Master thesis

The acceptance of elderly towards low sugar, protein-enriched forest fruit spreads

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Preface

In August 2016, I started with my thesis about the acceptance of elderly towards low sugar, protein-enriched forest fruit spreads. In the first week I did not know exactly where it would end but now after six months of lab work, sensory tests and writing, I can finally present my thesis to you. Of course without the help and support of some persons this was not possible and I would like to thank these persons.

First of all, I am thankful for the opportunity to do my thesis at the department of Food Quality and Design with the chair professor Vincenzo Fogliano. I would like to thank my supervisors, Jenneke Heising and Bea Steenbekkers, for their advice, tips and helping me when I did not know how to continue. I also appreciate the efforts that the lab technicians did to help me during my lab work. I would like to thank Nancy Janssen, dietitian at the hospital Gelderse Vallei, for the interview and to send me an e-mail in which she showed that she believed in protein-enriched fruit spreads. Also my friends and my mom who were willing to participate in my sensory tests and taste many (sometimes not so delicious) fruit spreads, thank you! Finally, I would like to express my gratitude to the contact persons of the organisations and elderly who participated in my research. I still remember one of them, an old lady in her wheel chair. Because a limited number of participants could taste at once, she had to wait for a while but when it was her turn, she was still smiling and enthusiastic. She told me that her granddaughter passed away that day but helping me gave her again a nice feeling and made her forget for a moment what happened that day.

Laura Mulders

Wageningen - February 2017

Abstract

Introduction. Malnutrition has a high prevalence in Dutch elderly and the major contributor to this problem is the deficiency of proteins.[33,52,81] There is especially a lack of proteins in the breakfast of Dutch elderly since the most consumed breakfast by them is a Dutch toast with fruit spread and margarine or butter.[10] To improve the protein intake of elderly at their breakfast, fruit spreads could be enriched with proteins. Additionally, a common illness in elderly is diabetes type two thus a low sugar fruit spread in which sugar is partly replaced by sorbitol could be interesting as well.[79]

Aim. The aim of this research was to develop low sugar, protein-enriched fruit spreads and assess the acceptance of elderly towards these fruit spreads.

Methods. Four fruit spreads were developed and assessed in the consumer study with 84 elderly above 65 years. Two fruit spreads in which 25% sugar was replaced by sorbitol, were enriched with 5% and 11.25% whey protein isolate (WPI) to study the effect of increasing protein concentration on the acceptance of elderly towards protein-enriched fruit spreads. The two other fruit spreads were not enriched with proteins but contained different amounts of sorbitol to find out whether sorbitol influenced the acceptance. In one of these fruit spreads, sugar was replaced by 25% sorbitol, in the other one only sugar was used. The fruit spreads for the consumer study were chosen based on the outcomes of a sensory test during the development of the fruit spreads. TSS, colour and texture of every fruit spread made in the development stage were also measured, because these quality attributes could be affected by the replacement of sugar by sorbitol and the addition of proteins.

Results. No systematic differences between the quality attributes were found when replacing sugar by increasing amounts of sorbitol. The addition of WPI resulted into whiter, less red and more blue fruit spreads which were stickier as well, but these differences were not significant ($p > 0.05$). In the consumer study the liking scores were not significantly ($p > 0.05$) influenced by replacing sugar by sorbitol, but the addition of proteins led to significant ($p < 0.05$) lower liking scores. Increasing the amount of proteins did not lead to a significant ($p > 0.05$) change in acceptance between the protein-enriched fruit spreads. However, the fruit spread enriched with 11.25% WPI was more often described as not delicious, not attractive and red cabbage than all fruit spreads.

Conclusion. The addition of proteins to fruit spreads led to a decrease in acceptance by the elderly. Since vision dominates taste, it might be possible that acceptance of the protein-enriched fruit spreads was mainly based on its unexpected appearance. This needs to be studied in further research.

Abbreviations

ANOVA	Analysis of variance
a_w	Water activity
CA	Correspondence analysis
EFSA	European Food Safety Authority
GP	*Geleipoeder*
HM pectin	High methoxyl pectin
JAR	Just-about-right
LM pectin	Low methoxyl pectin
PCA	Principal component analysis
SPI	Soy protein isolate
TSS	Total soluble solids
WPI	Whey protein isolate

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Chapter 1: Introduction

1.1 Protein deficiency in elderly and protein-enrichment of food products

1.1.1 Malnutrition in elderly

Malnutrition in elderly is a serious problem as it contributes significantly to morbidity and mortality. Since the society is aging, this problem will become more important.[13,81,86] In 2011 the prevalence of malnutrition in The Netherlands equalled 7% for elderly who were independently living and up to 33% for elderly in hospitals.[33] An efficient solution for this issue might not only decrease the health care costs, but might also give the elderly a better quality of life.[13,81]

The major contributor to the malnourishment is the deficiency of proteins and the body requires these molecules for tissue growth and maintenance.[52,81] The European Food Safety Authority (**EFSA**) recommends a dietary intake of proteins of 0.83 g per kg bodyweight per day for adults and this is the estimated protein intake for elderly in The Netherlands.[10,26] However, this recommendation does not take into account the changed protein turnover for elderly.[14,54] Protein degradation in elderly happens faster than protein synthesis which is partly due to the declining anabolic response to protein intake and this results into a negative nitrogen balance (**Figure 1**).[8,14,54,70]

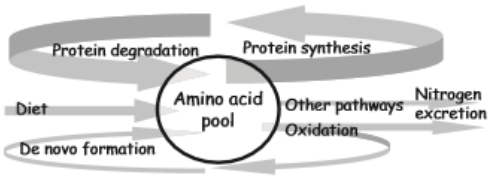

Figure 1. Schematic representation of amino acid metabolism.[41]

Studies indicate that a higher protein intake of 1.0-1.5 g per kg bodyweight per day or 20-30 g protein per meal is recommended for elderly to maintain the nitrogen balance.[10,14,54,86] Inadequate dietary intake of proteins might have disastrous consequences: poor working immune system, higher vulnerability for infectious diseases and longer recuperation time from illness.[14] However, not only an adequate protein intake is important, also physical activity stimulates the protein turnover by stimulating the protein synthesis more than the protein degradation.[14,70]

1.1.2 Protein-enrichment of food products

Different reasons for inadequate protein intake in elderly are given in literature. Taste, texture and odour become more important for elderly, because of possible chemosensory losses and impaired dentition.[18,65] Biting, chewing and swallowing difficulties can lead to a decrease in consumption of protein-rich foods as meat and nuts. Not only product-based reasons are given, but also the environment can play a critical role. The barriers mentioned by elderly are living alone, restricted mobility and disabilities.[11] Thus just increasing portion size or meal frequency does not necessarily improve the protein intake of elderly.[76] Moreover, a suitable strategy to improve the protein intake could be the protein enrichment of food products.[14,81] In the study of Silver *et al.* (2008), protein-enriched meals increased the nutrient intake in elderly at home. Additionally, Smoliner *et al.* (2008) concluded that elderly at nursing homes have an improved nutritional status when eating protein fortified food.

Especially the breakfast of elderly does not fulfil the requirement of 20-30 g protein per meal.[8,10] In the Cater with Care study, a significant increase in protein intake at breakfast was seen by fortifying bread and juices. Even this improvement did not lead to an adequate protein intake at breakfast (**Figure 2**).[10] To find out how to improve the protein intake of elderly at their breakfast, Nancy Janssen, an expert in nutrition for elderly and dietitian at the hospital *Gelderse vallei*, was interviewed (**Appendix I**). She mentioned that the most popular breakfast amongst Dutch elderly is a Dutch toast (Dutch: *beschuitje*) with jam and margarine or butter (**Figure 3**). Today the percentage of protein in jams ranges between 0.5-1.2%.[2,4] Furthermore, the study of van der Zanden *et al.* (2014) indicated that bread and bread spreads are appropriate products for protein enrichment in the opinion of elderly. Likewise, Nancy Janssen believes that the addition of proteins to jam can contribute to an improved protein intake in elderly although the portion size of jam equals 15 g.[42] On the other hand, the addition of proteins to jam might affect the sensory properties. By changing these properties, the risk of rejection of the new product exists.[69] This risk will be lower when the consumer understands the health benefits of the modified traditional product, as well as the acceptance towards it.[6]

Figure 3. Dutch toast with forest fruit jam and butter.

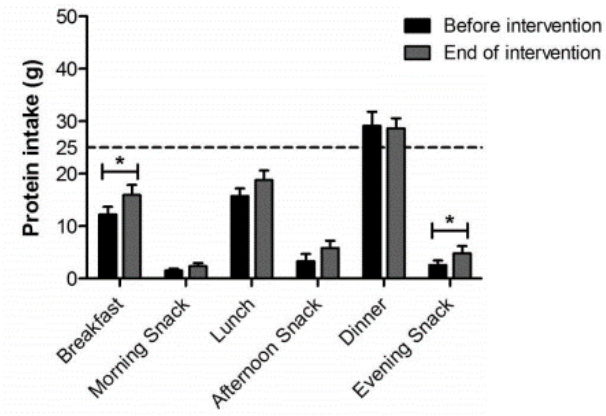

Figure 2. Cater with Care study: protein intake per meal in elderly before and after an intervention with protein-enriched food products.[10]

1.1.3 Impaired chemosensory capacities

When developing products for elderly, it has to be taken into account that the chemosensory capacities could decrease when aging due to drying out of the mucous layer and reduction of the production of new sensory cells.[50] The chemosensory capacities remain stable until the age of 60, afterwards increased detection thresholds, decreased perceived intensity of supra threshold concentration and decreased ability to distinguish between odours could be detected.[50,55,63] This decline is quality specific; the changes are not necessarily equal for different flavours.[20,50] The study of de Graaf *et al.* (1996) concluded that the difference in optimal flavour intensity between youngsters and elderly is larger for sweet than for savoury flavours. On the other hand, the study of Maitre *et al.* (2015) concluded that this difference is larger for salt than for sweet and sour.

On top of this, other factors influence the chemosensory capacities as well. In the study of Maitre *et al.* (2015), less elderly who were living independently had decreased chemosensory capacities compared to the elderly living in nursing homes. Furthermore, common neuro-degenerative disorders in this age group such as Alzheimer and Parkinson can cause a severe decline in odour identification.[50,55] The drugs usage that is accompanied with these diseases can also have an effect on the chemosensory and oral abilities.[50]

Thus, on average the chemosensory sensitivity of elderly is impaired but just increasing the flavour intensity of food products did not lead to an increase in food intake in most of the fifteen studies which were conducted.[5,45,48] Until now, no study suggested a clear solution for the development of food products for elderly because they are a heterogeneous group.

1.2 Low sugar, protein-enriched fruit spreads

1.2.1 Fruit spread

The definition of jam stated in the Codex Alimentarius (2009) is as follows: "Jam is the product brought to a suitable consistency, made from whole fruit, pieces of fruit, the unconcentrated and/or concentrated fruit pulp or fruit puree, of one or more kinds of fruit, which is mixed with foodstuffs with sweetening properties, with or without the addition of water." Jam of good quality is defined as a jam with a bright colour, typical sweet-sour flavour and pleasing consistency which is neither too stiff nor too liquid.[38,60] To meet these requirements, jams are usually made from fruit, sugar, water, thickening agent and acid that are mixed and concentrated by applying a thermal treatment.[38,51,21,82] Regarding the Codex Alimentarius (2009), only following extra ingredients are allowed to add to jam: herbs, spices, nuts, alcoholic drinks, essential oils, vegetable edible oils and fats.[16] As proteins are not included in this list of ingredients, the addition of proteins to jam leads to a name change, namely to fruit spread.

The most often used thickening agent is pectin, polygalacturonic acid esters, in which two types are distinguished based on the degree of methylation.[77,82,85] In high methoxyl pectin (**HM pectin**), 50-58% of the carboxyl groups are esterified.[80] Addition of at least 55% sugar and adjusting the pH below 3.5 lead to gel formation via hydrophobic interactions and hydrogen bonds.[77,80] The other type of pectin, low methoxyl pectin (**LM pectin**), has 20-40% esterified carboxyl groups.[80] Therefore, most carboxyl groups are available to form cross-links with divalent cations and subsequently trap liquid to form a gel. This mechanism is called an egg-box model (**Figure 4**). Thus to form a gel with LM pectin divalent cations such as calcium should be added.[51,77,80]

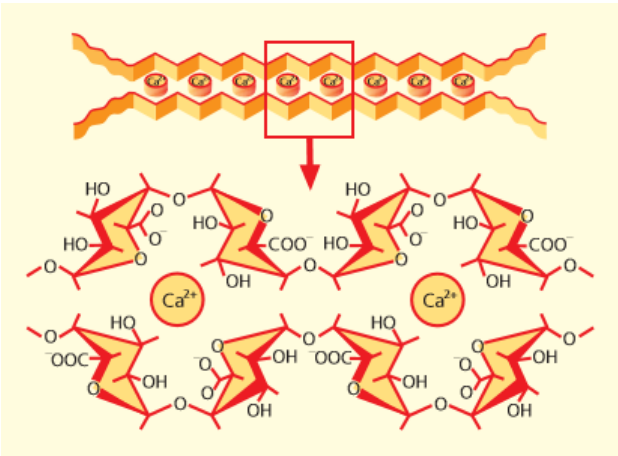

Figure 4. Low methoxyl pectin gelation: egg-box model.[35]

Pectin may also form a weak network with proteins when the pH is near or below the isoelectric point of the proteins but higher than pK_a of pectin. In this case, pectin is attracted to the positive charged proteins. The protein particles are wrapped inside strongly hydrated shells of pectin and these complexes are connected in a network.[77] Furthermore, pectin suppresses the heat coagulation of proteins by stabilising them due to the high molecular weight of pectin.[77,85]

1.2.2 Characteristics of dairy, soy and pulse proteins

Several proteins are used to fortify food products, but most often dairy and soy proteins are added.[15] To reach adequate nutritional quality, functional and sensory properties, a suitable protein has to be chosen. The nutritional quality of proteins is determined by their composition of essential amino acids and physiological utilisation.[32,88] An aspect of the physiological utilisation is the digestibility which is used to estimate the protein availability for intestinal absorption after digestion, so proteins with higher digestibility are more desirable.[3]

Dairy proteins have high nutritional values because they are complete in essential amino acids.[14,15,32] Whey proteins are superior to casein proteins as they even contain higher amounts of essential amino acids.[68] Additionally, whey proteins are waste products from cheese production and less expensive than casein proteins.[36] Therefore, more attention is paid to whey proteins. Whey proteins are a source of branched-chain amino acids (valine, leucine and isoleucine) which reduce the protein breakdown in the body.[3,15] Soy and pulse proteins are low in methionine and high in lysine which give them a lower nutritional quality than whey proteins.[32,74,88] However, a balanced animal-vegetable protein ratio is important and vegetable proteins can be combined with each other to overcome the problem of an incomplete amino acid profile.[14,75]

The digestibility of whey proteins is higher compared to soy and pulse proteins. This might be due to the fact that vegetable proteins contain antinutritional factors that form more complex protein structures which might decrease digestibility.[3] In general, soy proteins are more digested than pulse proteins.[3,12] Whey and pulse proteins are highly soluble at a pH between three and seven in contrast to soy proteins which have a low solubility at acidic pH.[59,84] Upon heating proteins can coagulate and the solubility decreases.[59] Furthermore, the water retention capacity of soy proteins is higher than this capacity of pulse and whey proteins.[74,84] Soy proteins even absorb twice as much water than whey proteins. Another property of soy proteins that is higher compared to whey and pulse proteins, is the emulsifying activity. This might cause more foam forming which is undesirable in jam.[84]

As mentioned earlier, the incorporation of proteins may also modify the sensory properties of a traditional jam.[69] Proteins have little flavour of their own but they bind with flavour components via

mainly hydrophobic interactions which cause a decrease in flavour intensity and change the overall aroma perception.[19,78] Also low retention of ketones by proteins lead to off-flavours.[83] Whey proteins contribute to a sweet aromatic, milky flavour but they are also associated with cardboard, animal and cucumber flavours. On the other hand, soy proteins are described as beany and grassy.[23,62] However, fruity flavours can mask the bitterness and off-flavours caused by proteins.[23] Not only the flavour is altered by adding proteins, also the texture might change since proteins have gelling properties.[62] Proteins are also associated with a chalky mouthfeel.[62]

1.2.3 Replacement of sugar by sorbitol

As 50% of the diabetic type two population in The Netherlands are elderly above 70 years old, low sugar jams can be interesting for them.[79] According to the legislation, jam should contain more than 35% fruit and at least 60% total soluble solids (**TSS**) measured with the refractometer and therefore more or less 50% sugar is added to jam.[28,60]

The sugar in jam can be partially or fully replaced by sweeteners: high intensity and bulking sweeteners. The first type of sweeteners does not have a caloric value, but could have a strong after taste.[57] On the other hand, the second group of sweeteners does not have a strong after taste. Sorbitol (E420) belongs to this last group and is a polyol with a caloric value of 2.4 kcal per g. This sweetener is often used in food products and accepted by consumers. Compared to sucrose, sorbitol has a relative sweetening index of 0.5 and it is also suitable for diabetics as it does not result in an increase in blood glucose or insulin secretion.[25,57] This polyol is also heat stable and highly soluble in water.[57] Partly substitution of sucrose by sorbitol in mango jam did not affect the sensory quality, but resulted into a weaker pectin network.[9] Another drawback of sorbitol is its side-effects such as laxative, diuretic and gastrointestinal effects when consuming an excessive amount, more than 50 g per day.[9,25]

1.3 Aim and research approach

The aim of this research is to assess the acceptance of elderly towards low sugar, protein-enriched fruit spreads. This is studied in two steps. First, protein-enriched fruit spreads in which sugar is partially replaced by sorbitol will be developed and selected for the consumer study based on the outcomes of a sensory test. Furthermore, the colour, TSS and spreadability will be measured because they might be influenced by the replacement of sugar by sorbitol and the addition of proteins. Other important aspects to check will be the water activity (**a_w**) and pH, both play a role in prevention of microbial growth. The second step will be a consumer study with at least 75 elderly above 70 years who consume jam. In this consumer study the overall liking of the fruit spreads will be evaluated to assess the acceptance of this target group. Also their willingness to consume the fruit spreads again will be asked.

Chapter 2: Material and methods

2.1 Material

2.1.1 Raw ingredients

At the moment of conducting the experiments, fresh fruit was not available and frozen fruits were used although they might have an influence on the sensory and physical properties of jam.[73] Nevertheless, frozen fruits have a more constant quality and are always available. Frozen strawberries, blueberries, raspberries and blackberries were from the *Albert Heijn* (Zaandam, The Netherlands) and were stored in a freezer at -18 °C.

Sugar from the brand *Van Gilse* was produced by *Suiker Unie* (Oud Gastel, The Netherlands). *Brouwmarkt* (Almere, The Netherlands) provided the sorbitol powder with a relative sweetening index of 0.5. The lemon juice was made by *Polenghi* (Milan, Italy) and consisted of 99.81% lemon juice, lemon oil and potassium metabisulphite. *Geleipoeder* (**GP**) from *Van Gilse* (Oud Gastel, The Netherlands) was used as a thickening agent and has following ingredients: fructose, pectin, citric acid, sorbic acid and vegetable oil (coconut and palm kernel oil). The vegetable oil (< 0.01%) is used as an ingredient in GP to prevent separation of pectin and sugar. Another thickening agent used in the fruit spreads was LM pectin derived from apples and combined with calcium citrate which were both provided by *Dragonspice Naturwaren* (Reutlingen, Germany).

