodium salt dehydrate (DCIP) Sigma Aldrich, Austria
All ingredients in rose hip soup
Tap water

Equipments:

Viscometer BROOKFIELD model DV-I + spindel No. 2, Brookfield Englabs inc, USA
Water bath set at 20 ° C
Thermometer
Glass beakers
Timer
pH meter SensION^{TM} HACH Benchtop Meter, USA
Compact titrator G20, Mettler Toledo, Switzerland
Scale showing 4 decimals
Scale showing up to 5 kg
Filter paper Munktell grade 002
Refractometer R90, Bellingham+ Stanley, England
Kitchen stove and cooking pan
Whisk
Watch glass
Plastic pipetts
Eppendorf^{TM} Centrifuge Model 5417C, Fischer Scientific, USA
Eppendorf tubes
Aluminium foil and Plastic foil
Differently sized measuring cylinders
Volumetric flasks

Computer programs:

The Unscrambler$^{®}$ X, CAMO software AS, Norway
Microsoft Office
Minitab Express^{TM}
The company’s computer programs

2.3 Analysis of commercial processed rose hip soups

Packages of ready to drink rose hip soup were collected during two production occasions every 45th minute picked from the production line. All samples were allowed to rest in room temperature minimum 2 days before exposed to laboratorial tests.

All picked soups were analysed for apparent viscosity, pH, sugar content (brix), total acid concentration and content of vitamin C. The packages of rose hip soups were shaken according to instructions given on the package and poured into glass beakers. The beakers were labelled and placed in a water bath set at 20 °C. The apparent viscosity and pH were measured at 20 °C ± 0.6 °C. The apparent viscosity was analysed using a viscometer set at 20 rpm equipped with spindel No.2 for one minute measuring time.

The instruments analysing brix and pH were calibrated and brix and pH were measured. The G20 compact titrator was calibrated for total acid concentration. The weight of each sample was programmed in the titrator before titration with NaOH 0.1 mol/L used as a base. 100 mg Vitamin C and 100 ml deionized water were mixed in order to calibrate the G20 compact titrator for vitamin C analysis. The flask was covered in aluminium foil to keep the vitamin C dark. DCIP 0.01 mol/L for vitamin C analysis was mixed using 0.3626 g DCIP in a 250 ml volumetric beaker and filled up to the mark with deionized water. The DCIP solution was solved using a magnetic stirrer before filtered through a Munktell filter paper grade 002. The G20 compact titrator was recalibrated for vitamin C analysis and the vitamin C content were measured using DCIP as a titrant solution and oxalic acid solution 0.1 M. The weights of each soup sample were programmed in the titrator before measuring.

2.4 Preparation of rose hip soup mixture, small-scale

The original recipe of rose hip soup was calculated to a lower volume. All ingredients in the soup were weighed (section 1.9). Guar gum was pre-solved in lukewarm tap water and placed in a hot water bath for 15 minutes to swell. The ingredients were mixed according to the manufacturing process (section 1.10). The citric acid solution was added to the soup by weighing.

2.5 Analysis on the acid influence

The weight of added citric acid were calculated to increase by 0, 20, 40, 60, 80, 100 and 120 % and decreased by 20, 40, 60, 80 and 100 % of the original added acid. The soup mixture was prepared (section 2.4) with the exception of not adding citric acid solution.

Each calculated dose of citric acid solution were weighed on watch glasses and rinsed into a cooking pan with 350 ml rose hip soup measured in a measuring cylinder. The mixture was stirred during heating on a kitchen stove to pasteurization temperature. To stimulate pasteurization holding time, the temperature was not allowed to decrease faster than a minute under the lowest temperature limit. The heated soup was transferred to a glass beaker, covered with plastic foil and allowed to rest 48 hours in room temperature. The test was repeated with all the calculated acid concentrations. The soups were stirred and evaporated water trapped on the inside of the plastic foils was added back to the soups. Apparent viscosity were measured at 20 °C ± 0.6 °C (section 2.3). The total acid concentrations were measured (section 2.3). To minimize the risk of a false relationship the samples were not prepared in concentration order.

2.6 Analysis of time dependent apparent viscosity decrease

4.5 L of soup was prepared according to instructions (section 2.4). A volume of 350-500 ml of soup was heated during constantly stirring to pasteurization temperature and held for 1 minute above the lowest temperature limit for pasteurization. The hot soup was transferred to a glass beaker and covered with plastic foil. The procedure was repeated every 6th hour in 36 hours with a new sample of unheated soup from the large mix. The test was made in duplicates with the same rose hip flour to spread the measuring points over the 36 hours. All samples were allowed to rest minimum 40 hours. The evaporated water trapped by the plastic foils was added back to the soup. The soups were temperate to 20 °C ± 0.6 °C before measured.

2.7 Analysis of solid content

Packages of rose hip soup picked from the line the second production occasion with an analysed spread in apparent viscosity (section 2.3), were further analysed for solid content. The packaged soups were shaken 30 seconds each. One gram of each soup was added to a pre-weighed Eppendorf tube and one ml of deionized water was added in each tube. The tubes were shaken to enable the fluids to mix. The samples were centrifuged 10 minutes at the speed 10 000 rpm. The supernatants were discarded and the weight of the tube and pellet were noticed. The weights of the pellets were calculated.

2.8 Analysis of time dependent apparent viscosity decrease in rose hip flour

In order to measure the apparent viscosity decrease caused by the rose hip flour, all ingredients with the exception of rose hip flour were added according to the instructions (section 2.4). The soup-base was heated to pasteurization temperature and held for 1 minute above the minimum pasteurization temperature. The soup-base was allowed to rest 18-20 hours. The double weight of rose hip flour, than the original recipe, was added to the soup-base temperate to 20 °C ± 0.6 °C and stirred. The apparent viscosity was immediately measured after addition of rose hip flour. The sample was placed in the viscometer constantly for 12 hours. The apparent viscosity was noticed every hour. To keep the temperature stabilized during measurement, the beaker with soup was placed in a water bath with the temperature controlled every hour. The test was repeated five times with different batches of rose hip flour. Additionally two soup-bases were analysed without any addition of rose hip flour. The two soup-bases were measured every hour, without being constantly placed in the viscometer.

2.9 Analysis of time dependent apparent viscosity decrease in pasteurized rose hip flour

In order to measure the apparent viscosity decrease caused by pasteurized rose hip flour, all ingredients with the exception of rose hip flour and 300 ml of water were added according to the instructions (section 2.4). The soup-base was heated to pasteurization temperature and held for 1 minute above the minimum pasteurization temperature. The double weight of rose hip flour was mixed with the rest of the water (300 ml) and pasteurized like the soup-base. The two solutions were allowed to rest 18-20 hours. 200 g of soup-base were mixed with 200 g of rose hip flour mix and mixed together using a whisk. The apparent viscosity were measured every hour in six hours at 20 °C ± 0.6 °C equipped with spindel No. 2. The measuring time where minimum 1 minute. The test was made with two different batches of rose hip flour.