The protein Simplesse®100 with a protein content of 53% was produced by *CP Kelco* (Lille Skensved, Denmark). Simplesse®100 is a microparticulated whey protein concentrate and often used as a fat replacer. This protein is also more stable than WPI and can withstand ultra-high temperature processing according to its producer. The second protein, soy protein isolate (**SPI**) with a protein content of 90%, was provided by Dutch Protein Service (Tiel, The Netherlands). The last protein, whey protein isolate (**WPI**) with a protein content of 90%, was produced by *Davisco Foods International* (Le Sueur, USA). Two artificial forest fruit flavours were added to the protein-enriched fruit spreads: *Patidess Forest Fruits* produced by *Gelatti BV* (Oldenzaal, The Netherlands) and *Decora Aroma mirtillo* produced by *Karma S.r.l.* (Salerno, Italy). Additionally, two natural flavours were added to the fruit spreads, namely a strawberry and a blueberry flavour from *LorAnn Oils* (Michigan, USA).

In the consumer study, each fruit spread (3.75 g) was presented on a quarter of a natural Dutch toast from the *Albert Heijn* (Zaandam, The Netherlands) on which unsalted butter (1.25 g), *Botergoud,* from *Campina* (Amersfoort, The Netherlands) was spread.

2.1.2 Forest fruit spreads

Four fruit spreads were developed and evaluated in the consumer study with elderly (**Table 1**). Two of the four samples were not enriched with proteins and in one of these samples 25% sugar was replaced by sorbitol. Both samples were reference samples to know whether addition of sorbitol influenced the degree of liking of the low sugar, protein-enriched forest fruit spreads. The other two fruit spreads in which sugar was replaced by 25% sorbitol, were enriched with proteins. One of those fruit spreads had a higher concentration of proteins (11.25% WPI) than the other fruit spread (5% WPI) in order to know what the effect of a higher amount of proteins on the acceptance was.

Table 1. Four fruit spreads which were developed and tested in this research.

	Fruit spread
1	100% sugar
2	25% sorbitol
3	25% sorbitol and 5% WPI
4	25% sorbitol and 11.25% WPI

2.2 Methods

2.2.1 Development of low sugar, protein-enriched forest fruit spreads

The development of the low sugar, protein-enriched fruit spreads and low sugar fruit spreads consisted of many optimisation steps which are summarised below (**Appendix II**). This development started with finding the right fruit composition. This means finding the fruit composition which gave an attractive colour and a fruity flavour since both quality attributes were influenced when adding proteins. The fruit spread made with strawberries, blueberries, raspberry juice and blackberry juice had the most acceptable composition according to the researcher. Afterwards two thickening agents, LM pectin and GP, were tested and GP gave the best result in the time frame of this research.

Not only the addition of proteins but also lowering the sugar amount in the fruit spreads was a goal of this research. The sugar level was decreased to 20%, the lowest level according to the guidelines of the producer of GP, and then partly replaced by sorbitol. Five fruit spreads with different amounts of sugar and/or sorbitol were chosen to use in further experiments: 100% sugar, 75% sugar-25% sorbitol, 50% sugar-50% sorbitol, 25% sugar-75% sorbitol and 100% sorbitol. Although the goal was to partly replace sugar by sorbitol, fruit spreads with only sugar or sorbitol were made as well to have more complete results. To the five fruit spreads, three types of proteins in different concentrations were added:

Simplesse®100, SPI and WPI. The fruit spreads enriched with SPI were not further optimised. Since SPI absorbs as twice as much water than WPI, SPI had to be dissolved in water before adding to the fruit spreads which resulted in a less fruity flavour.[74,84] Of all fruit spreads the quality attributes (TSS, colour and texture) were measured. Only the fruit spreads in which sugar was partly replaced by sorbitol, were assessed in a sensory test because the aim of this research was to partly replace sugar by sorbitol. In this sensory test the participants were asked to evaluate the samples on a just-about-right (**JAR**) scale and give liking scores for different attributes.

First, the protein-enriched fruit spreads were made with 5% WPI and 3.62% GP. The amount of GP was based on the guidelines of its producer. However, these fruit spreads were too thick and less GP, 2.66%, was added in the next optimisation step. This amount was more optimal. The fruit spreads enriched with 5% Simplesse®100 were also made with 3.62% GP, but were considered as right in thickness by the participants in the sensory test. Both proteins were also added in a concentration of 10% to the fruit spreads. The fruit spreads enriched with 10% WPI and made with 1.90% GP had the right thickness but were not fruity enough according to the participants. Therefore, 0.015% strawberry and 0.015% blueberry flavour were added and the liking of the fruit spreads increased compared to the fruit spreads without added flavours. The fruit spreads enriched with 10% Simplesse®100 and made with 2.52% GP contained white clumps because Simplesse®100 was not well dissolved. These white clumps were noticed by the participants and therefore, no further optimisation was carried out with Simplesse®100.

Because the fruit spreads in which sugar was replaced by 50% of sorbitol were too sour according to the participants and there is a big gap between replacement of sugar by 25% and 50% sorbitol, four additional sorbitol concentrations were tested: 25%, 31.25%, 37.5% and 43.75% sorbitol. This was done with the fruit spreads enriched with 5% WPI because higher concentrations of WPI could mask the sourness and the protein-enriched fruit spreads in the consumer study had to have equal amounts of sorbitol to know the effect on liking when increasing the amount of WPI. Furthermore, 0.005% strawberry and 0.005% blueberry flavour were added to these fruit spreads to increase the fruity flavour intensity which was decreased by addition of proteins. In the sensory test of these four fruit spreads, the fruit spread made with 25% sorbitol was liked the most.

In the final optimisation step of the protein-enriched fruit spreads, higher amounts of WPI were added to the fruit spread with 25% sorbitol: 11.25%, 12.5%, 13.75% and 15% WPI. Although the fruit spread enriched with 10% WPI got slightly higher liking scores, the fruit spread enriched with 11.25% WPI was chosen for the consumer study. Thus, the selected protein-enriched fruit spreads for the consumer

study were the fruit spreads in which sugar was replaced by 25% sorbitol and enriched with 5% and 11.25% WPI.

Also two fruit spreads which were not enriched with proteins were developed to be evaluated in the consumer study. First, the fruit spreads with 100% sugar, 25% sorbitol, 50% sorbitol, 75% sorbitol and 100% sorbitol were made with 3.81% GP. The amount of this thickening agent was based on the guidelines of its producer. However, the fruit spreads were too thick and the amount of GP was lowered. Due time restrictions the further optimisation was done on the fruit spreads with 100% sugar and 25% sorbitol. These fruit spreads were chosen because the purpose of them was to find out whether the liking was influenced by the replacement of sugar by sorbitol and 25% sorbitol was the selected amount of sorbitol for the protein-enriched fruit spreads in the consumer study. The first fruit spread with 100% sugar was made with 3.22% GP but was too thick and the concentration of GP was lowered to 2.52% which had a good thickness. The same was done for the fruit spread with 25% sorbitol: the first concentration of GP, namely 3.14%, was too much and was lowered to 2.46% which gave the right thickness. Thus, the selected reference fruit spreads for the consumer study were 100% sugar made with 2.52% GP and 25% sorbitol made with 2.46% GP.

2.2.2 Preparation of low sugar, protein-enriched forest fruit spreads

First, raspberries and blackberries were sieved (mesh diameter of 2 mm) to separate the seeds and juice. The seeds of these berries might stick between the teeth of elderly. Strawberries which were cut in pieces and blueberries which were cut in half, were mixed with the raspberry, blackberry and lemon juice. This mixture was cooked for 10 minutes at 90 °C in an open pot while continuously stirring. GP was mixed with sugar and/or sorbitol to avoid clumping and afterwards added to the boiling mixture of fruits.[30] After 2 minutes of pectin hydration, the pot was taken from the heat and cooled down. At 60 °C the proteins were slowly added while stirring gently and afterwards blueberry and strawberry flavours were added. Those two last steps were not done when the fruit spreads were not enriched with proteins.

2.2.3 Measurement of quality attributes

TSS

TSS, expressed in °Brix, of the fruit spreads was determined with the refractometer HI96801 (Hanna Instruments BV, Nieuwegein, The Netherlands). These measurements were carried out in triplicate at room temperature on the day after preparing the fruit spreads.

Colour

The colour of the fruit spreads was evaluated by the ColorFlex© EZ (HunterLab, Reston, USA) in which the colour coordinates were obtained from a 10° observer and D65 illuminant. This device was standardised with a black and white tile (L* = 93.18, a* = -1.10, b* = 1.23) provided by HunterLab, and a green tile (L* = 53.34, a* = -25.53, b* = 12.87) was used as control measurement. After standardisation, each cuvette was filled for 0.5 cm with a fruit spread and the parameters L*, a* and b* were reported. Within the CIELAB colour system, L* which constitutes the vertical axis of a three-dimensional colour space, ranges from 0 (black) to 100 (white). The colour parameters of chromaticity, a* and b*, characterise the horizontal axes in the colour space. Positive values of respectively a* and b* indicate respectively red and yellow. Negative values of a* indicate green and negative values of b* blue.[87] Also the colour measurements were done in triplicate by rotation of a sample in three different positions at room temperature on the day after preparing the fruit spreads.

Texture

The textural properties of the fruit spreads were measured using the TA.XT. Plus Texture Analyser (Stable Microsystems, Sprundel, The Netherlands). Spreadability is an important attribute of fruit spreads because they are spread on bread or Dutch toasts. This attribute includes hardness, stickiness, work of shear and work of adhesion.[9] Because the spreadability probe (perspex conical) was not available in the laboratory, the different textural properties were measured using a compression probe with a diameter of 1 cm.

Prior to the experiment, force calibration was done to standardise the instrument. The TA.XT. Plus Texture Analyser was operated at trigger button with a 5 kg load cell and a pre-test speed of 1 mm per second. When the trigger force of 0.05 N was achieved, the probe proceeds to penetrate the sample at a test speed of 1 mm per second to a distance of 15 mm. After reaching this depth, the probe was withdrawn from the sample at a post-speed of 10 mm per second. The maximum and minimum force, and the positive and negative area under the graph were recorded by the program Texture Exponent 32 (Stable Microsystems, Sprundel, The Netherlands). The maximum force which was measured at 15 seconds, is the force that the probe needed to penetrate the fruit spread with a depth of 15 mm and represented the hardness of the fruit spread. The minimum force was measured at the first peak after 15 seconds and gave an indication of the stickiness of the fruit spread. The positive area was a measure for the work of shear, and the negative for the work of adhesion. The day before analysing, the fruit spreads were prepared and poured warm in a small salad cup. The probe penetrated the sample at three different points near the centre of the fruit spread in the plastic cup. These measurements were performed in triplicate at room temperature.

2.2.4 Sensory test during the development and optimisation stage

The sensory test during the development and optimisation stage of the low sugar, protein-enriched fruit spreads was carried out by participants who were chosen via convenience sampling. This means that the selection was steered by the ease of accessibility. The test took place on different days in a cafeteria at the Wageningen University and Research. Depending on the progress of the research, the participants had to taste between three and twelve samples during a tasting session.

At least 15 minutes before the sensory test started, the fruit spreads were put at room temperature to enhance the perception of volatile flavours.[46] The samples were coded with a random three-digit number and presented in completely randomised order in a monadic sequence.[46,49] Because the most consumed breakfast of Dutch elderly is a Dutch toast with jam and margarine or butter, the fruit spreads were spread by the participants on a quarter of a Dutch toast. The amount of fruit spread on this quarter was chosen by the participant. Water was drunk by subjects between tasting different samples in order to clean their palate.[46]

In an optimisation process, JAR scales are used because they combine the intensity and hedonic judgments on a specific attribute and give direct information about what to optimise. The end anchors of the scale are “Too little” and “Too much” and the centre point can be labelled as JAR.[46] The questionnaire consisted of eight questions and a space to give comments about the fruit spreads (**Appendix III**). First, the participants rated the liking of a specific attribute on a nine-point hedonic scale (from one = dislike extremely to nine = like extremely). After assessing the liking of an attribute, they evaluated this attribute on a five-point JAR scale. The following attributes were rated: spreadability, viscosity (JAR), appearance, odour, fruitiness odour (JAR), taste and fruitiness taste (JAR). The attribute mouthfeel was left out because the Dutch toast made it hard to assess this attribute. The last question of the questionnaire was about the overall liking which was also evaluated on a nine-point hedonic scale (from one = dislike extremely to nine = like extremely). Normally this question is the first question because the flow of a questionnaire goes from more general to specific. When asking the more specific questions first, the participants may try to figure out what the issues are and take them into account when rating the samples on overall liking. They might give a false importance to certain attributes.[46] However, in this sensory test it was not possible to start with this question as the participants had to spread the fruit spreads on the Dutch toast by themselves. Therefore, first the spreadability was evaluated on liking and JAR scales.

2.2.5 Measurement of pH and a_w

The pH and a_w are both important to know to prevent microbial growth.[1] Additionally, the pH plays a role in the network forming between pectin and proteins.[77] The a_w of the fruit spreads was determined at a temperature of 25 °C by LabMaster-a_w (Novasina AG, Lachen, Germany). When the a_w was stable for 1 minute and the temperature for 2 minutes, the final a_w was reached. The pH was measured in 5 g of a fruit spread with pHenomenal® pH 1000 L (VWR, Amsterdam, The Netherlands) at room temperature. Both measurements were performed in triplicate on the day after preparing the spreads.

2.2.6 Determination of dry matter content

The dry matter content of the ingredients and fruit spreads was determined. First, aluminium boxes were heated for 30 minutes at 100 °C in a drying oven with forced convection (VWR, Amsterdam, The Netherlands). Then the boxes were cooled in the excicator for 20 minutes, weighed and filled with 1 g sample. The relative wet samples were mixed with 0.1 to 0.5 g sea sand to prevent film forming during drying. Afterwards, the samples were dried in oven at 100 °C during night, followed by 1 hour in the excicator. The dry matter content was calculated using formula (**2.1**). This procedure was carried out in triplicate.

$$\text{Dry matter (\%)} = 100 - \frac{\text{Weight box and sample before drying (g)} - \text{Weight box and sample after drying (g)}}{\text{Weight sample before drying (g)}} \cdot 100 \quad (\mathbf{2.1})$$

2.2.7 Consumer study

Hedonic analysis of the four fruit spreads was carried out by 90 Dutch independently living elderly who were recruited via convenience sampling. The sensory test was conducted at the place where the elderly were living, passing by or gathering together. Dependent on the situation, elderly were seated at the same table or face-to-face interviews were used. Furthermore, the participants were naive and only knew that the study was about fruit spreads.

The fruit spreads were taken out of the fridge at least 15 minutes before the start of the sensory test in order to enhance the perception of volatile flavours.[46] As mentioned before, the most consumed breakfast by elderly in The Netherlands is a Dutch toast with jam and margarine or butter. Therefore, the fruit spreads were presented on a quarter of a Dutch toast on a white plastic plate. Dependent on the preference of the participant, butter was spread on the Dutch toast as well. Each quarter of the Dutch toast contained more or less 1.25 g butter and 3.75 g fruit spread according to the suggested portion size of respectively 5 g and 15 g for a whole Dutch toast.[42] The samples were coded with a

random three-digit number and presented in completely randomised order.[46,49] Moreover, the samples were given in a monadic sequence. In between tasting of the samples, water was drunk by the subjects to clean their palate to avoid influence from the previous sample on the sensory rating of the subsequent sample.[46] In sensory tests with elderly the water drinking has to be strictly timed because they have a stronger olfactory adaptation and slower recovery.[72]

The questionnaire consisted of three main questions in a bigger font size due to possible decline of sight when aging (**Appendix IV**).[50] First, the overall liking of the fruit spreads was rated on a nine-point hedonic scale (from one = dislike extremely to nine = like extremely).[46] A category scale is particularly appropriate for studies with elderly because of their simplicity, robustness and flexibility.[34] Also a large rating scale is advised in consumer studies with elderly since they tend to rate towards the positive scale for pleasing the investigators who are taking care of them.[50] The second question was an open question: "Why do you like or dislike the fruit spread?". This question was not compulsory to be answered by the participants, because it is difficult to express why you like something. However, when they could fill in this question, it would give valuable information. The last question was about the willingness to eat the fruit spread again. After tasting all four fruit spreads, the elderly filled in some general questions about their age, gender and frequency of consuming jam.

2.2.8 Data analysis

The data analysis was done with the software R.3.2.2 (R Core Team, Vienna, Austria). The fruit spreads were analysed in triplicate in order to calculate the mean and standard deviation. For the quality attributes, a two-way analysis of variance (**ANOVA**) with a confidence level of 95%, and post hoc Tukey test were performed to determine if the fruit spreads were significantly ($p < 0.05$) different for a certain attribute.

The liking scores of the consumer study were also analysed with an ANOVA and post hoc Tukey test in order to find out which fruit spreads significantly ($p < 0.05$) differed from each other. The preferences of the participants were determined with a principal component analysis (**PCA**). The answers on the open question were analysed in a correspondence analysis (**CA**) to study a possible link between the fruit spreads and those answers. Prior to this analysis, the answers were translated to English and summarised. Also a Pearson's Chi-squared test was done to figure out whether particular associations between both categorical variables existed.[47]

Chapter 3: Development of low sugar, protein-enriched forest fruit spreads

3.1 Fruit composition

Strawberry spread is the most popular fruit spread but the addition of 5% WPI to this fruit spread resulted into an unattractive brownish colour.[43] A protein-enriched blueberry spread gave a more attractive colour but less fruity flavour than the strawberry spread. A combination of both berries was used with raspberries because of their intense fruity flavour and with blackberries because of their colour. Since the seeds of raspberries and blackberries can stick between the teeth of the elderly, they were separated from the juice by sieving. Additionally, lemon juice was added in order to get the most optimal spread (**Table 2**). This juice gave a fresher taste due to its sourness and it also lowered the pH which was important for the gelling of pectin.

Table 2. Fruits used in the low sugar, protein-enriched forest fruit spreads and the composition (%).

Fruit	Composition (%)
Strawberry	36.36
Blueberry	31.82
Raspberry juice	13.64
Blackberry juice	9.09
Lemon juice	9.09

3.2 Thickening agent

Since diabetes type two has a high prevalence in the Dutch elderly, a goal of this research was to lower the sugar level in the fruit spreads.[79] In low sugar fruit spreads LM pectin should be used as thickening agent and in order to form a network calcium citrate should be added.[51,77,80] A minimum sugar or sorbitol concentration of 20% was advised by the producer of LM pectin.