2.10 Stability analysis of rose hip soups

Apparent viscosities of 5 commercial processed rose hip soups were analysed 3 respectively 73 days after the production occasion to investigate the stability of the soups consistency. The stability of the apparent viscosity was compared within the same production minute.

2.11 Analysis of α-amylase activity in rose hip flour

The α-amylase activity were analysed by an external company using Phadebas® amylase test. Two batches of rose hip flour were analysed used in the soup production 2015-09-14 and 2015-11-09. The method is a quantitative test, but the company only ensured a qualitative result.

2.12 Statistical analysis

Statistical analyses were performed using Minitab Express^{TM}. Mean value and standard deviations were calculated using descriptive statistic. P-values and adjusted R^2 values were calculated using simple regression for all samples with the exception of the test with fixed acid concentrations, of which multiple regression was used instead. The p-values significance were analysed according to the star system, were p-values >0.05 were considered not to be significant.

3 Results

3.1 Historical data

Historical data compiled between 2007-01-09 and 2015-11-09 indicate considerable variations of the apparent viscosities measured during regular QA. The data indicates that the apparent viscosities are almost always less viscous than 400 cP, which is the minimum quality requirement. A distinct exception is noticed between late summer 2013 and spring 2014 where almost all batches were more viscous than 400 cP (figure 2). The pattern indicates that the analysed apparent viscosities are regularly higher or lower in periods, and that values usually do not appear as single values. The average apparent viscosity between 2007-01-09 and 2015-11-09 is 310 cP with the standard deviation of 90 cP.

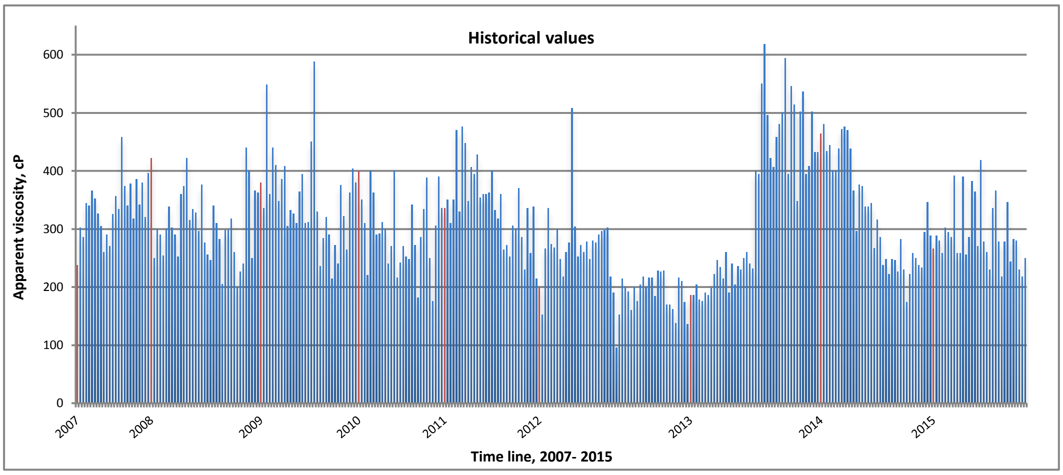

Figure 2. Analysed apparent viscosities measured during regular QA between the years 2007-2015. The apparent viscosities are regularly higher or lower in periods. The red bars highlight the first produced batch each year.

3.2 Apparent viscosity of collected samples

The measured apparent viscosities of the samples collected during commercial production, were generally higher in the entire production of batch number 2, produced 2015-09-28, compared with the first batch, produced 2015-09-14 (section 2.3). The first batch was in the beginning, to a higher extent, afflicted with technical problems compared to the second batch. The first batch had 11 individual mixing batches, which totally took almost 41 hours to be processed and packed, which theoretically gave 3 hours and 42 minutes per mixture. The batch generally had higher apparent viscosities in the end of the production. The average apparent viscosity of batch 1 was 254 cP with the standard deviation 25 cP (*Figure 3*). The second batch had 14 individual mixing batches, which totally took almost 30 hours to be processed and packed, which theoretically gave 2 hours and 6 minutes per mixture. The average apparent viscosity of batch 2 was 278 cP with the standard deviation 30 cP (*Figure 4*). The second batch, 2015-09-28, had a dip of the apparent viscosities between 23:08 and 05:03.

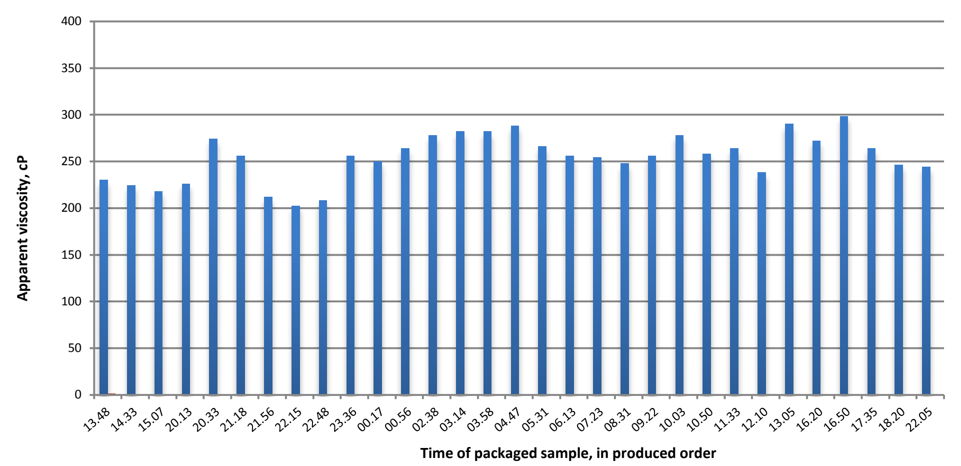

Figure 3. Measured apparent viscosities of rose hip soup from the first production occasion 2015-09-14. The average apparent viscosity was 254 cP with the standard deviation 25 cP.

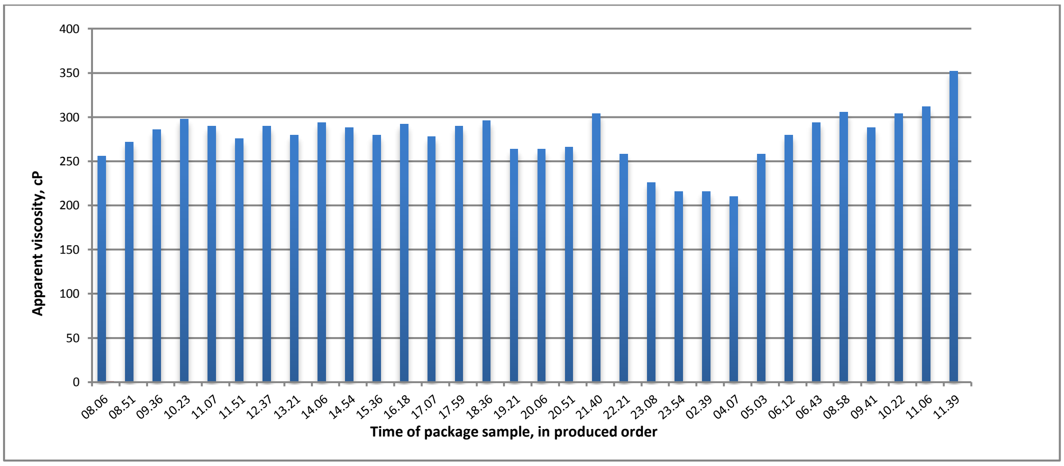

Figure 4. Measured apparent viscosities of rose hip soup from the second production occasion 2015-09-28. The average apparent viscosity was 278 cP with the standard deviation 30 cP.