Three low sugar fruit spreads with different concentrations LM pectin and calcium citrate were made (**Table 3**). First the pH of the fruit mixture was checked before adding LM pectin together with calcium citrate and sugar. The pH is a critical parameter when using LM pectin and has to be higher than 2.8 because only dissociated carboxylic groups take part in the cross linkages to form an egg-box model.[77] The pH of the fruit mixture equalled 3.1. Based on the guidelines of the producer of LM pectin, the amounts of both ingredients in the first fruit spread were chosen. However, this fruit spread was too

thick: it was even possible to take the entire fruit spread out of its cup at once. The same situation was seen when lowering the LM pectin with 1%. Also it was not possible to mix proteins with both fruit spreads. The producer of LM pectin did not mention which kind of fruits were used to set the guidelines of the amounts of the ingredients and fruits contain a pectin level dependent on the species and maturation. Citrus fruits are high (2.80-2.99%) in pectin and berries have a low to medium (0.10-0.88%) pectin level.[7,67]

In the third fruit spread, the concentration of LM pectin and calcium citrate was further lowered. This fruit spread was not as thick as the previous two fruit spreads, but small white clumps were visible caused by calcium citrate. These clumps were supposed to disappear after a day, however they were still visible after a couple of days. The texture of this fruit spread was also more brittle compared to the previous spreads. The brittleness could be due to exceeding the optimum calcium level.[53] Because in literature is written that finding a good balance between LM pectin and calcium citrate is difficult and it was not the main goal of this research, the researcher chose to continue with GP.[77] GP is a ready-to-use thickening agent used to make homemade low sugar fruit spreads.

Table 3. Ingredients and composition (%) of the fruit spreads with different amounts of LM pectin (low methoxyl pectin) and calcium citrate.

	Composition (%) of fruit spread		
Ingredients	**1**	**2**	**3**
Fruit	75.67	76.46	77.81
Sugar	19.86	20.07	20.42
LM pectin	3.78	2.78	1.41
Calcium citrate	0.69	0.70	0.35

3.2 Sugar and sorbitol

At least 20% sugar or sorbitol had to be added to the fruit spreads when using GP. One of the goals of this research was to partly replace sugar by sorbitol. In previous research, full replacement of sugar by sorbitol resulted in less accepted fruit spreads.[9] The substitution of sugar by sorbitol was done on the basis of the mass of sugar used and the relative sweetening index of sorbitol (0.5) in order to get fruit spreads with the same level of sweetness. When 50% sugar was replaced by sorbitol, the amount of sorbitol that had to be added, equalled twice the amount of sugar to get the same perceived sweetness level. Normally a trained panel is used to get products with the same level of perceived sweetness, but this was not possible in the time frame of this research.[9]

Five fruit spreads with different amounts of sugar and/or sorbitol in which the amount of sorbitol is compensated for its relative sweetness were evaluated (**Table 4** and **Appendix V**). Due to the thickness of the fruit spreads with 75% and 100% sorbitol, it was not possible to add 5% WPI. To both fruit spreads was a higher total mass of sugar and sorbitol added compared to the other three fruit spreads and hardness increased with TSS.[9] The researcher decided to continue with the fruit spreads in which was not compensated for the relative sweetness of sorbitol. In these fruit spreads the total mass of sugar and sorbitol did not vary. So if 50% sugar was replaced by sorbitol, the amount of sorbitol that had to be added, equalled the amount of sugar. Because every fruit spread contained 20% sugar and/or sorbitol in total, the sweetness level of these fruit spreads was not the same. However, by adding less sugar and/or sorbitol it was easier to add a higher percentage of proteins. In each experiment, the proteins were added to five different fruit spreads with different sugar and/or sorbitol levels: 100% sugar, 75% sugar-25% sorbitol, 50% sugar-50% sorbitol, 25% sugar-75% sorbitol and 100% sorbitol.

Table 4. Ingredients and composition (%) of the fruit spreads made with *Geleipoeder* (GP) and with different amounts of sugar and/or sorbitol in which the amount of sorbitol is compensated for its relative sweetening index (0.5).

	Composition (%) of fruit spread with				
Ingredients	**100% sugar**	**25% sorbitol**	**50% sorbitol**	**75% sorbitol**	**100% sorbitol**
Fruit	76.19	72.56	69.32	66.25	63.49
Sugar	20.00	14.28	9.10	4.35	0.00
Sorbitol	0.00	9.53	18.12	26.09	33.33
GP	3.81	3.63	3.47	3.31	3.17

3.3 Proteins

Proteins were added to the low sugar fruit spreads at a temperature of 60 °C. At lower temperatures than 60 °C the gelation process started and it became more difficult to mix the proteins with the fruit spread.[53] Additionally, it was important not to disturb the fruit spread while the gelation process was taking place, otherwise the gel strength and texture would be impaired.[30] On the other hand, higher temperatures could decrease the protein solubility which affects the protein functionality in an unfavourable way. When proteins are heated, denaturation can occur. Denaturation results in unfolding of the structures, which subsequently causes aggregation via hydrophobic interactions.[22,59] In general, the protein solubility increases between 40 and 50 °C.[59] Not only the temperature plays an important role in protein solubility, also pH has an effect on it. Acidic pH lead to a higher denaturation temperature.[22] The pH of the fruit spread before adding the proteins equalled 2.92 (± 0.04).

The first trials of protein-enriched low sugar fruit spreads were performed with different proteins: SPI, WPI and Simplesse®100. Of each protein 5% was immediately added to the low sugar fruit spreads. Due to its high water retention capacity, it was not possible to mix the complete amount of SPI with the fruit spreads.[74,84] Therefore, SPI was first dissolved in water (20 w/w%) and then added to the low sugar fruit spreads. This resulted into fruit spreads with less fruity flavour compared to the fruit spreads to which WPI and Simplesse®100 were immediately added. Thus, the researcher decided to not continue in further experiments with SPI.

3.4 Optimisation of low sugar forest fruit spreads enriched with 5% WPI

3.4.1 Low sugar fruit spreads enriched with 5% WPI and made with 3.62% GP

Recipe

Taking into account the guidelines of the producer of GP, 3.62% GP was used to make the five fruit spreads enriched with 5% WPI (**Table 5**).

Table 5. Ingredients and composition (%) of the fruit spreads enriched with 5% whey protein isolate (WPI), made with 3.62% *Geleipoeder* (GP) and with different sugar and sorbitol concentrations (0%, 25%, 50%, 75% and 100%).

Ingredients	Composition (%)
Fruit	72.38
Sugar/sorbitol	19.00
GP	3.62
WPI	5.00

Quality attributes

TSS of the five fruit spreads did not vary significantly ($p < 0.05$). This result was expected since the same amount of soluble solids was added. The only difference between the samples was the concentration of sugar and/or sorbitol, but the total amount of both ingredients did not differ. The average TSS of all samples equalled 47.41 (± 1.92) °Brix (**Table 6**).

The most obvious change due to the addition of proteins was the change in appearance: the transparency which is a characteristic of jams, disappeared. The colour parameter L* slightly increased,

a* did not decrease nor increase and b* slightly decreased with increasing amounts of sorbitol which means that the fruit spreads became whiter and less yellow (**Table 6**).[87] In the study of Basu *et al.* (2013), the colour parameters L* and b* decreased and a* increased, so the fruit spreads became less white, less yellow and more red when replacing sugar by higher amounts of sorbitol. The researchers of this study took into account the relative sweetness index of sorbitol and this resulted not only into an increase in amount of sorbitol but also into an increase in the total amount of sorbitol and sugar. They explained that the change in colour parameters could be due to the fact of the formation of brown pigments as a result of the Maillard reactions between amino acids and sugar and/or sorbitol.[9] However, Maillard reactions are only taking place between amino acids and reducing sugars to which sorbitol and sucrose do not belong. However, in the study of Basu *et al.* (2013) in which the total concentration of sugar and sorbitol differed, more brown pigments could be formed due to a lower water activity.[61] An increased rate of Maillard reactions was seen when the water activity was lowered and the addition of higher total amounts of sugar and sorbitol would lead to a decrease in water activity.[17,61] A last explanation could be that brown pigments were formed due to caramelization reactions.[38]

The addition of proteins to the fruit spreads resulted into a more dessert, mousse like texture. The proteins probably influenced the pectin network. At a pH near or below the isoelectric point of WPI and higher than the pK_a of pectin, pectin would be attracted to the positive charged proteins. Pectin wrapped the protein particles inside strongly hydrated shells and further connected these complexes in a weak network.[77] Additionally, the hardness increased with TSS, thus with addition of proteins. The spreadability of the fruit spreads was measured with the Texture Analyser. Higher maximum force (hardness) and positive area (work of shear) indicated less spreadable fruit spreads. Also higher absolute values of the minimum force (stickiness) and negative area (stickiness) resulted into less spreadable fruit spreads.[9]

The absolute values of the textural parameters of the fruit spreads with 25% and 50% sorbitol were significantly ($p < 0.05$) higher than the absolute values of these parameters of the other fruit spreads (**Table 6**). So the first mentioned fruit spreads were less spreadable than the other fruit spreads. These results were not as expected. In previous studies was concluded that increased sorbitol concentrations led to lower hardness values. Sorbitol competed with pectin for hydrogen bonding with water which resulted in weaker junction zones and a less stable pectin network.[9] This was also seen in the study of Hyvönen and Törmä (1983) in which more pectin was added to the fruit spreads with sugar alcohols to get an acceptable texture. No systematic differences were found with increasing sorbitol concentrations for the other textural parameters in these studies.[8]

Table 6. Quality attributes (total soluble solids (TSS), colour and texture) of the fruit spreads with different amounts of sugar and/or sorbitol, enriched with 5% whey protein isolate and made with 3.62% *Geleipoeder*.

Fruit spread	TSS (°Brix)	L*	a*	b*
100% sugar	48.23 ± 0.31[a]	19.34 ± 0.10[c]	27.37 ± 0.12[a]	3.14 ± 0.22[a]
25% sorbitol	48.80 ± 1.77[a]	19.29 ± 0.07[c]	26.96 ± 0.16[b]	2.94 ± 0.20[a]
50% sorbitol	47.91 ± 0.72[a]	20.49 ± 0.05[b]	26.57 ± 0.06[c]	2.37 ± 0.11[b]
75% sorbitol	45.97 ± 0.49[a]	20.62 ± 0.03[b]	27.62 ± 0.12[a]	2.96 ± 0.15[a]
100% sorbitol	46.13 ± 3.45[a]	21.28 ± 0.07[a]	27.57 ± 0.12[a]	2.53 ± 0.21[b]
Fruit spread	**Positive area (N·s)**	**Negative area (N·s)**	**Maximum force (N)**	**Minimum force (N)**
100% sugar	11.26 ± 0.56[c]	-0.62 ± 0.06[a]	0.86 ± 0.05[d]	-0.42 ± 0.03[a]
25% sorbitol	20.86 ± 0.06[a]	-0.93 ± 0.07[b]	1.53 ± 0.01[b]	-0.69 ± 0.02[b]
50% sorbitol	22.19 ± 1.10[a]	-0.92 ± 0.06[b]	1.85 ± 0.16[a]	-0.62 ± 0.03[b]
75% sorbitol	15.50 ± 1.34[b]	-0.65 ± 0.07[a]	1.23 ± 0.15[c]	-0.48 ± 0.04[a]
100% sorbitol	16.71 ± 1.28[b]	-0.67 ± 0.08[a]	1.23 ± 0.10[c]	-0.47 ± 0.05[a]

Different letters within a column indicate significant differences according to the Tukey test ($p < 0.05$).

Sensory

The sensory test in the development and optimisation stage was conducted by five participants (four female and one male) with an average age of 33.8 (± 15.2). Due to time restriction only five participants were recruited, but sensory tests with consumers are normally done with more than 75 participants to get reliable results. Additionally, the participants had an average age less than the predetermined age of 70 years for subjects in the consumer study. After the age of 60 years the chemosensory sensitivity of humans could be impaired.[50] However, the group of elderly is also heterogeneous, thus some elderly could have similar chemosensory capacities or even better than the participants used in this sensory test. Furthermore, just increasing the flavour intensity was not a good solution for a higher food intake in elderly in some cases.[5,45,48] For those reasons, the fruit spreads were optimised according to the opinion of the five participants.

The results showed that the fruit spread with 50% sorbitol was overall the most liked fruit spread, but the spreadability of this sample was less liked among the other samples: this fruit spread was too thick according to four of the five participants. The fruit spread with 75% sorbitol was more liked for spreadability and the five participants rated the viscosity of this fruit spread as JAR (**Table 7** and **Figure 5**). Also the results of the Texture Analyser indicated that the fruit spreads with 25% and 50% sorbitol were less spreadable than the fruit spread with 75% sorbitol (**Table 6**). However, the fruit spread with

75% sorbitol had a less liked odour and taste than the two fruit spreads with lower amounts of sorbitol (**Table 7**). Furthermore, the comments of the participants pointed out that the fruit spread with 75% sorbitol was too sour.

In the next optimising step, less GP (2.66%) was added to the fruit spreads in order to decrease the viscosity. Since proteins have gelling properties, less gelling agent than recommended by the producer was probably needed.[62] However, the fruit spread with 75% sorbitol and 2.66% GP could be less liked than the fruit spread with 3.62% GP because the viscosity of the latter mentioned fruit spread was rated as optimal by all participants in this sensory test.

Table 7. Liking of the attributes (spreadability, appearance, odour and taste) and the overall liking of the fruit spreads with different amounts of sugar and sorbitol enriched with 5% whey protein isolate and made with 3.62% *Geleipoeder*, evaluated on a nine-point hedonic scale.

Fruit spread	Spreadability	Appearance	Odour	Taste	Overall liking
25% sorbitol	5.6 ± 0.6	5.6 ± 0.6	5.0 ± 1.2	6.4 ± 0.6	6.4 ± 0.6
50% sorbitol	4.6 ± 1.5	6.2 ± 0.8	5.0 ± 1.7	6.4 ± 1.1	6.6 ± 0.9
75% sorbitol	6.4 ± 0.6	6.0 ± 0.7	4.6 ± 1.1	6.0 ± 0.7	6.0 ± 1.0

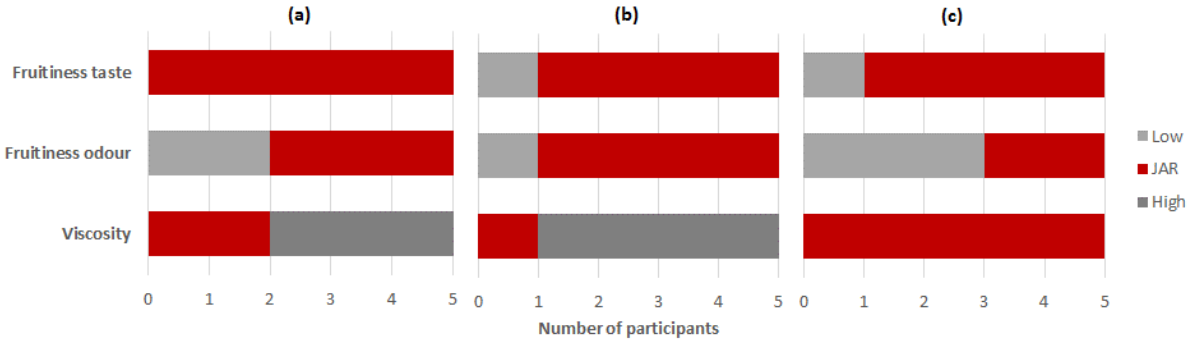

Figure 5. Number of participants that rated the fruit spreads with **(a)** 25% sorbitol, **(b)** 50% sorbitol and **(c)** 75% sorbitol enriched with 5% whey protein isolate and made with 3.62% *Geleipoeder* on a just-about-right (JAR) scale as low, JAR or high for the attributes fruitiness taste, fruitiness odour and viscosity.

3.4.2 Low sugar fruit spreads enriched with 5% WPI and made with 2.66% GP

Recipe

The following five fruit spreads enriched with 5% WPI were made with 2.66% GP (**Table 8**).

Table 8. Ingredients and composition (%) of the fruit spreads enriched with 5% whey protein isolate, made with 2.66% *Geleipoeder* (GP) and with different sugar and sorbitol concentrations (0%, 25%, 50%, 75% and 100%).

Ingredients	Composition (%)
Fruit	73.14
Sugar/sorbitol	19.20
GP	2.66
WPI	5.00

Quality attributes

The average TSS of all samples equalled 47.71 (± 1.03) °Brix, but TSS of two samples differed significantly ($p < 0.05$) (**Table 9**). This unexpected significant difference could be explained by differences in the cooking process. During some experiments the cooking plate was occupied by more students which made it more difficult to control the cooking temperature and time.

The colour parameters (L*, a*, b*) increased slightly when replacing sugar by higher concentrations of sorbitol (**Table 9**). So the fruit spreads became more white, red and yellow when adding more sorbitol.[87] The absolute values of the textural parameters of the fruit spreads with 100% sugar and 100% sorbitol were the lowest of the five fruit spreads and thus both fruit spreads were more spreadable than the other fruit spreads (**Table 9**).[9] Compared to the fruit spreads made with 3.62% GP, the positive area and maximum force decreased and thus the hardness and work of shear decreased which was expected when adding less thickening agent. The lower amount of GP led to stickier fruit spreads since the absolute values of the negative area and minimum forced increased (**Table 6** and **Table 9**).[9]

Table 9. Quality attributes (total soluble solids (TSS), colour and texture) of the fruit spreads with different amounts of sugar and/or sorbitol, enriched with 5% whey protein isolate and made with 2.66% *Geleipoeder*.

Fruit spread	TSS (°Brix)	L*	a*	b*
100% sugar	48.23 ± 0.90[ab]	20.64 ± 0.03[b]	26.19 ± 0.09[b]	0.80 ± 0.12[c]
25% sorbitol	46.87 ± 0.64[ab]	19.41 ± 0.03[d]	28.07 ± 0.04[b]	1.48 ± 0.23[a]
50% sorbitol	48.20 ± 0.87[ab]	20.51 ± 0.04[c]	28.89 ± 0.12[a]	1.73 ± 0.12[a]
75% sorbitol	48.63 ± 0.59[a]	22.86 ± 0.06[a]	28.78 ± 0.09[a]	1.36 ± 0.11[ab]
100% sorbitol	46.60 ± 0.35[b]	22.91 ± 0.04[a]	27.97 ± 0.10[b]	0.98 ± 0.09[bc]
Fruit spread	**Positive area (N·s)**	**Negative area (N·s)**	**Maximum force (N)**	**Minimum force (N)**
100% sugar	7.93 ± 0.69[c]	-0.46 ± 0.04[a]	0.69 ± 0.02[c]	-0.35 ± 0.02[a]
25% sorbitol	11.05 ± 0.41[b]	-0.62 ± 0.05[bc]	0.91 ± 0.03[b]	-0.46 ± 0.03[b]
50% sorbitol	12.85 ± 0.28[a]	-0.67 ± 0.04[c]	1.09 ± 0.04[a]	-0.48 ± 0.02[b]
75% sorbitol	13.12 ± 0.71[a]	-0.66 ± 0.01[c]	1.04 ± 0.10[ab]	-0.47 ± 0.02[b]
100% sorbitol	9.62 ± 0.66[b]	-0.52 ± 0.05[ab]	0.72 ± 0.07[c]	-0.36 ± 0.05[a]

Different letters within a column indicate significant differences according to the Tukey test ($p < 0.05$).

Sensory

The overall most liked fruit spread was the fruit spread with 25% sorbitol which had also the highest score for all attributes except for odour (**Table 10**). The odour of this fruit spread was perceived as not fruity enough by three of the five participants. The same was seen for the fruit spreads with 50% and 75% sorbitol. Also the taste of those two fruit spreads was perceived as not fruity enough and too sour according to the comments of the participants (**Figure 6**). Three of the five participants pointed out that the fruit spreads with 50% and 75% sorbitol were more glossy than the fruit spread with 25% sorbitol. This phenomenon was also seen in confectionery products: addition of a higher amount of sorbitol to a gelling agent, led to products with more gloss.[31]

The overall liking of the fruit spreads with 2.66% GP decreased compared to the fruit spreads made with 3.62% GP, but the liking scores of spreadability increased (**Table 7** and **Table 10**). Meanwhile, more participants rated the fruit spread with 75% sorbitol and 2.66% GP as too high in viscosity compared to the fruit spread with 75% sorbitol and 3.62% GP (**Figure 5** and **Figure 6**). Because of these inconsistent results and the fruit spread with 25% sorbitol was rated as JAR in viscosity by the majority of the participants and was not too sour, the concentration GP was not further lowered.

Table 10. Liking of the attributes (spreadability, appearance, odour and taste) and the overall liking of the fruit spreads with different amounts of sugar and sorbitol enriched with 5% whey protein isolate and made with 2.66% *Geleipoeder*, evaluated on a nine-point hedonic scale.

Fruit spread	Spreadability	Appearance	Odour	Taste	Overall liking
25% sorbitol	5.6 ± 0.9	6.0 ± 0.0	4.6 ± 0.9	6.0 ± 1.2	6.2 ± 0.5
50% sorbitol	5.4 ± 0.9	5.6 ± 0.9	5.2 ± 1.5	5.4 ± 1.5	6.0 ± 0.7
75% sorbitol	5.4 ± 0.9	5.2 ± 1.3	5.0 ± 1.2	5.8 ± 1.5	6.0 ± 1.4

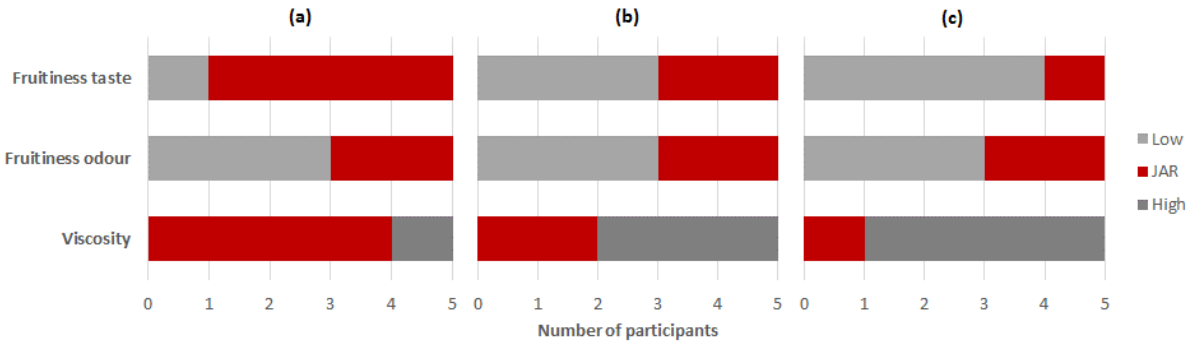

Figure 6. Number of participants that rated the fruit spreads with **(a)** 25% sorbitol, **(b)** 50% sorbitol and **(c)** 75% sorbitol enriched with 5% whey protein isolate and made with 2.66% *Geleipoeder* on a just-about-right (JAR) scale as low, JAR or high for the attributes fruitiness taste, fruitiness odour and viscosity.

3.5 Optimisation of low sugar forest fruit spreads enriched with 5% Simplesse®100

Recipe

Besides 5% WPI, 5% Simplesse®100 was also added to the five fruit spreads with different amounts of sugar and/or sorbitol (**Table 11**). The amount of GP was chosen based on the guidelines of its producer. Simplesse®100 would withstand more extreme conditions than WPI. However, the addition of Simplesse®100 led to visible white clumps in the fruit spreads (**Figure 7**). The consumers would maybe think that these clumps were the seeds of fruit, so the researcher decided to continue with the evaluation of these spreads.

Quality attributes

The average TSS of the five fruit spreads was 47.95 (± 1.34) °Brix. No systematic differences between the colour parameters of the fruit spreads were found when replacing sugar by increasing amounts of sorbitol. The textural parameters of the fruit spreads with 100% sugar, 25% and 50% sorbitol and the

Table 11. Ingredients and composition (%) of the fruit spreads enriched with 5% Simplesse®100, made *Geleipoeder* (GP) and with different sugar and sorbitol concentrations (0%, 25%, 50%, 75% and 100%).

Ingredients	Composition (%)
Fruit	72.38
Sugar/sorbitol	19.00
GP	3.62
Simplesse®100	5.00

Figure 7. Fruit spread with 25% sorbitol and enriched with 5% Simplesse®100.

fruit spreads with 75% and 100% sorbitol differed significantly ($p < 0.05$) (**Table 12**). The two fruit spreads with the highest concentration of sorbitol were less spreadable than the other fruit spreads.[9]

Compared to the fruit spreads enriched with 5% WPI, L* decreased and b* increased so the fruit spreads with Simplesse®100 were less white and more yellow.[87] An explanation for the fact that the fruit spreads enriched with 5% Simplesse®100 were less white than the fruit spreads enriched with 5% WPI, could be that Simplesse®100 was not as well dissolved as WPI in the fruit spreads. The absolute values of the textural parameters slightly increased when replacing 5% WPI by 5% Simplesse®100, so the fruit spreads enriched with 5% Simplesse®100 were less spreadable than the fruit spreads enriched with 5% WPI (**Table 9** and **Table 12**).[9]

Sensory

The fruit spread with 25% sorbitol was overall the most liked (**Table 13**). Only one participant of the five rated the fruitiness odour as too low for all three fruit spreads (**Figure 8**). This is an improvement compared to the fruit spreads enriched with 5% WPI which were perceived as not fruity enough (**Figure 6**). However, the overall liking of the fruit spreads enriched with 5% Simplesse®100 decreased in comparison with the fruit spreads enriched with 5% WPI (**Table 10** and **Table 13**). As expected the participants thought that the white clumps were seeds of fruit. This could be the reason why they evaluated these fruit spreads as fruitier than the fruit spreads enriched with 5% WPI: they thought that

Table 12. Quality attributes (total soluble solids (TSS), colour and texture) of the fruit spreads with different amounts of sugar and/or sorbitol, enriched with 5% Simplesse®100.

Fruit spread	TSS (°Brix)	L*	a*	b*
100% sugar	47.10 ± 0.00[cd]	15.31 ± 0.11[b]	27.82 ± 0.08[a]	4.65 ± 0.17[b]
25% sorbitol	46.63 ± 0.42[d]	13.17 ± 0.07[e]	27.09 ± 0.11[b]	4.49 ± 0.14[b]
50% sorbitol	47.93 ± 0.38[b]	13.46 ± 0.09[d]	27.00 ± 0.10[b]	5.46 ± 0.09[a]
75% sorbitol	50.33 ± 0.15[a]	16.15 ± 0.05[a]	27.97 ± 0.07[a]	4.68 ± 0.27[b]
100% sorbitol	47.77 ± 0.06[bc]	14.18 ± 0.09[c]	25.86 ± 0.10[c]	4.26 ± 0.16[b]
Fruit spread	**Positive area (N·s)**	**Negative area (N·s)**	**Maximum force (N)**	**Minimum force (N)**
100% sugar	9.38 ± 0.49[b]	-0.55 ± 0.02[a]	0.74 ± 0.02[b]	-0.40 ± 0.02[a]
25% sorbitol	10.10 ± 1.09[b]	-0.50 ± 0.19[a]	0.90 ± 0.20[b]	-0.44 ± 0.03[a]
50% sorbitol	11.53 ± 1.13[b]	-0.54 ± 0.04[a]	0.94 ± 0.07[b]	-0.45 ± 0.01[a]
75% sorbitol	19.29 ± 0.64[a]	-0.73 ± 0.11[a]	1.59 ± 0.09[a]	-0.64 ± 0.07[b]
100% sorbitol	20.77 ± 1.25[a]	-0.79 ± 0.13[a]	1.74 ± 0.23[a]	-0.65 ± 0.08[b]

Different letters within a column indicate significant differences according to the Tukey test ($p < 0.05$).

they saw fruit seeds so the fruit spreads should be made with a lot of fruit. Additionally, the viscosity was more times evaluated as JAR than the fruit spreads enriched with 5% WPI and the same amount of GP (**Figure 6** and **Figure 8**). This could be explained by the fact that Simplesse®100 was less dissolved than WPI.

Table 13. Liking of the attributes (spreadability, appearance, odour and taste) and the overall liking of the fruit spreads with different amounts of sugar and/or sorbitol enriched with 5% Simplesse®100.

Fruit spread	Spreadability	Appearance	Odour	Taste	Overall liking
25% sorbitol	6.0 ± 1.0	5.4 ± 0.9	5.6 ± 0.9	5.4 ± 0.9	5.6 ± 1.1
50% sorbitol	5.0 ± 0.7	5.2 ± 1.3	5.4 ± 0.9	5.2 ± 1.3	4.8 ± 1.5
75% sorbitol	3.6 ± 0.9	4.4 ± 1.1	4.2 ± 0.8	5.8 ± 1.1	5.0 ± 1.4

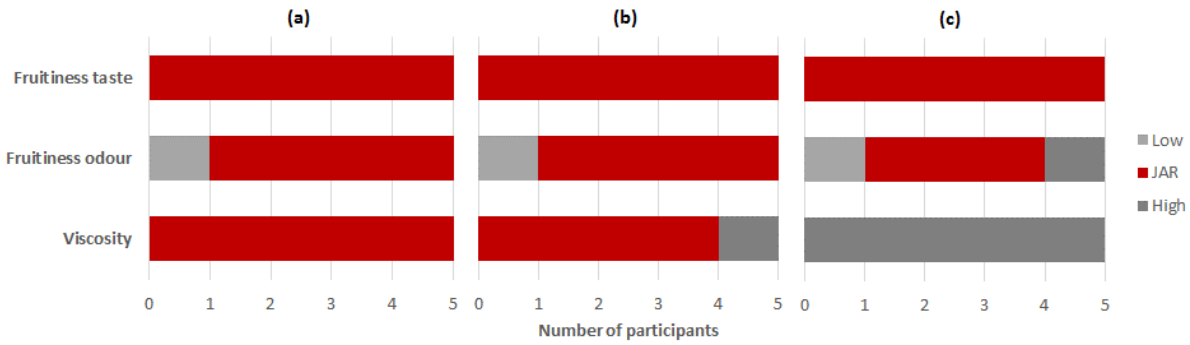

Figure 8. Number of participants that rated the fruit spreads with **(a)** 25% sorbitol, **(b)** 50% sorbitol and **(c)** 75% sorbitol enriched with 5% Simplesse®100 on a just-about-right (JAR) scale as low, JAR or high for the attributes fruitiness taste, fruitiness odour and viscosity.

3.6 Optimisation of low sugar forest fruit spreads enriched with 10% WPI

Recipe

Less GP was added to the fruit spreads enriched with 10% WPI compared to the fruit spreads enriched with 5% WPI as proteins have gelling properties (**Table 14**).[62] Prior to developing these fruit spreads, fruit spreads enriched with 7.5% WPI were made and evaluated (**Appendix VI**).

Table 14. Ingredients and composition (%) of the fruit spreads enriched with 10% whey protein isolate (WPI), made with 1.90% *Geleipoeder* (GP) and with different sugar and sorbitol concentrations (0%, 25%, 50%, 75% and 100%).

Ingredients	Composition (%)
Fruit	69.78
Sugar/sorbitol	18.32
GP	1.90
WPI	10.00

Quality attributes

The average TSS of the five fruit spreads was 51.25 (± 1.90) °Brix. The colour parameter L* did not increase nor decrease with higher amounts of sorbitol, but the colour parameter a* increased and b* decreased (**Table 15**). This means that the fruit spreads became more red and blue when replacing sugar by higher sorbitol concentrations.[87] The absolute values of the textural parameters of the fruit spread with 100% sorbitol were significantly ($p < 0.05$) lower than the absolute values of these

parameters of the other fruit spreads (**Table 15**). Thus the fruit spread with 100% sorbitol was less spreadable.[9]

As expected the average TSS of the fruit spreads enriched with 10% WPI increased in comparison to the spreads enriched with 5% WPI. This increase in WPI also resulted into an increase of L*, a decrease of a* and b* became negative (**Table 9** and **Table 15**). Thus the fruit spreads enriched with 10% WPI were whiter, less red and more blue than the fruit spreads enriched with 5% WPI which was expected.[87] The difference in colour of the fruit spreads enriched with 5% and 10% WPI was also visible to the naked eye (**Figure 9**).

When comparing the fruit spreads enriched with 10% WPI with the fruit spreads enriched with 5% WPI, no systematic differences were found for the positive area and maximum force. Although TSS increased by adding more proteins and thus it would be expected that the hardness would increase, the hardness did not increase.[9] In general, adding 10% WPI to the fruit spreads resulted into higher absolute values of the negative area and minimum force so the fruit spreads became stickier (**Table 9** and **Table 15**).[9]

Table 15. Quality attributes (total soluble solids (TSS), colour and texture) of the fruit spreads with different amounts of sugar and/or sorbitol, enriched with 10% whey protein isolate and made with 1.90% *Geleipoeder*.

Fruit spread	TSS (°Brix)	L*	a*	b*
100% sugar	51.87 ± 2.72^{a}	30.84 ± 0.19^{a}	22.87 ± 0.12^{d}	-4.12 ± 0.02^{b}
25% sorbitol	51.73 ± 0.06^{a}	27.32 ± 0.24^{c}	24.45 ± 0.16^{b}	-3.33 ± 0.08^{a}
50% sorbitol	52.37 ± 0.72^{a}	29.26 ± 0.05^{b}	24.38 ± 0.07^{b}	-4.05 ± 0.14^{b}
75% sorbitol	51.37 ± 0.15^{a}	28.89 ± 0.20^{b}	23.30 ± 0.17^{c}	-4.88 ± 0.03^{c}
100% sorbitol	48.93 ± 2.54^{a}	30.88 ± 0.04^{a}	25.68 ± 0.04^{a}	-4.89 ± 0.07^{c}
Fruit spread	**Positive area (N·s)**	**Negative area (N·s)**	**Maximum force (N)**	**Minimum force (N)**
100% sugar	12.75 ± 0.26^{a}	-0.92 ± 0.03^{c}	1.01 ± 0.03^{a}	-0.67 ± 0.01^{c}
25% sorbitol	10.82 ± 0.19^{b}	-0.77 ± 0.03^{b}	0.85 ± 0.02^{b}	-0.57 ± 0.01^{b}
50% sorbitol	13.32 ± 0.44^{a}	-0.90 ± 0.02^{c}	1.02 ± 0.03^{a}	-0.66 ± 0.00^{c}
75% sorbitol	13.39 ± 0.17^{a}	-0.94 ± 0.04^{c}	0.98 ± 0.03^{a}	-0.67 ± 0.01^{c}
100% sorbitol	6.20 ± 0.39^{c}	-0.49 ± 0.01^{a}	0.48 ± 0.07^{c}	-0.35 ± 0.01^{a}

Different letters within a column indicate significant differences according to the Tukey test ($p < 0.05$).

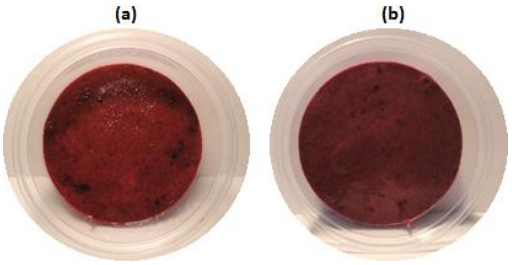

Figure 9. Fruit spreads with 25% sorbitol enriched with **(a)** 5% whey protein isolate and **(b)** 10% whey protein isolate.

Sensory

The fruit spread with 50% sorbitol was overall the most liked (**Table 16**). However, two of the five participants wrote down that this fruit spread was too sour, the other three participants liked the fresh taste. The viscosity of these fruit spreads was rated as JAR, but the fruitiness of the taste and odour was too low (**Figure 10**). When comparing with the fruit spreads enriched with 5% WPI, the overall liking decreased, probably due to the missing fruitiness of the odour and taste (**Table 10** and **Table 16**). Proteins could result into a decrease in flavour intensity and the decrease in intensity is bigger when adding more proteins.[19,78,83]

Table 16. Liking of the attributes (spreadability, appearance, odour and taste) and the overall liking of the fruit spreads with different amounts of sugar and sorbitol enriched with 10% whey protein isolate and made with 1.90% *Geleipoeder*, evaluated on a nine-point hedonic scale.

Fruit spread	Spreadability	Appearance	Odour	Taste	Overall liking
25% sorbitol	6.4 ± 0.6	6.2 ± 0.8	4.0 ± 0.7	5.0 ± 1.9	5.0 ± 1.9
50% sorbitol	6.0 ± 1.2	6.0 ± 0.7	3.8 ± 0.8	5.2 ± 1.9	5.2 ± 1.3
75% sorbitol	6.2 ± 0.5	5.8 ± 0.5	3.8 ± 0.8	4.6 ± 1.5	4.6 ± 1.5

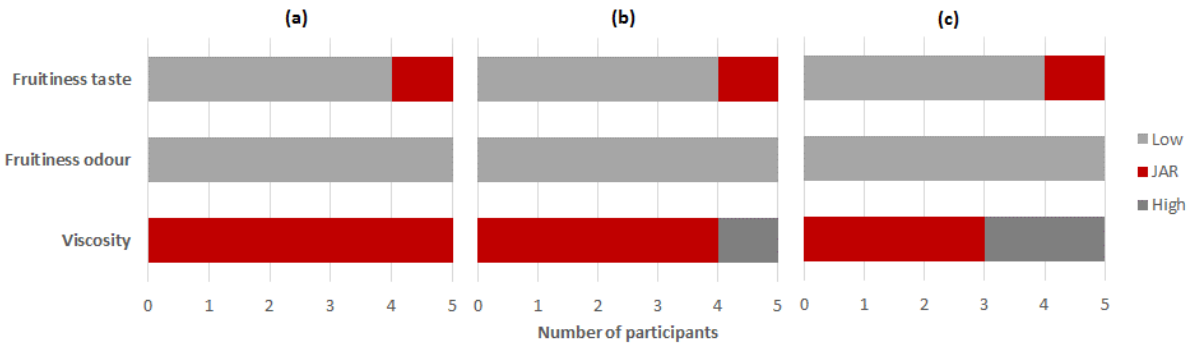

Figure 10. Number of participants that rated the fruit spreads with **(a)** 25% sorbitol, **(b)** 50% sorbitol and **(c)** 75% sorbitol enriched with 10% whey protein isolate and made with 1.90% *Geleipoeder* on a just-about-right (JAR) scale as low, JAR or high for the attributes fruitiness taste, fruitiness odour and viscosity.

To get a fruitier flavour, flavours or salt could be added. Salt is a flavour enhancer, but the participants could not taste a difference between fruit spreads enriched with 10% WPI with 25% sorbitol with or without salt. Additionally, a lot of food products should be lowered in salt level and thus salt would not be the optimal solution. Then two artificial forest fruit flavours were tested in the concentration advised by their producers. This resulted into fruit spreads with 25% sorbitol which had a candy-like taste and odour. Because no natural forest fruit flavours were available, a combination of 0.015% natural strawberry and 0.015% natural blueberry flavour was added to the fruit spread. The fruitiness of the taste and odour of the fruit spread was evaluated as JAR by four out of the five participants. The overall liking increased to 6.2 (± 1.5), the odour to 5.4 (± 1.5) and the taste to 6.4 (± 0.9). The addition of a small amount of flavours would not lead to a change in the previously tested quality attributes and therefore these attributes were not measured.