3.3 Time decrease of apparent viscosity

The apparent viscosity of small-scale mixture of rose hip soup that was allowed to rest different periods of time before heat treated (section 2.6), decreased with increasing time (*Figure 5*). To have a clear decrease of the apparent viscosity, the double weight of rose hip flour were added. The major loss of the apparent viscosity appeared early when all the ingredients were mixed. Duplicates were made, both of them following a decreasing pattern. The decrease of apparent viscosity was 258 cP in test 1 and 108 cP in test 2. The average loss of apparent viscosity was 183 cP. For both of the analysed samples, the relation between apparent viscosity and resting time were considered not to be significant with p-values 0.0760 (adjusted R^2-value 60.39 %) and 0.1676 (adjusted R^2-value 36.36 %).

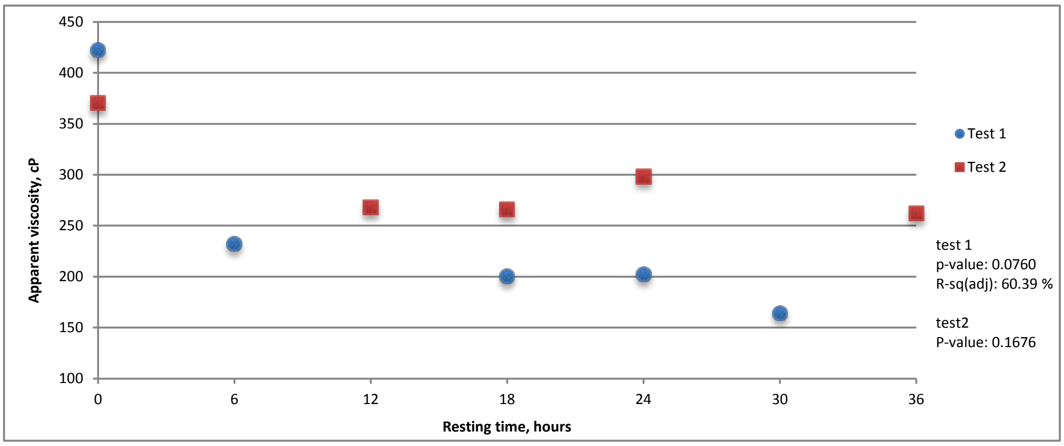

Figure 5. Decrease of apparent viscosity in small-scale test allowed to rest different periods of time before heat treated.

When all ingredients were pasteurized, with the exception of the rose hip flour (section 2.8), the major decrease appeared the first hours after the rose hip flour were added (*Figure 6*). The rose hip flour 1 used in soup production 2015-11-09 was analysed two times due to the deviant pattern. Both times the curves were lower compared with the other flours, and with different apparent viscosities measured at T=0 (time 0 hours). The decrease of apparent viscosity of the other flours followed similar degradation patterns. When no rose hip flours were added, the soup-bases appeared stable (*Figure 7*) (section 2.8). The result measuring the apparent viscosity over six hours with heat treated rose hip flours showed much lower decreases (*Figure 8*). The decreases were within one star significance with p-values 0.0106 (flour 1) and 0.0171 (flour 2). The adjusted R^2 values were 71.16 % and 65.38 % respectively.

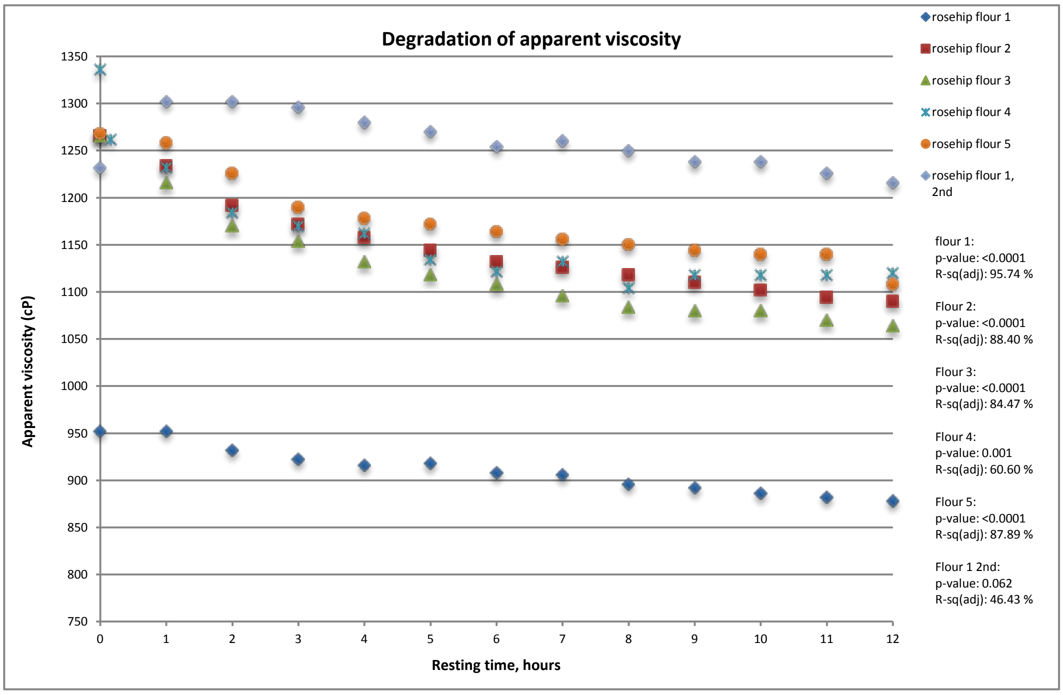

Figure 6. Apparent viscosities for the soups when the rose hip flours were added without heat treatment.