3.7 Optimisation of low sugar forest fruit spreads enriched with 10% Simplesse®100

Recipe

The next step in the development process was the addition of 10% Simplesse®100 (**Table 17**). More GP was added to these fruit spreads than to the fruit spreads enriched with 10% WPI because more GP was needed in the fruit spreads enriched with 5% Simplesse®100 than the fruit spreads enriched with 5% WPI.

Table 17. Ingredients and composition (%) of the fruit spreads enriched with 10% Simplesse®100, made with *Geleipoeder* (GP) and with different sugar and sorbitol concentrations (0%, 25%, 50%, 75% and 100%).

Ingredients	Composition (%)
Fruit	69.29
Sugar/sorbitol	18.19
GP	2.52
Simplesse®100	10.00

Quality attributes

The average TSS of the five fruit spreads is 50.93 (± 1.07) °Brix. The colour parameters L*, a* and b* did not show systematic differences with increasing amount of sorbitol. The fruit spreads with 75% and 100% sorbitol had textural parameters that were significantly ($p < 0.05$) higher in absolute terms

than those parameters of the fruit spreads with lower amounts of sorbitol (**Table 18**). So the fruit spreads with 75% and 100% sorbitol were less spreadable.[9]

In comparison with the fruit spreads with 5% Simplesse®100, L* increased, a* stayed the same and b* decreased (or became negative). Thus the fruit spreads enriched with 10% Simplesse®100 were more white and blue than those enriched with 5% Simplesse®100 (**Table 12** and **Table 18**).[87] The same was seen when comparing fruit spreads enriched with 5% and 10% WPI (**Table 9** and **Table 15**). The absolute values of the textural parameters of the fruit spreads enriched with 5% Simplesse®100 slightly increased compared to the absolute values of these textural parameters of the fruit spreads enriched with 10% Simplesse®100 (**Table 12** and **Table 18**). Thus the fruit spreads enriched with 10% Simplesse®100 were less spreadable and the increase in hardness was expected since it increases with TSS which increased with increasing protein concentration.[9]

Table 18. Quality attributes (total soluble solids (TSS), colour and texture) of the fruit spreads with different amounts of sugar and/or sorbitol, enriched with 10% Simplesse®100.

Fruit spread	TSS (°Brix)	L*	a*	b*
100% sugar	50.10 ± 1.51^{a}	20.25 ± 0.05^{b}	26.47 ± 0.08^{b}	-1.26 ± 0.19^{d}
25% sorbitol	50.00 ± 0.62^{a}	21.52 ± 0.06^{a}	27.30 ± 0.13^{a}	0.70 ± 0.03^{a}
50% sorbitol	51.47 ± 0.70^{a}	19.44 ± 0.06^{c}	26.77 ± 0.18^{b}	0.23 ± 0.14b
75% sorbitol	51.13 ± 0.61^{a}	18.88 ± 0.02^{d}	25.55 ± 0.07^{c}	-0.55 ± 0.02^{c}
100% sorbitol	51.97 ± 0.06^{a}	21.50 ± 0.01^{a}	26.61 ± 0.04^{b}	-0.59 ± 0.04^{d}
Fruit spread	**Positive area (N·s)**	**Negative area (N·s)**	**Maximum force (N)**	**Minimum force (N)**
100% sugar	10.26 ± 1.19^{c}	-0.78 ± 0.14^{a}	0.90 ± 0.06^{c}	-0.59 ± 0.06^{a}
25% sorbitol	12.09 ± 0.67^{c}	-0.61 ± 0.13^{a}	0.99 ± 0.05^{bc}	-0.52 ± 0.04^{a}
50% sorbitol	14.31 ± 0.24^{b}	-0.82 ± 0.06^{a}	1.15 ± 0.03^{b}	-0.65 ± 0.00^{a}
75% sorbitol	24.71 ± 1.63^{a}	-1.13 ± 0.23^{b}	1.78 ± 0.09^{a}	-0.90 ± 0.07^{b}
100% sorbitol	25.66 ± 1.05^{a}	-1.13 ± 0.10^{b}	1.82 ± 0.11^{a}	-0.91 ± 0.08^{b}

Different letters within a column indicate significant differences according to the Tukey test ($p < 0.05$).

Sensory

The overall liking score of the fruit spread with 50% sorbitol was the highest. As the results of the textural analysis showed: the fruit spread with 75% sorbitol was less spreadable. This fruit spread was also less times rated as JAR for the attribute viscosity (**Table 19** and **Figure 11**). The addition of extra

5% Simplesse®100 led to a decrease in liking scores especially in odour and taste (**Table 13** and **Table 19**). This decrease was also seen when adding 10% WPI instead of 5% WPI (**Table 10** and **Table 16**).

As mentioned before, the addition of 5% Simplesse®100 resulted into visible white clumps and these clumps were more visible when adding 10% Simplesse®100. In this sensory test, a comment of a participant was: "It seems that a white powder is not well dissolved in the fruit spread. I could spread out the clumps and the fruit spread became less attractive." Additionally, fruit spreads with a combination of 5% and 10% Simplesse®100 and WPI were made because Simplesse®100 seemed to give a fruitier flavour but WPI gave more attractive spreads. Although the white clumps in these fruit spreads were less visible, the participants gave again comments about a not well dissolved white powder (**Appendix VII** and **Appendix VIII**). After all, the researcher chose to further optimise the fruit spreads made with WPI since no white clumps were visible in these spreads.

Table 19. Liking of the attributes (spreadability, appearance, odour and taste) and the overall liking of the fruit spreads with different amounts of sugar and/or sorbitol enriched with 10% Simplesse®100.

Fruit spread	Spreadability	Appearance	Odour	Taste	Overall liking
25% sorbitol	6.4 ± 0.6	4.2 ± 1.8	3.2 ± 1.8	4.8 ± 2.2	4.6 ± 1.3
50% sorbitol	5.8 ± 1.1	4.8 ± 1.8	3.4 ± 1.8	4.0 ± 1.6	4.8 ± 1.3
75% sorbitol	5.0 ± 1.4	4.2 ± 1.9	3.0 ± 1.6	3.6 ± 2.1	3.8 ± 1.1

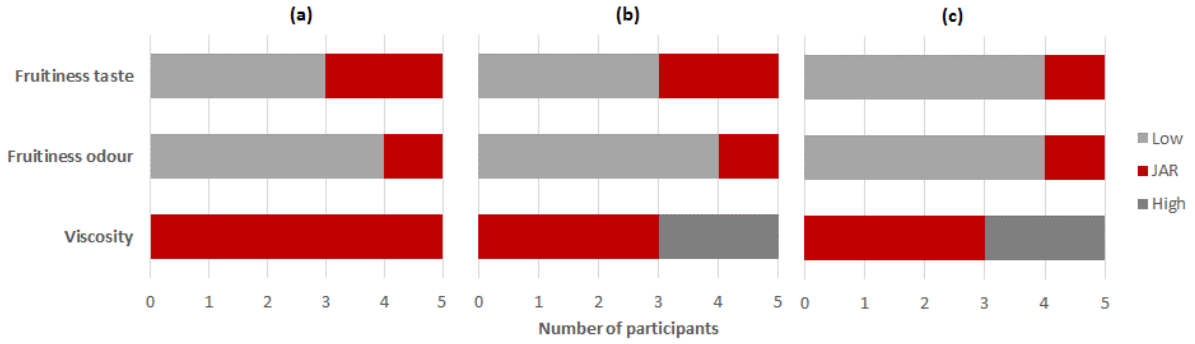

Figure 11. Number of participants that rated the fruit spreads with **(a)** 25% sorbitol, **(b)** 50% sorbitol and **(c)** 75% sorbitol enriched with 10% Simplesse®100 on a just-about-right (JAR) scale as low, JAR or high for the attributes fruitiness taste, fruitiness odour and viscosity.

3.8 Optimisation of low sugar forest spreads enriched with 5% WPI and 25-43.75% sorbitol

Recipe

The fruit spreads with 50% and 75% sorbitol enriched with 5% WPI were too sour according to the five participants in the sensory test and the fruit spread with 25% sorbitol enriched with 5% WPI was overall the most liked. Between the most liked spread and the spread that was perceived as too sour, was a gap of 25% sorbitol. Therefore, three additional fruit spreads with concentrations between 25% and 50% sorbitol were made: 31.25%, 37.5% and 43.75% sorbitol (**Table 20**). Additionally, 0.005% natural strawberry and 0.005% natural blueberry flavours were added since the fruit spreads enriched with 5% WPI were perceived as not fruity enough (**Figure 6**).

Table 20. Ingredients and composition (%) of the fruit spreads enriched with 5% whey protein isolate (WPI), made with 2.66% *Geleipoeder* (GP), with different sugar and sorbitol concentrations (0%, 25%, 50%, 75% and 100%) and flavours.

Ingredients	Composition (%)
Fruit	73.07
Sugar/sorbitol	19.26
GP	2.66
WPI	5.00
Flavours	0.01

Quality attributes

The average TSS of the fruit spreads equalled 46.37 (± 0.96) °Brix. The colour parameters L* and a* increased slightly and no systematic differences were found for b* as a consequence of replacing higher amounts of sugar by sorbitol. The absolute values of the textural parameters of the fruit spreads with 31.25% and 37.5% sorbitol were higher than the absolute values of these parameters of the fruit spreads with 25% and 43.75% sorbitol, so the first mentioned fruit spreads were less spreadable (**Table 21**).[9]

Table 21. Quality attributes (total soluble solids (TSS), colour and texture) of the fruit spreads with different amounts of sugar and sorbitol enriched with 5% whey protein isolate, made with 2.66% *Geleipoeder* and flavours.

Fruit spread	TSS (°Brix)	L*	a*	b*
25% sorbitol	46.03 ± 0.15[bc]	18.55 ± 0.03[d]	27.93 ± 0.09[b]	2.31 ± 0.23[a]
31.25% sorbitol	47.47 ± 0.67[a]	22.91 ± 0.02[a]	28.76 ± 0.16[a]	0.74 ± 0.05[c]
37.5% sorbitol	45.23 ± 0.15[c]	22.24 ± 0.04[b]	28.46 ± 0.01[a]	1.14 ± 0.05[b]
43.75% sorbitol	46.73 ± 0.29[ab]	21.72 ± 0.18[c]	28.51 ± 0.09[a]	1.32 ± 0.09[b]
Fruit spread	**Positive area (N·s)**	**Negative area (N·s)**	**Maximum force (N)**	**Minimum force (N)**
25% sorbitol	7.76 ± 0.28[b]	-0.55 ± 0.03[ab]	0.63 ± 0.03[c]	-0.39 ± 0.02[b]
31.25% sorbitol	12.67 ± 0.09[a]	-0.72 ± 0.01[c]	1.06 ± 0.06[a]	-0.54 ± 0.01[c]
37.5% sorbitol	12.21 ± 0.33[a]	-0.60 ± 0.03[b]	0.90 ± 0.02[b]	-0.43 ± 0.00[b]
43.75% sorbitol	7.21 ± 0.12[b]	-0.50 ± 0.03[a]	0.63 ± 0.02[c]	-0.35 ± 0.02[a]

Different letters within a column indicate significant differences according to the Tukey test ($p < 0.05$).

Sensory

The fruit spread with 25% sorbitol was overall the most liked and got the highest liking scores for all attributes (**Table 22**). The addition of flavours also resulted into higher liking scores (**Table 10** and **Table 22**). Besides the JAR attributes asked in the previous sensory tests, the attribute sweetness was added to the list of attributes. This was done because it was the purpose of this optimisation step to find out which concentration of sorbitol, and so which level of sweetness, was still accepted by the participants. The fruit spread with 43.75% sorbitol was too sour according to two of the five participants (**Figure 12**). This implied that based on sourness the maximum sorbitol level could be 37.5%. However, this fruit spread was less liked probably due to its lower score for spreadability (**Table 22**). No further optimisation of this fruit spread was done due to time restrictions. Additionally, elderly could have impaired chemosensory characteristics and therefore perceive the sweetness lower than the five participants did.[20] So the researcher decided to take the fruit spread with 25% sorbitol and enriched with 5% WPI as the fruit spread enriched with a lower amount of proteins in the consumer study.

Table 22. Liking of the attributes (spreadability, appearance, odour and taste) and the overall liking of the fruit spreads with different amounts of sugar and sorbitol enriched with 5% whey protein isolate, made with 2.66% *Geleipoeder* and flavours, evaluated on a nine-point hedonic scale.

Fruit spread	Spreadability	Appearance	Odour	Taste	Overall liking
25% sorbitol	6.8 ± 0.5	6.8 ± 0.5	5.6 ± 0.5	6.4 ± 1.1	6.6 ± 1.1
31.25% sorbitol	6.0 ± 1.2	6.6 ± 0.6	5.4 ± 1.1	6.4 ± 1.1	5.8 ± 0.8
37.5% sorbitol	5.6 ± 0.9	5.4 ± 0.9	4.6 ± 0.6	4.8 ± 0.8	5.6 ± 1.1
43.75% sorbitol	6.2 ± 0.5	6.0 ± 0.7	4.6 ± 0.6	5.6 ± 0.6	5.6 ± 0.6

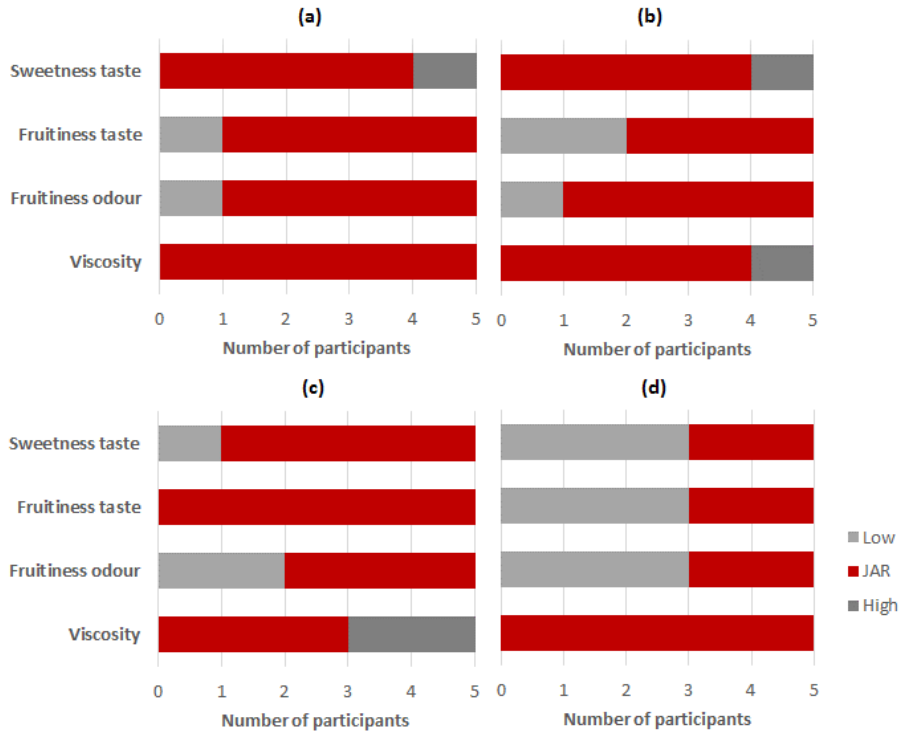

Figure 12. Number of participants that rated the fruit spreads with **(a)** 25% sorbitol, **(b)** 31.25% sorbitol, **(c)** 37.5% sorbitol and **(d)** 43.75% sorbitol enriched with 5% whey protein isolate, made with 2.66% *Geleipoeder* and flavours on a just-about-right (JAR) scale as low, JAR or high for the attributes sourness taste, fruitiness taste, fruitiness odour and viscosity.

3.9 Optimisation of low sugar forest fruit spreads enriched with 11.25%, 12.5%, 13.75% and 15% WPI

Recipe

Until now the highest concentration of WPI added to the fruit spreads was 10% WPI. To achieve a protein concentration as high as possible, four fruit spreads enriched with different high amounts of

WPI were tested: 11.25%, 12.5%, 13.75% and 15% (**Table 23**). The concentrations of GP were chosen based on the concentrations added to the previous fruit spreads enriched with WPI.

In the previous step the researcher concluded to take the fruit spread with 25% sorbitol and enriched with 5% WPI as a sample in the consumer study. The protein-enriched fruit spreads in the consumer study should have the same amount of sorbitol to find out what the effect of increasing protein concentration on liking would be. Thus, the optimisation of the fruit spreads with higher amounts of WPI was only done with fruit spreads with 25% sorbitol.

Table 23. Ingredients and composition (%) of the fruit spreads enriched with different concentrations of whey protein isolate (WPI) and made with *Geleipoeder* (GP) and 25% sorbitol.

	Composition (%) of fruit spread with			
Ingredients	**11.25% WPI**	**12.5% WPI**	**13.75% WPI**	**15% WPI**
Fruit	68.91	68.06	67.21	66.35
Sugar/sorbitol	18.09	17.87	17.64	17.42
GP	1.72	1.55	1.37	1.21
WPI	11.25	12.50	13.75	15.00
Flavours	0.03	0.02	0.02	0.02

Quality attributes

In general, TSS increased with the amount of WPI as expected. The colour parameters L* and b* increased, and a* decreased with the addition of higher amounts of WPI (**Table 24**). This means that the fruit spreads became more white, less blue and less red.[87] The absolute values of the textural parameters decreased with increasing amounts of WPI (**Table 24**). So the fruit spreads enriched with 13.75% and 15% WPI were more spreadable than the other fruit spreads.[9]

Sensory

The fruit spread enriched with 11.25% WPI was overall the most liked and had the highest liking score for every attribute (**Table 25**). This fruit spread was also evaluated by more participants as JAR than the other fruit spreads. Especially the fruitiness of the taste and odour was rated more times as not enough when increasing the amount of proteins. Furthermore, the fruit spreads enriched with 13.75% and 15% WPI were perceived as too thin which was in line with the results obtained by the Texture Analyser (**Figure 13**). The participants also commented that both fruit spreads had a chemical taste which were probably caused by the off-flavours of WPI.

Table 24. Quality attributes (total soluble solids (TSS), colour and texture) of the fruit spreads with 25% sorbitol and enriched with different concentrations of whey protein isolate (WPI).

Fruit spread	TSS (°Brix)	L*	a*	b*
11.25% WPI	54.97 ± 0.06[c]	33.72 ± 3.46[a]	22.33 ± 0.06[a]	-4.33 ± 0.05[b]
12.5% WPI	58.23 ± 0.91[b]	32.74 ± 0.10[a]	20.80 ± 0.10[b]	-4.54 ± 0.08[b]
13.75% WPI	57.50 ± 0.00[b]	35.30 ± 0.13[a]	20.20 ± 0.05[c]	-4.48 ± 0.06[b]
15% WPI	59.70 ± 0.00[a]	35.98 ± 1.23[a]	17.39 ± 0.28[d]	-3.89 ± 0.12[a]
Fruit spread	**Positive area (N·s)**	**Negative area (N·s)**	**Maximum force (N)**	**Minimum force (N)**
11.25% WPI	9.74 ± 0.60[a]	-0.79 ± 0.11[c]	0.78 ± 0.03[a]	-0.57 ± 0.09[b]
12.5% WPI	8.13 ± 0.49[b]	-0.70 ± 0.09[bc]	0.66 ± 0.05[b]	-0.50 ± 0.03[b]
13.75% WPI	4.18 ± 0.42[c]	-0.47 ± 0.14[ab]	0.35 ± 0.03[c]	-0.30 ± 0.07[a]
15% WPI	3.56 ± 0.15[c]	-0.38 ± 0.06[a]	0.32 ± 0.01[c]	-0.24 ± 0.03[a]

Different letters within a column indicate significant differences according to the Tukey test ($p < 0.05$).

Compared with the liking scores of the fruit spread enriched with 10% WPI, the overall liking and taste slightly decreased (**Table 16** and **Table 25**). Because the decrease was not so big (0.2-0.4), the fruit spread enriched with 11.25% WPI was chosen as fruit spread with the higher amount of proteins in the consumer study.

Table 25. Liking of the attributes (spreadability, appearance, odour and taste) and the overall liking of the fruit spreads with 25% sorbitol and enriched with different concentrations of whey protein isolate (WPI), evaluated on a nine-point hedonic scale.

Fruit spread	Spreadability	Appearance	Odour	Taste	Overall liking
11.25% WPI	6.6 ± 0.6	5.8 ± 0.8	5.4 ± 0.9	6.0 ± 1.2	6.0 ± 1.4
12.5% WPI	6.6 ± 0.6	5.4 ± 0.6	4.0 ± 1.0	4.4 ± 1.5	5.2 ± 1.3
13.75% WPI	4.0 ± 0.7	3.4 ± 0.6	3.6 ± 0.9	3.8 ± 1.3	4.4 ± 0.6
15% WPI	2.4 ± 0.6	1.8 ± 0.8	2.8 ± 0.8	2.2 ± 0.8	2.6 ± 1.1

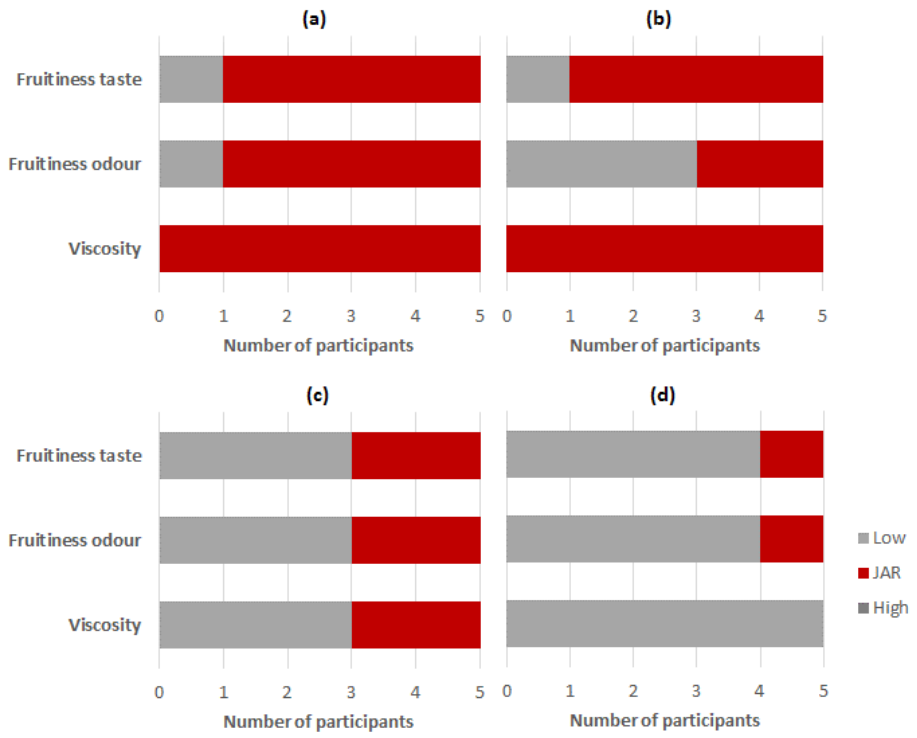

Figure 13. Number of participants that rated the fruit spreads with 25% sorbitol and enriched with **(a)** 11.25% whey protein isolate (WPI), **(b)** 12.5% WPI, **(c)** 13.75% WPI and **(d)** 15% WPI on a just-about-right (JAR) scale as low, JAR or high for the attributes fruitiness taste, fruitiness odour, and viscosity.

3.10 Optimisation of low sugar forest fruit spreads

3.10.1 Low sugar fruit spreads made with 3.81% GP

Recipe

Besides optimisation of the protein-enriched fruit spreads, the fruit spreads without protein enrichment were optimised. In these fruit spreads the amount of GP was based on the guidelines of its producer (**Table 26**).

Table 26. Ingredients and composition (%) of the fruit spreads made with 3.81% *Geleipoeder* (GP) with different sugar and sorbitol concentrations (0%, 25%, 50%, 75% and 100%).

Ingredients	Composition (%)
Fruit	76.19
Sugar/sorbitol	20.00
GP	3.81

Quality attributes

The average TSS of the fruit spreads was equal to 44.05 (± 1.93) °Brix. When sugar was replaced by increasing sorbitol concentrations, the colour parameters L*, a* and b* increased so the spreads became more white, red and yellow (**Table 27**).[87] Furthermore, the difference between the textural parameters of the fruit spread with 100% sugar and the fruit spreads in which sugar was replaced by sorbitol was significant ($p < 0.05$) (**Table 27**). The fruit spread with 100% sugar was less hard than the other fruit spreads in which sugar was replaced by sorbitol. This was not as expected because the fruit spreads with sorbitol would be less hard than the fruit spread with only sugar.[9]

In comparison with the fruit spreads enriched with 5% WPI, L* and a* decreased and b* increased. Thus the fruit spreads without enrichment of proteins were less white, red and more yellow.[87] Compared to the fruit spreads enriched with 5% WPI, the positive area and maximum force of the fruit spreads without protein enrichment were higher, and the absolute values of the negative area and minimum force were lower (**Table 6** and **Table 27**). This means that the fruit spreads without protein enrichment were harder and less sticky.[9] However, these fruit spreads were also too thick because the entire fruit spread could be taken out of its cup at once. Therefore, in the next step in the optimisation less GP was added.

Table 27 Quality attributes (total soluble solids (TSS), colour and texture) of the fruit spreads with different amounts of sugar and/or sorbitol and made with 3.81% *Geleipoeder*.

Fruit spread	TSS (°Brix)	L*	a*	b*
100% sugar	44.80 ± 1.35^{a}	3.87 ± 0.09^{d}	8.77 ± 0.12^{e}	0.41 ± 0.26^{c}
25% sorbitol	44.80 ± 1.47^{a}	6.10 ± 0.12^{b}	17.25 ± 0.24^{b}	2.61 ± 0.37^{ab}
50% sorbitol	40.77 ± 1.95^{a}	6.21 ± 0.05^{b}	16.30 ± 0.28^{c}	2.56 ± 0.11^{ab}
75% sorbitol	45.77 ± 5.82^{a}	6.91 ± 0.09^{a}	18.58 ± 0.04^{a}	3.49 ± 0.43^{a}
100% sorbitol	44.10 ± 2.48^{a}	5.56 ± 0.09^{c}	15.41 ± 0.22^{d}	2.15 ± 0.39^{b}
Fruit spread	**Positive area (N·s)**	**Negative area (N·s)**	**Maximum force (N)**	**Minimum force (N)**
100% sugar	13.06 ± 2.00^{c}	-0.49 ± 0.05^{a}	1.00 ± 0.04^{b}	-0.34 ± 0.06^{a}
25% sorbitol	24.46 ± 1.03^{a}	-0.82 ± 0.10^{b}	1.89 ± 0.16^{a}	-0.56 ± 0.01^{b}
50% sorbitol	20.83 ± 1.12^{ab}	-0.65 ± 0.02^{ab}	1.68 ± 0.09^{a}	-0.47 ± 0.05^{ab}
75% sorbitol	17.21 ± 1.16^{bc}	-0.57 ± 0.08^{a}	1.44 ± 0.31^{ab}	-0.44 ± 0.03^{ab}
100% sorbitol	20.98 ± 3.18^{ab}	-0.69 ± 0.11^{ab}	1.94 ± 0.25^{a}	-0.53 ± 0.12^{ab}

Different letters within a column indicate significant differences according to the Tukey test ($p < 0.05$).

3.10.2 Low sugar fruit spreads made with different amounts of GP

Recipe

Due to time restrictions, only the fruit spreads with 100% sugar and 25% sorbitol were analysed. The chosen protein-enriched fruit spreads contained 25% sorbitol and in order to know what the effect of the addition of proteins on the acceptance was, the reference sample and protein-enriched samples had to contain equal amounts of sorbitol. The purpose of the reference sample with 100% sugar was to find out what the effect of the replacement of sugar by sorbitol on the acceptance was. Therefore, it was decided to give the fruit spread with 100% sugar and 25% sorbitol the same perceived sweetness. Because a trained panel was not available, the relative sweetness indices of both sugar and sorbitol were taken into account to achieve the same perceived sweetness level. As a result of the previous experiment, less GP was added to the fruit spreads with 100% sugar and 25% sorbitol (**Table 28**).

Table 28. Ingredients and composition (%) of the fruit spreads with 100% sugar or 25% sorbitol and made with *Geleipoeder* (GP).

	Composition (%) of fruit spread			
Ingredients	**1**	**2**	**3**	**4**
Fruit	78.70	76.72	79.27	77.26
Sugar	18.08	15.10	18.21	15.21
Sorbitol	-	5.03	-	5.07
GP	3.22	3.14	2.52	2.46

Quality attributes

TSS of the samples did not significantly ($p > 0.05$) differ although the total amount of sugar and sorbitol was higher for the fruit spreads with 25% sorbitol. The colour parameters differed significantly ($p < 0.05$) between the fruit spreads with 100% sugar and 25% sorbitol. The absolute values of the textural parameters of the fruit spreads with 25% sorbitol were higher than the absolute values of these parameters of the fruit spreads with 100% sugar (**Table 29**). Thus the fruit spreads with 25% sorbitol were less spreadable than the fruit spreads with 100% sugar.[9]

Table 29. Quality attributes (total soluble solids (TSS), colour and texture) of the fruit spreads with 100% sugar or 25% sorbitol and made with different amounts of *Geleipoeder* (*GP*).

Fruit spread	TSS (°Brix)	L*	a*	b*
100% sugar - 3.22% *GP*	41.23 ± 4.29[a]	6.87 ± 0.02[a]	19.42 ± 0.31[a]	4.20 ± 0.18[a]
25% sorbitol - 3.14% *GP*	42.27 ± 3.87[a]	5.99 ± 0.10[b]	17.10 ± 0.25[b]	2.77 ± 0.13[bc]
100% sugar - 2.52% *GP*	48.95 ± 0.92[a]	4.41 ± 0.21[d]	12.61 ± 0.19[d]	2.01 ± 0.37[c]
25% sorbitol - 2.46% *GP*	44.40 ± 3.54[a]	5.13 ± 0.31[c]	15.29 ± 0.27[c]	3.12 ± 0.47[b]
Fruit spread	**Positive area (N·s)**	**Negative area (N·s)**	**Maximum force (N)**	**Minimum force (N)**
100% sugar - 3.22% *GP*	12.65 ± 2.47[b]	-0.45 ± 0.23[a]	1.13 ± 0.02[a]	-0.37 ± 0.13[a]
25% sorbitol - 3.14% *GP*	17.58 ± 1.70[ab]	-0.59 ± 0.23[a]	1.60 ± 0.16[a]	-0.42 ± 0.11[a]
100% sugar - 2.52% *GP*	15.38 ± 3.99[ab]	-0.57 ± 0.05[a]	1.20 ± 0.48[a]	-0.41 ± 0.08[a]
25% sorbitol - 2.46% *GP*	20.68 ± 1.91[a]	-0.88 ± 0.16[a]	1.75 ± 0.51[a]	-0.54 ± 0.00[a]

Different letters within a column indicate significant differences according to the Tukey test ($p < 0.05$).

Because of time restriction, the fruit spreads were not evaluated in a sensory test. Based on the results of the Texture Analyser and by comparing with the chosen fruit spreads enriched with proteins, the researcher chose the fruit spreads made with the lowest amount of GP for the consumer study. More GP was added to the fruit spreads enriched with proteins than to the reference fruit spreads although protein have gelling properties.[62] On the other hand, proteins could interact with pectin to form a weak network and this could result into addition of more GP.[77]

3.11 Fruit spreads of the consumer study

During the development and optimisation process, four samples were chosen for the consumer study (**Table 30**). Based on dry matter, 14.10% WPI was added to the fruit spread enriched with 5% WPI and 28.72% WPI to the fruit spread enriched with 11.25% WPI (**Appendix IX**).

In the reference fruit spreads with 100% sugar and 75% sugar-25% sorbitol were respectively 2.41% and 2.35% of the energy value provided by proteins. For the fruit spread enriched with 5% WPI equalled this value 18.87% and could be claimed that this fruit spread was a source of protein. The proteins in the fruit spread enriched with 11.25% WPI accounted for 34.51% of the energy value. Therefore, this fruit spread could be labelled as high in protein (**Appendix X**).[29]

Table 30. Ingredients and composition (%) of the fruit spreads chosen for the consumer study made with *Geleipoeder* (GP); reference fruit spreads: 100% sugar and 25% sorbitol, and protein-enriched fruit spreads: 5% and 11.25% whey protein isolate (WPI).

	Composition (%) of fruit spread			
Ingredients	**100% sugar**	**25% sorbitol**	**5% WPI**	**11.25% WPI**
Fruit	79.27	77.19	73.07	68.91
Sugar	18.21	15.44	14.61	13.70
Sorbitol	-	4.91	4.65	4.39
GP	2.52	2.46	2.66	1.72
WPI	-	-	5.00	11.25
Flavours	-	-	0.01	0.03

The pH and a_w of the four fruit spreads were measured in order to know if microbial growth was prevented. Bacteria grow the fastest in a pH range between 6 and 8, yeasts between 4 and 6 and filamentous fungi between 3.5 and 4. The limiting water activity of the growth of micro-organisms is about 0.6.[1] There was no difference in pH between the reference samples, but the pH of the protein-enriched fruit spreads was significantly ($p < 0.05$) higher (**Table 31**). Normally, the pH of a jam lays between 2.8 and 3.4.[30] The a_w of the fruit spreads did not significantly ($p < 0.05$) differ from each other, thus these spreads did not differ in amount of free water. In previous studies the a_w of jam was between 0.82 and 0.94.[1,64] Based on the pH and a_w, the fruit spreads should be stored in the refrigerator to prevent microbial growth.[1] Furthermore, the dry matter content of the fruit spreads increased with the addition of proteins as expected (**Table 31**).

The pH of protein-enriched fruit spreads suggest that pectin formed a weak network with proteins and the texture of these fruit spreads was influenced by the addition of proteins. The weak network is formed when the pH is near or below the isoelectric point and higher than the pK_a of pectin. The isoelectric point of whey proteins is at a pH of 4.5 and the pK_a of pectin is generally between 3.5 and 4.5.[77] When looking to the pH of the protein-enriched fruit spreads, a weak network between pectin and proteins could be formed and it could be an explanation why less GP was added to the reference fruit spreads than to the protein-enriched fruit spreads (**Table 31**).

Table 31. pH, water activity (aw) and dry matter content (%) of the fruit spreads chosen for the consumer study; reference fruit spreads: 100% sugar and 25% sorbitol, and protein-enriched fruit spreads: 5% and 11.25% whey protein isolate (WPI).

Fruit spread	pH	a_w	Dry matter content (%)
100% sugar	3.14 ± 0.00	0.95 ± 0.01	40.41 ± 0.48
25% sorbitol	3.15 ± 0.05	0.94 ± 0.01	42.97 ± 0.22
5% WPI	3.82 ± 0.04	0.94 ± 0.00	46.63 ± 0.29
11.25% WPI	4.51 ± 0.04	0.94 ± 0.01	52.79 ± 2.08

Chapter 4: Consumer study

4.1 Participants in the consumer study

The participants were recruited at places where they gathered together, were living or passing by. Nine different organisations for elderly and service flats were willing to help: *65+ Werkgroep* (Wageningen), *AB Zuylenstede* (Utrecht), *Beatrix* (Utrecht), *Bij Bosshardt* (Utrecht), *De Speler* (Utrecht), *Odensehuis* (Wageningen), *Oog voor Utrecht* (Utrecht), *Roosebrink* (Wageningen) and *Senioren Ontmoetingspunt Doetinchem* (Doetinchem). At most of these places activities such as knitting, crocheting and painting were taking place. Because of these kind of activities, the majority of the elderly were female. Additionally, men were less willing to participate in a research about fruit spreads because they did not like sweet food products.

In total 90 people started with filling in the questionnaire, but three of them left the test early. In literature is described that studies with elderly are characterised by a high dropping out rate. Hereby, a higher number of respondents should be recruited to reach above the desired number of completely filled in questionnaires.[50] This was not the case for this research, but the elderly had to be convinced to continue until the end of the test. So more questions or more samples would have led to a higher dropping out rate. Because of the impatience of the elderly, the last sample(s) could be rated differently than the first one(s). To avoid differences in the rating of the samples due to the order, a randomised block design was used.

Of the 87 participants who completed the test, 72 were above 70 years old and 64 of them consumed jam. The age limit of 70 years was chosen based on the interview with Nancy Janssen (**Appendix I**). For health professionals, people are called elderly when they are above 70 because on average at the age of 73 the first health accident occurs.[50] However, the most of the previous mentioned organisations allowed people above 65 years to enter their activities. Therefore, it was difficult to interview only people above 70 years. Even when the researcher told them that they had to be above 70 years, the elderly younger than 70 years participated and some of them lied about their age. For this reason, elderly above 65 years were also allowed to participate and in the data analysis was checked if the age had an influence on the results. Of the participants who completed the questionnaire, 84 were above 65 years and 75 of them consumed jam (**Appendix XI**). The average age of the participants above 65 years old equalled 77.0 (± 7.3) years and the age range was from 65 to 98 years. This age group was divided in four categories: 65-69, 70-74, 75-79, 80-84 and 85+.

As mentioned before, elderly are a heterogeneous group and two elderly of the same age may show dissimilar functional, sensory and cognitive abilities.[50] This difference was also seen between the organisations of the participants. In the *Odensehuis*, elderly in an early stage of dementia were gathering together. They were joined by a family member or volunteer to help them during filling in the questionnaire. These elderly were enthusiastic to participate and taste the fruit spreads. They could remember the taste of the previous fruit spread and how often they consumed jam. The most difficult question for them was the question about their age. Furthermore, the volunteer who was working with elderly in the community centre *De Speler* and *Beatrix*, told the researcher that the elderly from *De Speler* were feeling older compared to the elderly with the same age living somewhere else. They were aging faster because of poverty and loneliness. On the other hand, the elderly at the organisation in the community centre *Beatrix* were feeling younger and were more active than elderly of the same age somewhere else. In the data analysis, it was checked if the elderly from different organisations, evaluated the fruit spreads different.