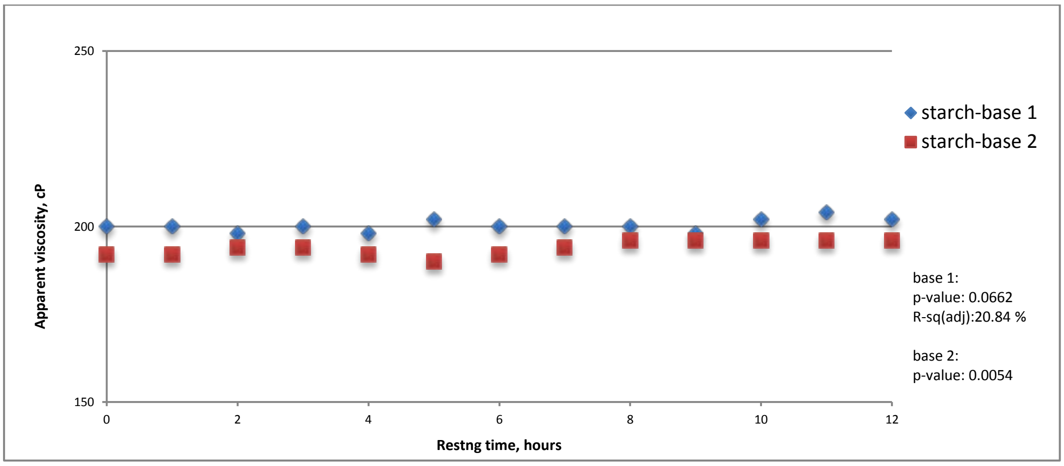

Figure 7. The apparent viscosity of two tested soup-bases during 12 hours measuring.

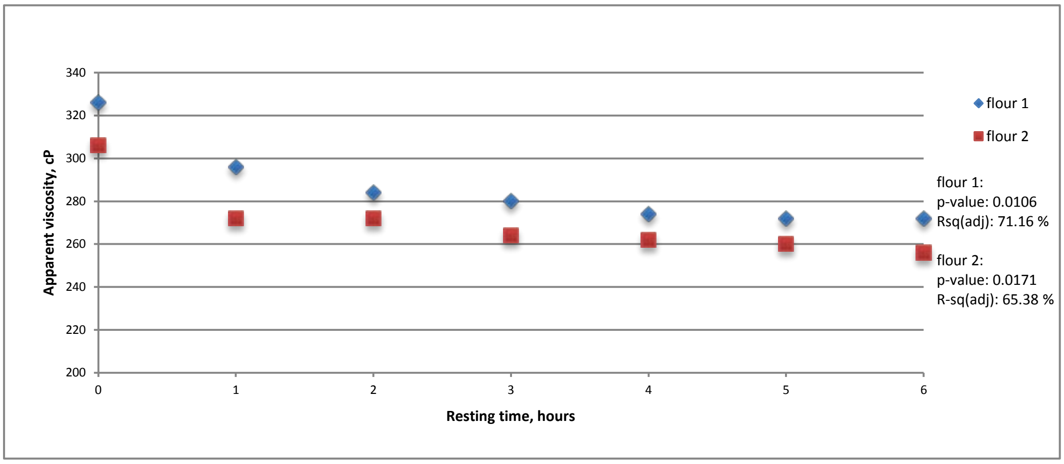

Figure 8. The apparent viscosity of two heat treated rose hip flours during 6 hours measuring.

The processed rose hip soups were stable in the package (section 2.10). The measured apparent viscosities 3 days after production compared with 73 days after production showed that the apparent viscosity increased with time (*Table 1*). The average increase in apparent viscosity was 30 cP with the standard deviation 23 cP.

Table 1. Differences between apparent viscosity analysed 3 days and 73 days after the production of the soup. The apparent viscosity increased in all tested samples

Soup sample, no.	3 days, cP	73 days, cP	Difference, cP
1	298	300	2
2	292	310	18
3	266	328	62
4	216	256	40
5	280	310	30

3.4 Apparent viscosity in relation to acid concentration and pH

The collected samples might indicate that apparent viscosity increases with increasing acid concentration (*Figure 9*). In batch 1 the correlation is not significant with the p-value 0.1231 and the adjusted R^2-value 4.83 %. In batch 2 the correlation is of one star significance with the p-value 0.0174 and the adjusted R^2-value 14.69 %. The relation between apparent viscosity and acid concentration showed with one star significance (p-value 0.0132, adjusted R^2-value 53.3 %) an optimum acid concentration between 2.0 and 2.5 mg/g (*Figure 10*) in a small-scale test with different fixed acid concentrations. The relation between pH and apparent viscosity appears not to be significant (*Figure 11*). The relation between vitamin C and apparent viscosity appears not to be significant in both of the batches with p-values 0.1231 (adjusted R^2 value 4.83%) and 0.0685 (adjusted R^2 value 7.66 %) (*Figure 12*).

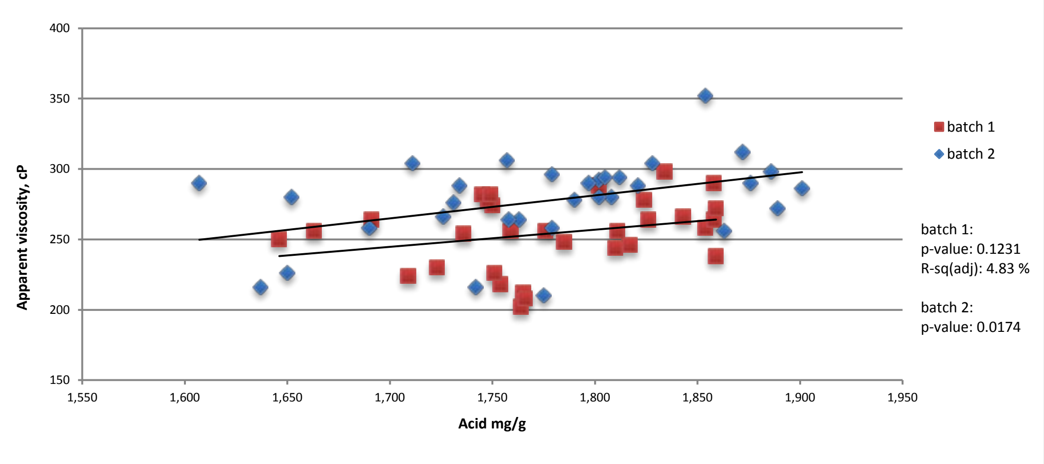

Figure 9. The figure shows the apparent viscosity in relation to acid concentration in the two analysed batches of commercial rose hip soup, which appears not to be significant.

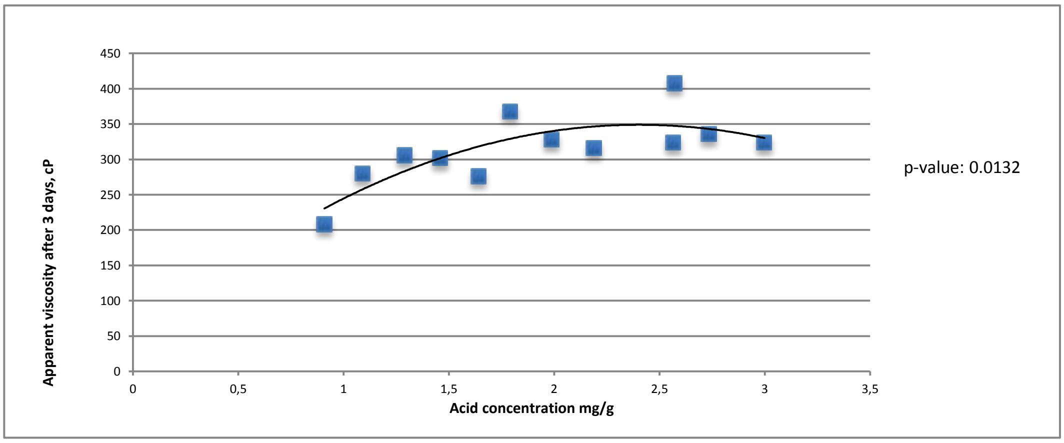

Figure 10. Measured apparent viscosity at different fixed acid concentrations in rose hip soup.