4.2 Experimental set-up of the consumer study

The elderly were interviewed at the place where they were sitting and dependent on the situation, some elderly were seated at the same table. Sensory tests are normally taking place at sensory booths. By keeping the environment standardised in these type of booths and the participants separated during the sensory test, the respondents are less biased.[46] However, this was not possible since the elderly were not mobile and were not able to travel to the sensory booths. When the elderly were sitting at the same table, they could communicate with each other. Although it was mentioned that every participant got the samples in a different order and that their opinion was important, they talked with their neighbours: “This sample is more delicious than the previous one.” or “The second jam was the best.” These comments could influence the other participants. Also the choice of butter was influenced by the people who were seated at the same table. In most cases if one participant wanted butter on its Dutch toast, the other participants wanted the same or vice versa. The elderly were also distracted by the activities that they were doing and so less focused on tasting.

Some elderly had hearing or writing difficulties and then it was necessary to collect data via face-to-face interviews. The interviewer adapted the explanations to each individual and respected his or her own rhythm.[40,50] At least five participants thought that they had to associate the first sample with one on the nine-point hedonic scale and the second sample with two, etc. These participants were helped through the questionnaire. Hereby, the researcher could have influenced the subjects which could lead to biases and longer sessions.[50] Therefore, the interviewer also paid attention to their facial expressions, so they could not hide their honest opinion. Also the participants often asked: “To which

jam do I have to compare the first fruit spread? It is difficult when I do not know how the other samples will taste." Then the researcher explained that the words written in the nine-hedonic scale (from one = dislike extremely to nine = like extremely) could help them to give a liking score. Furthermore, the randomised block design made sure that the order of the samples did not have an influence on the evaluation of the fruit spreads.

A quarter of a Dutch toast with fruit spread was presented to the participants on a white plate. Although spreadability is an important characteristic of jam, the elderly were not asked to spread the fruit spreads on a Dutch toast. Some elderly had limited cognitive abilities and would have more difficulties to follow a protocol that requires attention to two tasks.[50] Even some elderly already had difficulties with tasting and thinking about how much they liked it. Additionally, the researcher made sure that the amount of fruit spreads on each quarter of a Dutch toast was standardised, but participants complained that there was too much or too les fruit spread on the quarter of the Dutch toast.

With elderly as participants in a sensory test, it was important that they rinsed their palate with water in between tasting the samples. Elderly have a stronger olfactory adaptation and slower recovery and therefore a strictly rinsing with water of 2 minutes was determined before the sensory test.[72] The participants were too impatient so the next fruit spread was immediately given after completing the questionnaire of the previous fruit spread. The elderly took some sips of water after filling in the first question, namely the nine-point hedonic scale, and then they continued with answering the other two questions. Thus there was some time between tasting the samples, but this time was not standardised because some elderly answered the questions quicker than others. Elderly also preferred to drink tea or coffee when tasting the fruit spreads but the researcher made sure that they drunk water. However, sometimes it was not possible to avoid that they drunk coffee before the tasting.

Because tasting sessions took place on different days, new fruit spreads had to be made five times. The fruit spreads were made according the recipes but some variation could occur in the fruit spreads. However, one batch of fruit spreads was evaluated by 52.4% of the participants so probably the influence of the variation would be minimal.

4.3 Liking scores and willingness to consume of the fruit spreads in the target group

4.3.1 Choice of target group

First, the order effect, first sample effect and previous sample effect were checked and were not significant ($p > 0.05$). This means that the order, the first sample and previous sample did not influence the liking scores which was expected because a randomised block design was used.

Prior to the consumer study, the target group was set on elderly above 70 years old who consume jam. However, elderly older than 65 years and elderly who never consume jam completed the questionnaire as well. So it was checked if the average liking scores and willingness to consume the fruit spreads again differed for each group. The average liking scores between the group with elderly above 70 years who consumed jam and this group plus the elderly above 70 years who did not consume jam, did not differ significantly ($p < 0.05$). Also between both groups, no big difference was seen in the number of participants that answered "yes" on the question if they were willing to consume the fruit spreads again. The same was seen when the age limit of these groups was set on 65 years. Also when comparing the whole group of at least 70 years old participants with the whole group of at least 65 years old participants, no significant difference ($p < 0.05$) was found between the liking scores and no big difference was noticed between the number of participants that wanted to consume the fruit spreads again. This also applied for both groups when leaving out the participants who never consumed jam. Furthermore, for every group was seen that the reference fruit spreads had significantly ($p < 0.05$) higher liking scores than the protein-enriched fruit spreads. The reference fruit spreads did not significantly ($p > 0.05$) differ from each other, and this was also the case for the protein-enriched fruit spreads (**Figure 14** and **Figure 15**). Taking into account all these results, the chosen target group was the broadest group: above 65 years old and the participants who never consumed jam included.

When dividing this target group according to their age group, their consumption frequency, their gender, their organisation, face-to-face interview or not and butter or not, no significant ($p > 0.05$) differences in average liking scores within each group were found. Thus these characteristics did not influence the participants' liking scores. Even the face-to-face interviews did not lead to higher liking scores to please the researcher. Also the elderly from *De Speler* who were assumed to feel older compared to other elderly, and elderly from *Beatrix* who were assumed to feel younger than other elderly, did not give different liking scores. A significant difference ($p < 0.05$) in liking scores was found between the participants who were willing to consume a fruit spread again and the participants who

were not. The participants who ticked the box "yes" gave the fruit spreads higher liking scores (yes: 7.4 ± 1.0 and no: 5.3 ± 1.5) as expected.

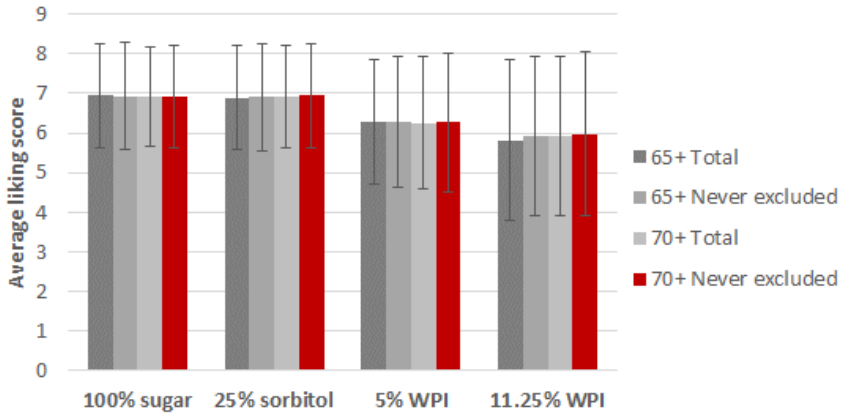

Figure 14. Average liking scores of the reference fruit spreads: 100% sugar and 25% sorbitol, and the protein-enriched fruit spreads: 5% and 11.25% whey protein isolate (WPI) evaluated on a nine-point hedonic scale.

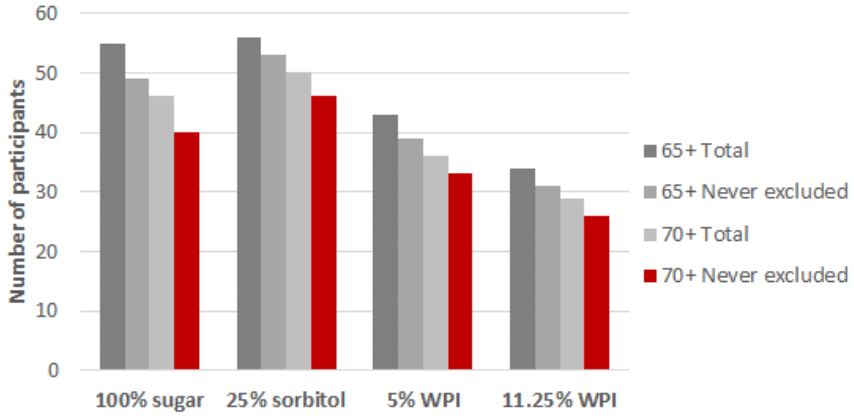

Figure 15. Number of participants that wanted to consume the fruit spreads again; reference fruit spreads: 100% sugar and 25% sorbitol, and protein-enriched fruit spreads: 5% and 11.25% whey protein isolate (WPI).

4.3.2 Liking sores and willingness to consume of the fruit spreads

The protein-enriched fruit spreads were significantly ($p < 0.05$) less liked than the reference fruit spreads by the elderly in the target group, so the addition of proteins led to significant lower liking scores. There was no significant ($p > 0.05$) difference between the reference fruit spreads which means that the partly replacement of sugar by sorbitol did not influence the liking scores. This was also seen in the study of Basu and Shivhare (2013) in which the substitution of sorbitol did not affect the sensory quality of mango jam. Between the protein-enriched fruit spreads no significant ($p > 0.05$) difference

was found for the liking scores. Thus the addition of an extra 6.25% WPI did not result into significantly lower liking scores (**Table 32**).

The number of participants that ticked the box "yes" on the question if they wanted to consume a fruit spread again, was higher for the reference fruit spreads than for the protein-enriched fruit spreads. Only one more participant was willing to consume the fruit spread with 25% sorbitol than the fruit spread with 100% sugar. This difference was bigger between the protein-enriched fruit spreads: an additional nine participants were not willing to consume again the fruit spread enriched with 11.25% WPI compared to the fruit spread enriched with 5% WPI (**Table 32**). Thus, although the liking scores for both protein-enriched fruit spreads did not significantly differ, there was a difference in willingness to consume these fruit spreads again.

Table 32. Average liking scores evaluated on nine-point hedonic scale and number of participants that wanted to consume the fruit spreads again; reference fruit spreads: 100% sugar and 25% sorbitol, and protein-enriched fruit spreads: 5% and 11.25% whey protein isolate (WPI).

Fruit spread	Average liking score	Number of participants that wanted to consume the fruit spread again
100% sugar	6.9 ± 1.3^{a}	55
25% sorbitol	6.9 ± 1.3^{a}	56
5% WPI	6.3 ± 1.6^{b}	43
11.25% WPI	5.8 ± 2.0^{b}	34

Different letters indicate significant differences according to the Tukey test ($p < 0.05$).

4.4 Preference of the target group

A PCA was done to figure out which fruit spread(s) the participants in the target group preferred and if they all preferred the same fruit spread(s). Two products are closer in a PCA when they are liked similar or preferred the same way by the participants. Prior to the PCA, the participants who had not any preference were left out since they could not influence the results of the PCA.[47] In total 8 participants did not prefer a certain fruit spread, they gave the fruit spreads the same liking scores and were left out.

The first two dimensions of the PCA explained in total 79.44% of the variance. As a rule of thumb a variance accounted for of 60% was seen as satisfactory. Dimension one opposed the fruit spread with 11.25% WPI and the reference fruit spreads. In other words, participants who preferred 100% sugar fruit spread tended to also like more 25% sorbitol fruit spread and tended to appreciate less 11.25% WPI fruit spread, and vice versa (**Figure 16**). As more variables were positively correlated with the first

dimension, the majority participants preferred the reference fruit spreads. However, the variables were scattered around the circle which means that the consumers had different preferences and this is in line with the fact that elderly are a heterogeneous group (**Figure 17**).

4.5 Reason(s) behind liking scores

4.5.1 Comments

Open questions could be a solution to get more information from elderly in a sensory test.[40] The second question of the questionnaire was the open question: "Why do you like or dislike this fruit spread?" As expected not all elderly could answer this question. The answers on this question were first translated to English and comments with a similar meaning were changed to the same words. For example, the word fruity was used for comments such as "fruity taste", "fruity flavour", "nice fruity taste". After the translating and summarising the answers on the open question, 20 different words were left (**Table 33**). Additionally, 204 of the 360 times that the participants had the chance to answer the open question, they were not able to do it. Thus the participants did not give many comments and they gave many different comments.

Table 33. 20 words left after translating and summarizing the answers on the open question: "Why do you like or dislike the fruit spread?" and how often they were used by the participants for all the fruit spreads.

Words			
Attractive (2)	Fruity (7)	Not fresh (1)	Too sour (25)
Delicious (37)	Less fruity (6)	Not attractive (7)	Too sticky (5)
Delicious after taste (3)	Long after taste (1)	Not delicious (7)	Too sweet (14)
Dough (5)	Natural (2)	Not too sweet (11)	Too thick (2)
Fresh (18)	Neutral (14)	Red cabbage (7)	Yogurt (1)

4.5.2 Correspondence analysis

To analyse textual data such as the answers on the open question, a CA was used. A CA is a reference method to study the link between two categorical variables or a graphical and exploratory variant of the Pearson's Chi-squared test. Prior to this analysis the comments that were rarely used, were left out because they would influence the analysis as they were very specific to some fruit spreads.[47] The words that were at least used five times were selected: "delicious", "dough", "fresh", "fruity", "less fruity", "neutral", "not attractive", "not delicious", "not too sweet", "red cabbage", "too sour", "too sticky" and "too sweet".

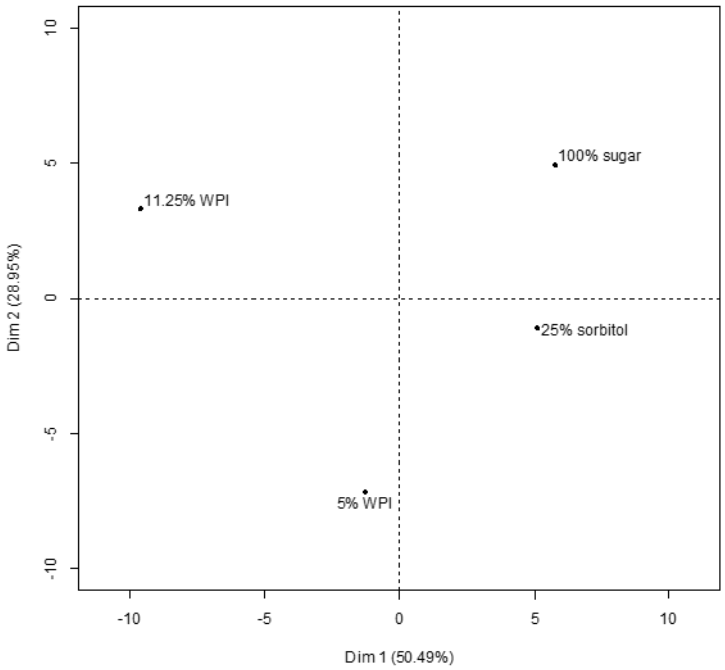

Figure 16. Representation of the reference fruit spreads with 100% sugar and 25% sorbitol, and the protein-enriched fruit spreads with 5% and 11.25% whey protein isolate (WPI) on the first two dimensions resulting from a principal component analysis on all participants.

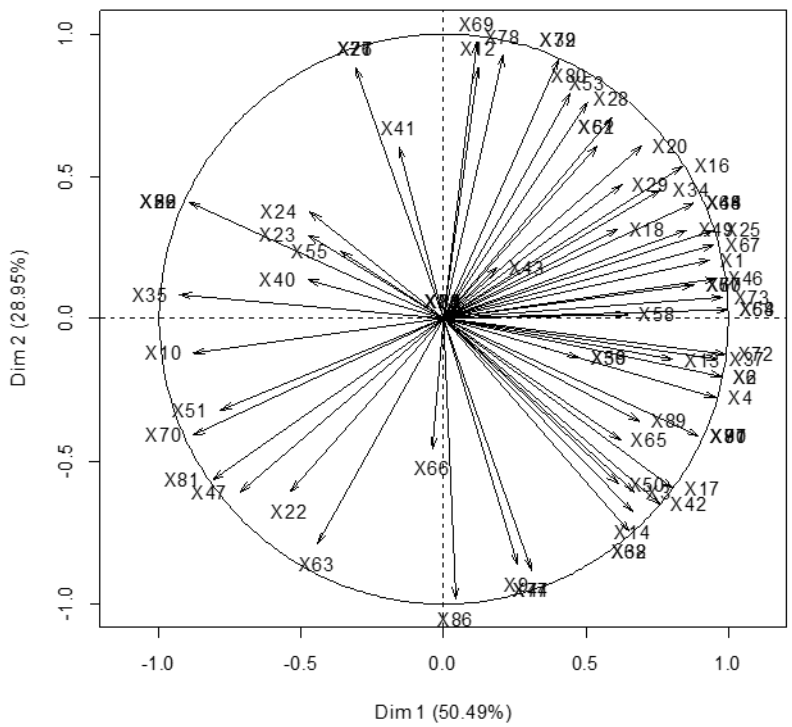

Figure 17. Representation of the participants on the first two dimensions resulting from a principal component analysis.

The Pearson's Chi-squared test was done to find out if there were any particular associations between the comments and the fruit spreads. This test was significant ($p < 0.05$) so there were those particular associations and a CA could be done.

The first two dimensions of the CA explained in total 89.96% of the variance and this was seen as satisfactory. Dimension one opposed the reference fruit spreads and the fruit spreads enriched with 11.25% WPI. This dimension could be described as the dimension that represented the addition of WPI. The reference fruit spreads were more often associated with the comments "too sour", "not too sweet", "fresh" and "delicious" than the protein-enriched fruit spreads. On the other hand, the fruit spread enriched with 11.25% was described more often as "too sticky", "red cabbage" and "not delicious" (**Figure 18**).

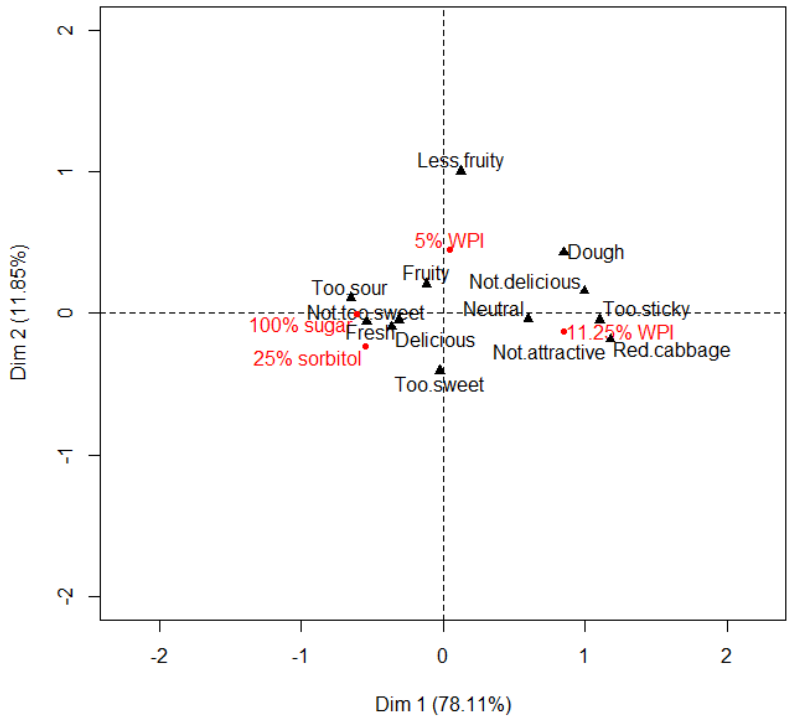

Figure 18. Representation of the reference fruit spreads with 100% sugar and 25% sorbitol, and the protein-enriched fruit spreads with 5% and 11.25% whey protein isolate (WPI) on the first two dimensions resulting from a correspondence analysis (CA) on all participants (red). Representation of the comments used at least five times by the participants on the first two dimensions resulting from a CA (black).

The comment "too sour" was specifically ($p < 0.05$) associated with the fruit spread with 100% sugar. The participants used this word more often to characterise this fruit spread than for all fruit spreads. On contrary, the comment "too sour" was specifically ($p < 0.05$) associated with the fruit spread enriched with 11.25% WPI but in the sense that the participants used this word less often to characterise this fruit spread than for all fruit spreads. The same was seen for the word "delicious".