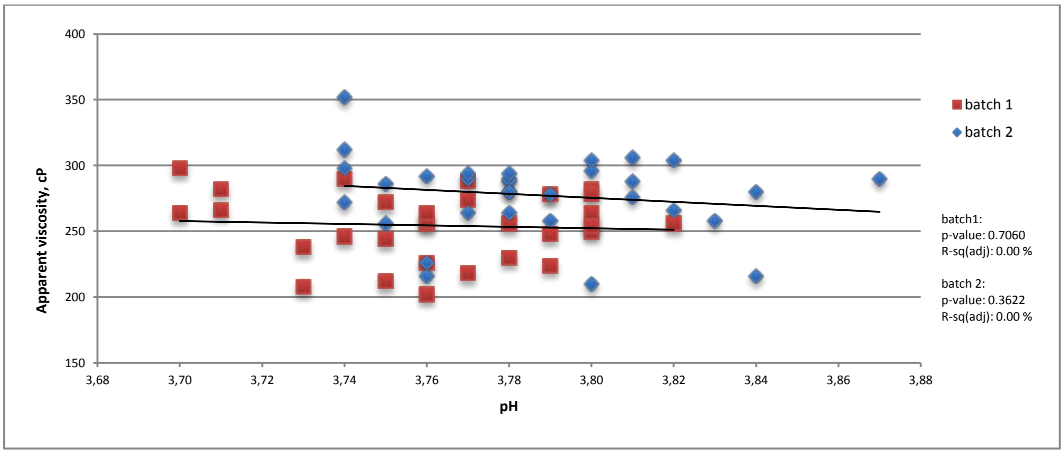

Figure 11. Apparent viscosity in relation to pH in commercial rose hip soup, which appears not to be significant.

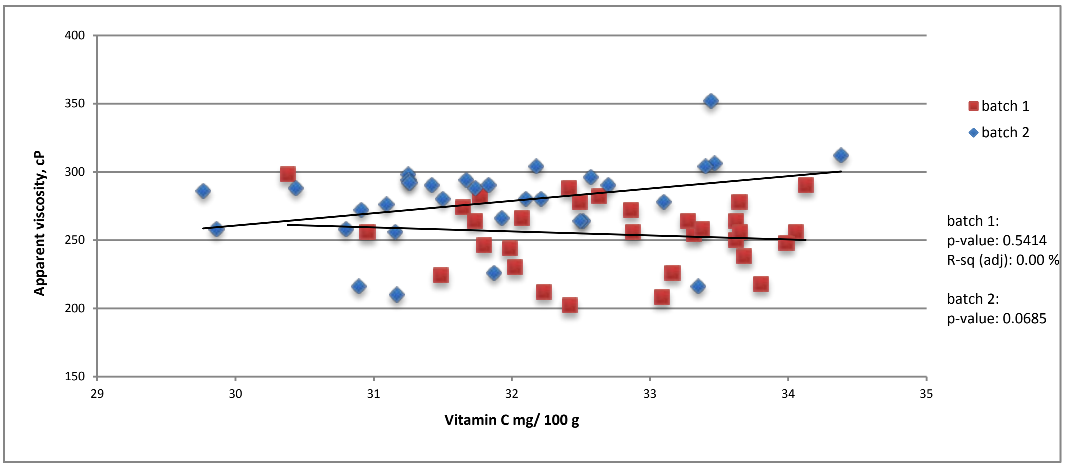

Figure 12. Apparent viscosity in relation to vitamin C in commercial rose hip soup, which appears not to be significant.

3.5 Apparent viscosity and brix

The measured brix is very equal between the individual mixing batches and between the two production batches. Brix between 12.0 and 12.2 are the most common concentrations. Batch 2 was a bit more distributed compared to batch 1. The p-value was for the first batch 0.3712 (adjusted R^2-value 0.00 %) and for the second batch p-value 0.9049 (adjusted R^2-value 0.00 %) which indicate that the relation is not significant.

3.6 Apparent viscosity in relation to solid content

In the samples with a higher amount of solids a higher apparent viscosity was observed within one stars significance (p-value 0.0155 and adjusted R^2-value 32.54 %) (*Figure 13*).

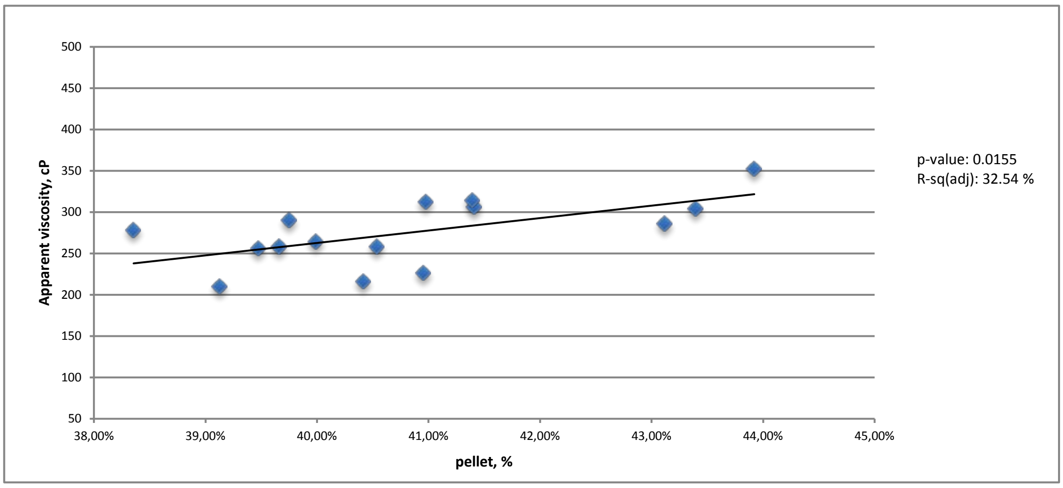

Figure 13. Correlation between solids (pellet) and apparent viscosity in commercial rose hip soup.

3.7 PCA analysis

A PCA analysis of the data from the collected samples over the production time (score plot) of batch 1 (blue) and batch 2 (red) shows an irregular relation to one another in both of the batches (*Figure 14*a). The apparent viscosity did not have a relation to brix or vitamin C content (*Figure 14*b). The points for apparent viscosity and pH or acid content are closer but do not likely have a relation to one another.

3.8 Analysis of α-amylase activity in rose hip flour

Of the two analysed batches of rose hip flour, the batch used in soup production 2015-11-09 α-amylase activity was detected. In the flour batch used in soup 2015-09-14, α-amylase activity was not detected.

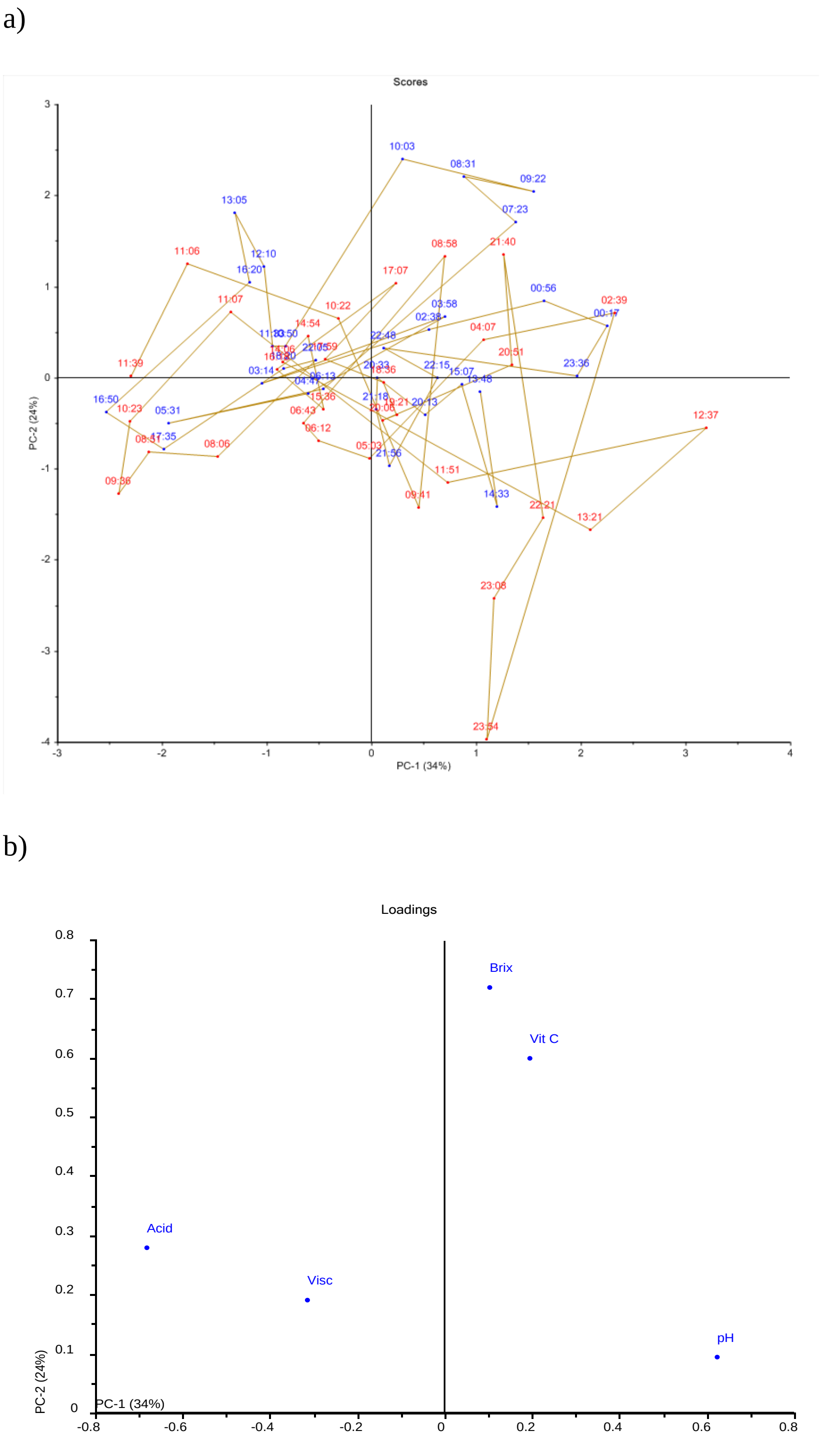

Figure 14. a) score plot and b) loading plot of the first two principal compartments from PCA-analysis of collected samples of rose hip soup produced from two different batches at different times. Batch 1= blue, batch 2= red.

4 Discussions

The results indicate that the decrease of apparent viscosity in rose hip soup very likely is related with the time the rose hip flour is allowed to rest mixed with the other ingredients before pasteurization. This is probably due to an increased activity of enzymes. During the two analysed production occasions, the first batch was in higher extent troubled with technical problems leading to an extended production time, compared with the second batch. The first batch also had a lower average apparent viscosity, 254 ± 25 cP compared to the second batch 278 ± 30 cP (*Figure 3, Figure 4*). The dip of apparent viscosity in batch 2 between 23:08 and 05:03 might correspond to the technical problems in the process, which occurred at that point.

According to the performed decreasing test (*Figure 5*), the major apparent viscosity decrease appered the first hours after the ingredients were mixed. The second decreasing test using untreated rose hip flour (*Figure 6*), 5 p-values out of 6 were 0.001 or < 0.0001, combined with very high adjusted R^2-values. This indicates that it is very likely, within three stars significance, that the result is repeatable. The p-value 0.001 for rose hip flour No. 4 would probably be lower, but due to clumps caused by the flour, the apparent viscosity appeared higher at time 0 (T=0). 10 Minutes after T=0 the apparent viscosity had decreased to a similar level like for the flours 2, 3 and 5 at T=0. The flours did clump in all the samples but in higher extent in the sample for rose hip flour 4. The 6th p-value (flour 1 second time measured) from the degradation test is higher (0.062) and considered not to be significant. The adjusted R^2 value is 46.43 %. This is the same flour analysed in test 1, which due to the deviant pattern were analysed 2 times. The second point when apparent viscosity was noticed (T=1) it had increased. This might be due to the sample was not constantly placed in the viscometer, like in the other tests, and therefore had lower circulation which allow clumps to be present also after 1 hour or due to a measurement error. The deviant apparent viscosity at T=1 might be the reason to the higher p-value and the lower adjusted R^2 value compared with the first time measured (flour 1). The soup-base without addition of rose hip flour were stable over time which proves that the decrease in apparent viscosity likely is caused by the rose hip flour (*Figure 7*). The further test where pasteurized soup-base were mixed with separately pasteurized rose hip flours, showed that pasteurized rose hip flour did not cause much apparent viscosity decrease (*Figure 8*). Small air bubbles trapped in the samples when mixing the two solutions, probably caused the drop of apparent viscosity in the beginning of the test when they were released. It is also possible that the rose hip flour had some clumps during heat treatment and therefore was not sufficiently treated. Another explanation could be if the two pasteurized samples where contaminated with degrading enzymes during analysing, this is though very unlikely since the decrease in apparent viscosity was not dominated at the end of the measurement. But even though some decrease occurred, it was not much and it was a big difference compared to the decrease that occurred when the rose hip flour was not heat treated. The p-values are of one star significance and with relatively high adjusted R^2 values which indicate that the results most likely are repeatable. The storage test of commercial rose hip soup showed that the pasteurization is sufficient to stabilize the soup since the apparent viscosity increases over time during storage (*Table 1*).

Data collected in this study between January 2007 and November 2015 indicates, likewise the earlier investigation performed by the manufacture, on a seasonal variation without many single protruding values (*Figure 2*). Data between 2012-06-06 and 2014-07-25 shows a seasonal variation with a clear breakpoint 2013-07-01. When the harvest of rose hips in South America takes place during spring and the apparent viscosity breakpoint appears in the summer, it is possible that newly harvest raw material is used in the soup. The rain precipitation in Consepción, between Santiago and Aisén in Chile, were during the entire year of 2013 the lowest since 1985 with a total rain precipitation of 593 mm (*Table 2*). The lowest rain value between January and April was also found in 2013, which are the months closest before and during the harvest season of rose hips. (TuTiempo, 2015). Salmenkallio-Marttila & Hovinen (2005) describes that the concentration of α-amylases and xylanases increased in rye at higher rain percipitation during the harvest season. That might partly explain the higher value of the apparent viscosity in the rose hip soup produced in year 2013 if the total content of active enzymes were lower due to the low rain precipitation. On the other hand, the highest rain value was observed in year 2007 which did not remarkable lower the values of apparent viscosity in the soup (*Figure 2*). Since the rain precipitation is not exclusivly the only parameter that can affect the apparent viscosity in rose hip soup, any conclusions might not be possible only based on the rain precipitation before and during harvest. The earlier years, the breakpoints where the measured values of apparent viscosity changes are not that clear but it follows a pattern to be high or low in periods.

Table 2. Rain precipitation (mm) in Consepción, Chile, between the years 2006 until 2014 during the months before harvesting of rose hips, which takes place in March and April (TuTiempo, 2015)

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014
Jan	31	36	4	9	19	21	17	2	7
Feb	2	36	1	10	29	7	35	23	4
March	10	9	6	8	5	25	9	3	67
April	101	103	53	14	8	87	3	7	8
Total	144	184	64	41	60	139	63	34	86

The rose hip peels that are used in the soup are dried before milled into flour, without any additional thermal-treatment or enzyme inactivation treatment. The reason of the drying process is to lower the water content and not to inactivate or sterilize the raw material. The treatment enables enzyme residues to be present in the flour when the drying process is not necessarily enough to annihilating enzymes according to Perdana *et al.*, 2012. The external analysis detected α-amylase activity in one of the two analysed rose hip flour batches. The batch used in soup production 2015-11-09 had a positive result while the batch used in soup production 2015-09-14 had a negative result (section 3.8). Since a decrease of the apparent viscosity was obtained in both the flour batches it is likely that enzymatic activity are present in both of the flours. The lowest decrease was obtained in the sample where α-amylase activity was detected, and the flour batch where no activity was detected followed the time degrading pattern like most of the tested flours and had a p-value of <0.0001 and an adjusted R^2 value of 88.4%. That the external company only detected α-amylase activity in one of the two samples does not necessarily proves that the negative test does not contain enzymes. The negative result could be due to measurement errors or that other enzymes than α-amylase were decreasing the thickness of the soup.

The concentrations of vitamin C were similar between the batches. No significant relation between vitamin C and apparent viscosity were found in any of the two batches. The PCA-analysis (*Figure 14*) also declines correlation between the vitamin C concentration and apparent viscosity. That vitamin C is not related with the decrease of apparent viscosity indicates that the soup, after heat treatment, is stable without enzymatic degradation (*Figure* 12).

The easiest and most stable solution to avoid enzymatic degradation in the rose hip soup would be to use enzyme free rose hip flour. But there are some possibilities to limit the impact of enzymes also in the factory. One possibility would be to add the rose hip flour at the end instead of early in the process and thereby minimise the degradation time. This solution requires planning and a risk would be if the packing process unexpectedly would be troubled of technical issues causing a process stop when the rose hip flour already is added. A more stable solution would be to use the equipment heating the guar gum to pasteurize the rose hip flour mixed with some water before adding it to the mixing tank. This would destroy the enzymes and the product would be stable over time also in the mixing tank.

Other possible explanations to a low apparent viscosity due to negative impact on the gelatinisation process, according to the literature, are acid concentration (AC), agitation or sugar content (section 1.6). Since the acid concentration naturally varies the concentration is adjusted in the mixing process with addition of citric acid solution, which stabilizes the acid concentrations between the batches. The measured acid concentrations were quite stable in all measured samples between $1.646<AC<1.859$ the first batch and $1.607<AC<1.901$ the second batch (*Figure 9*). The p-value of the first batch (0.1231) is not significant between acid concentration and apparent viscosity while the second batch is one star significant (0.0174), but with a low adjusted R^2 value (14.69 %). According to the PCA-analysis (*Figure 14*), the relationship between acid content and apparent viscosity is not very credible in the two analysed batches. The pH in the first batch was between $3.73<pH<3.82$ and was in the second batch between $3.74<pH<3.87$, both batches were not significant in relation to apparent viscosity (*Figure 11*). The laboratorial test, on the other hand, with fixed acid concentrations in rose hip soup indicated that the acid concentration and apparent viscosity likely had an optimum point (*Figure 10*). According to Hirashima *et al*., (2005) the effect of acid depends on the concentration and acidic conditions, and a pH between $3.5<pH<5.5$ would contribute with an increased apparent viscosity. It contributes with this result that the apparent viscosity within 1 stars significance (p-value 0.0132 and adjusted R^2 value 53.3 %) has an optimum, which is close to the target acid concentration and pH of the commercial produced rose hip soup.

That a relation between brix and apparent viscosity would be present is highly unlikely since the measured brix is similar between the batches (section 3.5) with very high p-values and 0.00 % adjusted R^2 value in both of the batches. The relation is also declined using PCA-analysis (*Figure 14*). It is also unlikely that agitation would be the only reason for the low apparent viscosity since it can’t explain the variation of the apparent viscosity when the process always is similar between the batches. The earlier investigation performed by the company lowering the process pressure did not increase the apparent viscosity to approved levels. The analysis of solids in the soup showed that the higher amount of solids the higher the apparent viscosity appeared (p-value 0.0155, adjusted R^2-value 32.54 %) (*Figure 13*). Since the content of solids are uneven within the same batch, an increased agitation in the sterile tank would probably contribute with an equality of the apparent viscosity within each batch. A risk factor would be to increase the agitation too much, which instead would cause a lower apparent viscosity all through the batch.

A further investigation is recommended to evaluate the current quality limits between 400 – 700 cP at 20°C ±1°C measured with a Brookfield viscometer. This is recommended since not many of all soup batches produced over the last 8 years have lived up to the current quality limits. Even if the probable enzymatic degradation would be limited, it is not likely that the apparent viscosity would increase that much and be close to the upper limit. Therefore an adjustment of the upper limit might be recommended and the further target to minimize the enzymatic degradation, which would contribute with a more even and stable product. It has to be taken into account that the soup with a too low apparent viscosity has been on the market for at least 8 years and that consumers probably are used the current mouthfeel, taste and consistency. It is not to be forgotten that food quality includes, like Peri (2005) described it: "…the requirements necessary to satisfy the needs and expectations of the consumer".

4.1 Sources of error

During two production occasions, 11 and 14 mix cycles each, packages of ready rose hip soup were collected to analyse. Each mix cycle was planned to take 1.5 hours to pack, if no technical issues occurred. Packages of rose hip soup were therefore targeted to be collected every 45th minute to theoretically analyse the start, middle and end package of each mix cycle. But due to technical problems or staff breaks the production had to be paused at some points, and no samples could be picked at exact wanted time.

Compilation of the historical data of apparent viscosity measured during regular QA only shows one measured value of one mixing batch in the middle of each produced batch. Therefore the historical value is not a representative value of the apparent viscosity through the entire batch. But since the variation was not very big it is still a good source indicating seasonal differences even though it is not exact. In order to have a more exact value, more packages within the historical batches should have been measured. But an increased number of measurements on apparent viscosity may be out of the purpose of regular QA since it does not affect food security.

The experiment of time depending breakdown of apparent viscosity in heat treated rose hip flour, less rose hip flour was added than in the time depending breakdown with untreated flour (*Figure 8*). In the untreated experiment 12.6 g rose hip flour was added per beaker (ca 400 ml), in this experiment 7.41 g flour was calculated to have been used. Rose hip flour was mixed and pasteurized with 340 ml water allowed to rest 18-20 hours before mixed with a prepared soup-base. The apparent viscosity would have been too low to measure if all the rose hip mix was used, therefore a lower amount of rose hip mix was added. This might probably have lead to a lower content of active enzymes. But since about 2/3 of the flour was added and a large difference between untreated and treated flour was observed, it is likely that the result is trustful. Totally, the pasteurized sample decreased 50 and 54 cP with the largest degradation the first hour when air bubbles left the sample. Between hours 1 to 6 the decrease were 16 and 24 cP, which are much lower than the untreated rose hip flour measured.

During the test with fixed acid concentrations, only one cooking pan was used and the experiment took almost 3.5 hours to complete. This enable enzymatic degradation affecting the apparent viscosity, to minimize a false relationship samples with the different acid concentration were not prepared in sequent order.

A quantitative analysis of enzyme activity of the rose hip flour would have been preferable. But since the external company only ensured a qualitative result it was used instead. To analyse the flour with another method would have contribute with a higher cost and need of time. Instead the apparent viscosity degradation in soups with different rose hip flours were made and combined with detection of α-amylase.

5 Conclusions

During this project a number of conclusions were made. The decrease of apparent viscosity is very likely related with the time the mixed soup is allowed to rest in the mixing tank before pasteurization. It is likely that the untreated rose hip flour causes the decrease due to the degradation by endogenous enzymes. The rose hip soup appears stable after pasteurization. An uneven measured apparent viscosity within each mixing batch of produced rose hip soup is likely caused by varying content of solids in the ready soup, which is likely caused by an insufficient circulation in the sterile tank allowing the solids to slightly separate from the water phase. The conclusion is also that the acid content has an optimum contributing with higher apparent viscosity and that the soup already is close to the optimum. Brix, pH or vitamin C are probably not correlated with the apparent viscosity in this case.

6 References

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A manufacture of rose hip soup commissioned this investigation and report. The company requests to be anonymous in the published report.

7 Appendix

7.1 Popular scientific text

Rose hip soup

- when time becomes a problem

In a food industry it is an important factor that the products are equal every time produced. A manufacturing company of rose hip soup has problems to have an equality of the soups thickness and mouthfeel, which often instead end up thinner than expected. Active enzymes acting like scissors are likely to be the villains of the piece.

Industrially manufacturing of a food product put high demands on the manufacturing company. The company has to fulfil obvious demands, for example to ensure that the food is safe to eat, but the company also has to be sure that the food product appears equal to the consumers every time it is eaten. In the term *food quality* it is included that a certain food is expected to behave in a certain way, for example crisps are expected to have a crunchy sound when chewed and a fruity soup is expected to have a good mouthfeel without being to thick or to runny, above the obvious demand to contribute with a good taste. To have a uniform product could be more problematic than it sounds, especially if high amounts of natural raw material like berries is used. This is due to the natural variation between harvests, which the manufacture cannot always control.

One factor that varies between the annual harvests in crops is the amount of active enzymes. Enzymes are proteins that specific cut target structures, for example starch, like small scissors cutting a single paper, into smaller and smaller pieces. The cutting can therefore cause an unwanted consistency of the final food product the longer the enzymes are allowed to work. Enzymes are naturally present in crops, and they can be inactivated if treated with heat, gamma irradiation or with very high pressure.

A manufacturing company has problems with the production of rose hip soup and the soup is often thinner and doesn't always have the right mouthfeel as they expect. Compiled historical data of the thickness of the soup proves that the problem has been present at least eight years back. The historical data also proves that an annual variation of the soups thickness is present. This is likely to be caused by different amounts of active enzymes in the raw material, in this case the rose hip flour. The weather during growing of the raw material can have an influence of the enzyme content, the higher the rain precipitation the higher the enzyme content. A variation of the enzyme content would explain the annual variation of the soups thickness.

In small-scale tests it was observed that the longer the soup-mix was allowed to stand unheated before the heating process, the thinner did the soup end up. If the soup was mixed with unheated rose hip flour, the consistency of the soup became thinner in relation with time. If the soup instead was mixed with heat treated rose hip flour the consistency did not became much thinner at all. This pattern is associated with active enzymes. To be sure that enzymes are present in the rose hip flour, two samples were sent to an external company for enzyme activity detection of which one sample gave a positive result. This proves that enzymes most likely are involved causing the thin soup.

Additional in the study no relation between the soups thickness and content of sugar, vitamin C, pH or acid concentration in the commercial produced soup was found. In a small-scale test it was seen that different acid concentrations could contribute with different thickness of the ready product. Up to a certain concentration the thickness was increased, and was decreasing after the optimum point, with a pattern like a sad mouth. The produced commercial soups appeared to be close to the optimum acid concentration to contribute with the most thickness of the product. Therefore the acid concentration cannot explain the thin soup.

An action to avoid the thin soup is therefore to limit the natural, but unwanted degradation caused by enzymes. This can be made by minimize the time in the production before heat treatment where rose hip flour and other ingredients are mixed, or to treat the rose hip flour with hot water before mixed in the soup. Another option is to use rose hip flour that is treated to be free from active enzymes. These actions would contribute with an equal thickness of the rose hip soup every time it is consumed.