Additionally, the comments “red cabbage” and “not attractive” were significantly ($p < 0.05$) more often used to describe the fruit spread enriched with 11.25% WPI than for all fruit spreads. The word “delicious” was significantly ($p < 0.05$) more used to describe the fruit spread with 25% sorbitol than for all fruit spreads. No comments were significantly associated with the fruit spread enriched with 5% WPI and so this fruit spread could be seen as a more average product. Probably, the participants found it more difficult to describe this fruit spread because it might have less distinct characteristics than the fruit spread enriched with 11.25% WPI.

Although the liking scores of the reference fruit spreads did not significantly ($p > 0.05$) differ from each other, the fruit spread with 100% sugar was perceived as too sour and the fruit spread with 25% sorbitol as delicious. The participants could taste a difference in sweetness although the amount of sugar and sorbitol was compensated for their relative sweetness indices. It could be the case that the participants preferred the taste of the fruit spread with only sugar above the one in which sugar was replaced by sorbitol, but the sourness of the first mentioned fruit spread could have decreased its liking score.

The fruit spread enriched with 11.25% WPI was described as not too sour and not delicious. The addition of proteins might have led to a decrease in fruity flavour intensity and creation of off-flavours which could lead to the comment not delicious.[83] Additionally, the appearance of this fruit spread reminded the participants of red cabbage and was not seen as attractive. Since vision dominates taste, the description of this fruit spread as not delicious could be influenced by its appearance.[24] When comparing the colour of the fruit spreads with each other, there was a visible difference between the reference fruit spreads, the fruit spread enriched with 5% WPI and the fruit spread enriched with 11.25% WPI (**Figure 19**). This was also seen during the development and optimisation phase of the fruit spreads: the colour parameters varied when adding proteins or increasing the amount of proteins. The addition of WPI resulted into whiter, less red, more blue and not transparent fruit spreads.

Figure 19. A Dutch toast divided in four pieces with the reference fruit spreads with 100% sugar (left upper corner) and 25% sorbitol (right upper corner), and the protein-enriched fruit spreads with 5% (left bottom corner) and 11.25% (right bottom corner) whey protein isolate.

After the sensory test, the researcher spoke with the participants and they could be divided in two groups. One group did not mind that the protein-enriched fruit spreads did not look like jam. They called it jam instead of a fruit spread because of its fruity flavour and it was spread on a Dutch toast like the participants usually do with jams. This group of participants paid attention to the taste: “As long as it is tasty, it is fine for me.” However, they could still be influenced by the colour although they said they were not. The other group was not only focused on the taste but also on its unexpected colour. They thought that the protein-enriched fruit spreads looked more like a dessert or red cabbage and this influenced their appetite. Even when the fruit spreads were not called jams, they expected a transparent food product.

The purpose of this research was also explained to the participants after the sensory test and they became more interested in the protein-enriched fruit spreads and they would even like to buy these fruit spreads. When they understood the health benefits of the modified traditional product, they accepted the product more and this suggested that the use of health claims could be an important parameter to ensure the success of the protein-enriched fruit spreads.[6]

Awhile after the sensory test, some participants mentioned that their mouth was dry and it felt like something was sticking against their palate and teeth. In previous literature it was already described that proteins could lead to a chalky mouthfeel.[62] Also some participants commented that the fruit spread enriched with 11.25% WPI was too sticky. The textural parameters measured with the Texture Analyser, were not significantly ($p > 0.05$) different for the reference and protein-enriched fruit spreads. However, the stickiness was higher for the protein-enriched fruit spreads.

Conclusion

To increase the protein intake of Dutch elderly during breakfast, low sugar fruit spreads were enriched with proteins. In the first phase of this research, four fruit spreads for the consumer study were developed. Two of the four fruit spreads were reference samples and they were not enriched with proteins. One of the reference fruit spreads was made with sugar, meanwhile in the other one 25% sugar was replaced by sorbitol. The other two fruit spreads in which 25% sugar was replaced by sorbitol, were enriched with 5% and 11.25% WPI. Not only trials were made with WPI but also Simplesse®100 was used to enrich the fruit spreads. The addition of Simplesse®100 to the fruit spreads resulted into undesired white clumps which were noticed by the participants in the sensory test during the development stage, and therefore fruit spreads enriched with WPI were chosen for the consumer study.

The quality attributes TSS, colour and spreadability were measured during the development of the fruit spreads. No systematic differences for these parameters could be found when replacing sugar by higher concentrations of sorbitol. However, increasing the amount of proteins resulted into whiter, less red and more blue fruit spreads and the fruit spreads also became stickier but these differences were not significant ($p > 0.05$). In the sensory test during the development stage, the liking scores decreased when adding proteins especially due to a decrease in the fruity flavour intensity. To increase the fruitiness of the protein-enriched fruit spreads, strawberry and blueberry flavours were added.

The four fruit spreads were evaluated by 84 elderly above 65 years old in the consumer study. The liking of the fruit spreads enriched with proteins, rated on a nine-point hedonic scale, was significantly ($p < 0.05$) lower than the liking of the reference fruit spreads. The liking of both reference fruit spreads did not differ significantly ($p > 0.05$) from each other. This was also seen for the protein-enriched fruit spreads: no significant ($p > 0.05$) difference between the liking scores of these fruit spreads. Thus the participants could taste a difference due to the addition of proteins to the fruit spreads but not due to the partly replacement of sugar by sorbitol and due to an increase of the protein concentration. The fruit spread enriched with the highest amount of proteins was more often described with the words “not delicious”, “red cabbage” and “not attractive” than all fruit spreads. Adding proteins resulted into a colour change and the fruit spreads were even not transparent anymore. The lower liking score of the fruit spread enriched with 11.25% WPI and the description as not delicious might be influenced by its not attractive and unexpected appearance since vison dominates taste. This could also be the case for the fruit spread enriched with 5% WPI. Thus, the low sugar, protein-enriched fruit spreads were less liked than the low sugar fruit spreads but the reason behind the lower liking scores is not clear yet.

Recommendations

- To determine the amount of sugar and sorbitol that has to be added to get the same level of perceived sweetness, a trained panel can be used instead of relying on the relative sweetness indices of sugar and sorbitol.
- The difference in colour between the reference fruit spreads, the fruit spread enriched with 5% and 11.25% WPI could have influenced the liking scores since vision dominates taste.[24] To make this difference less visible, colourants could be added to the protein-enriched fruit spreads. However, this would not lead to transparent fruit spreads.
- Because taste is dominated by vision, the difference in liking scores between the reference and protein-enriched fruit spreads could be explained by the difference in appearance.[24] To find out whether the difference in liking scores was influenced by a difference in taste, blind sensory tests could be done. The participants would not be biased by their vision in these tests.
- If the participants would not give different liking scores to the reference and protein-enriched fruit spreads in the blind sensory tests, branded sensory tests could be done in which the ingredients and claims of the protein-enriched fruit spreads are visible for the participants. They might evaluate the protein-enriched fruit spreads different because they will understand the health benefits of the modified traditional product.[6]
- If the participants would give different liking scores to the reference and protein-enriched fruit spreads in the blind sensory tests, a way should be found to increase the fruity flavour intensity and mask the off-flavours caused by proteins.[19,78,83] The fruity flavour intensity could be increased by adding proteins which have a certain flavour. Proteins with strawberry, blueberry, etc. flavours are available on the market. However, not only the flavour but also the texture was affected when adding proteins, so it might be that only increasing the flavour intensity would not be a solution for higher liking scores.

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Appendix

Appendix I. Interview Nancy Janssen

Nancy Janssen is a dietitian in the hospital Gelderse Vallei in Ede. She works at the geriatrics and did research in the field of dietary intake in elderly. One of these studies is the Cater with Care study. The goal of this study was to increase protein intake by older adults with or at risk of undernutrition (www.caterwithcare.nl).

- I am doubting between two target groups namely athletes and elderly. Which of these two groups looks the most interesting to you?

If it is possible, I would suggest to focus on both of them and on patients after a surgery. But of course, you do not have enough time to investigate all these groups. I have more experience with research on elderly, and I do not know if athletes would consume jam as often as elderly do.

- Do you think that protein enriched jams will significantly contribute to a decrease of protein deficiency in elderly? In the end, the portion size of jams is only 15 g.

We have seen that the most popular breakfast of elderly is a Dutch toast with jam and margarine or butter. The recommended protein intake of a meal is 20 g. Currently, elderly have an intake of 1 g of protein at breakfast. Some of them will reach an intake of 5 g when they consume a protein enriched bread. So they do not reach the recommended protein intake in their breakfast. I would be very happy with an increase in proteins in the most consumed breakfast product, jam. It is even a dream come true.

- What would you suggest as the final concentration of proteins in the jam?

I would suggest 5 g proteins of 15 g jam that elderly consume at breakfast. So that is a final concentration of 30% proteins. From previous research, I know that protein enriched products could have a grainy texture. Jams are not consumed as such: you spread it on bread with margarine or butter. Thus, it could be that the grainy texture of jam is not a big problem.

- What are your experiences with elderly and protein enriched food products? Do they accept these kind of products?

Elderly are conservative in terms of their food. They eat the same food products as they did 20 years ago, even of the same brand. That is why it is very difficult to give them new products enriched with proteins. So the protein jam is a great idea, because of the reason that I mentioned earlier: the most popular breakfast of elderly is a biscuit with jam. Probably, we cannot help the current generation

elderly with these kind of products. They will not buy them and they do not know how important an adequate protein intake is. However, their families can do the groceries and buy the protein enriched products. Also in this case, the families have to realise the importance of protein intake. Most people do not realise that an adequate level of proteins in the diet can prevent many problems. We are trying to raise awareness of an adequate protein intake among especially the new generation elderly. Luckily, this generation is already more aware of the health benefits of food. Also, in marketing programs the new generation elderly should be targeted. For your research, I would suggest to work with elderly above 70 years.

- In the literature, I read about the changed protein turnover in elderly. Many authors suggest a higher recommended daily intake of protein for elderly than the amount that is suggested by Voedingscentrum and Codex Alimentarius (0.8 g per kg bodyweight per day). What do you think about this situation?

In my opinion, Voedingscentrum sticks to old values. The protein turnover in elderly is changed, so they need higher levels of proteins in their diet compared to younger adults. The degradation of muscle cells in elderly is faster than the synthesis of these cells. In elderly who have a chronic or acute disease, the breakdown is even faster. Studies suggest an intake of 1.2 g protein per kg bodyweight per day, some of these studies even 1.5 g. Unfortunately, elderly reach 0.8 g protein per kg bodyweight per day. However, not only higher protein intake is important, but also being active.

- Besides adding proteins, would you also use alternative sweeteners instead of sugar? Or decrease the amount of sugar?

Elderly like sweet products, but not too sweet. Many of the elderly have diabetes type two, so for them it would be interesting to use alternative sweeteners. But be careful, some of the elderly do not want to eat products with sweeteners. On the Internet they read all kind of bad stories about sweeteners.

- Do you know which flavour of jams is most popular in elderly?

I think it would be strawberry jam, but I am not sure. I will ask it in the kitchen of the hospital. They know which jam is the most ordered.

- As you have experience with research of elderly, do you have some tips?

It will be a challenge. You can try to go to elderly homes or Thuis (community centre in Wageningen). Also many elderly pass by the central hall of the hospital. We are often willing to help in these kinds of researches. And whether elderly want to participate in your research? It depends on the person. In the beginning they could be shy, but they will participate because they want to help you.

Appendix II. Visualisation of the development of the fruit spreads for the consumer study

The development of the low sugar, protein-enriched fruit spreads and low sugar fruit spreads which were selected to be assessed in the consumer study, consisted of many optimisation steps (**Figure 20**).

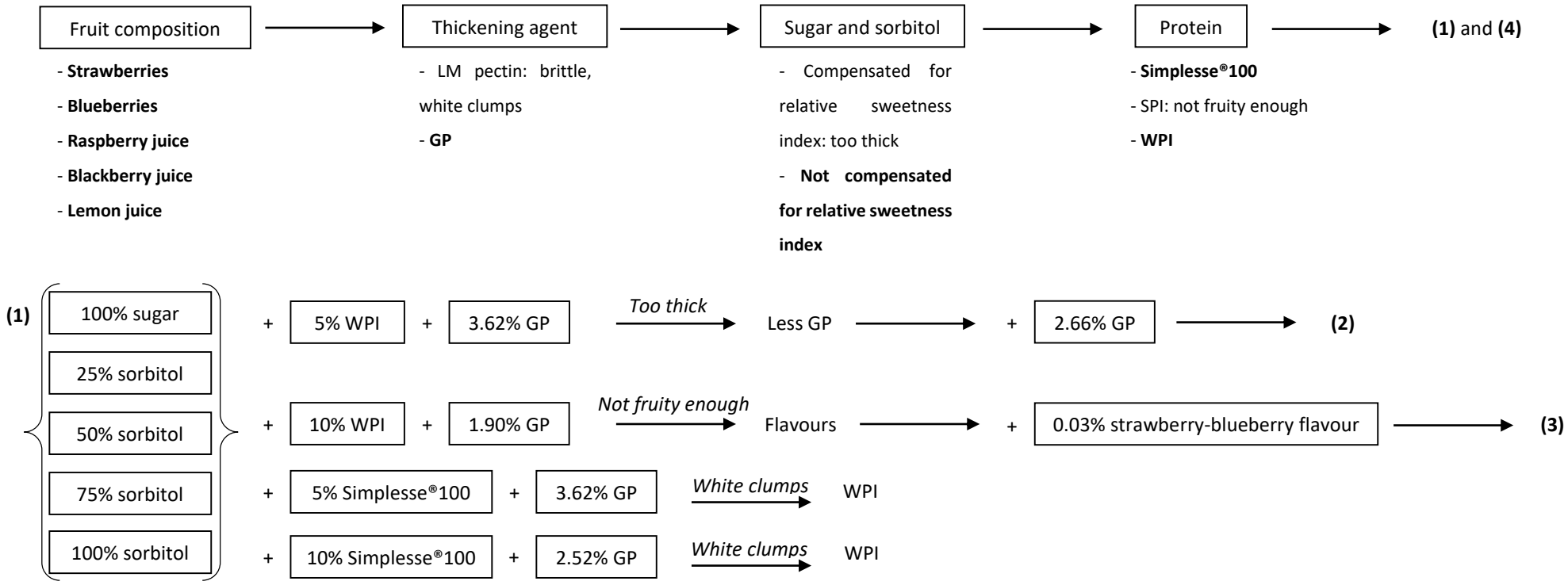

Figure 20. Visualisation of the development of the fruit spreads selected to be assessed in the consumer study.

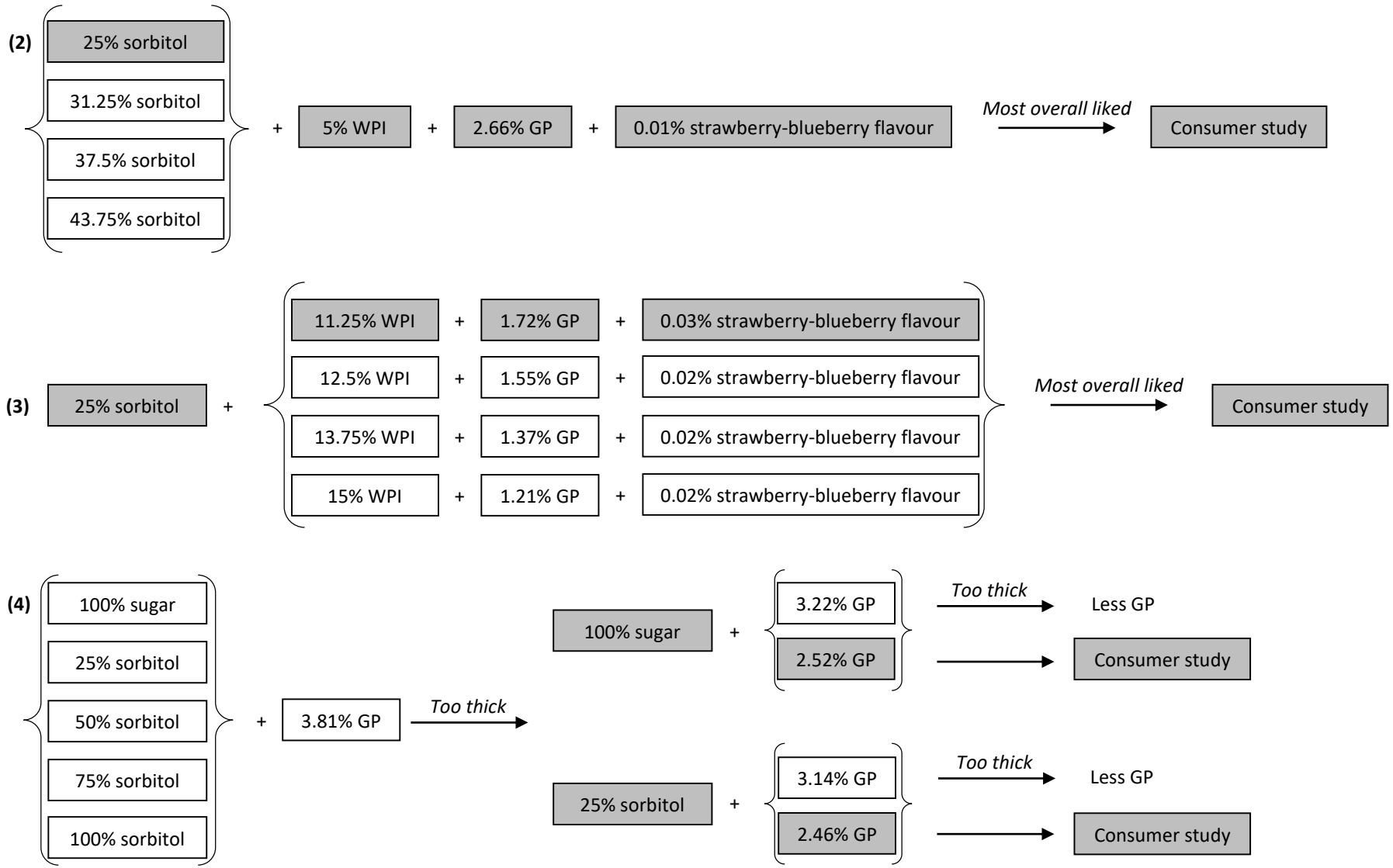

Figure 20. (continued) Visualisation of the development of the fruit spreads selected to be assessed in the consumer study.

Appendix III. Questionnaire of the sensory test in the development and optimisation stage of low sugar, protein-enriched forest fruit spreads

Participant number: …… **Sample number:** ……

Please spread the fruit spread on the biscuit, and thick the box that best describes your opinion.

How much do you like or dislike the spreadability of the fruit spread?

1. Dislike extremely	**2.** Dislike very much	**3.** Dislike moderately	**4.** Dislike slightly	**5.** Neither like nor dislike	**6.** Like slightly	**7.** Like moderately	**8.** Like very much	**9.** Like extremely

How would you describe the viscosity of the fruit spread?

Much too thin	Somewhat too thin	Just about right	Somewhat too thick	Much too thick

Please take a look at the fruit spread on the biscuit, and thick the box that best describes your opinion.

How much do you like or dislike the appearance of the fruit spread on the biscuit?

1. Dislike extremely	**2.** Dislike very much	**3.** Dislike moderately	**4.** Dislike slightly	**5.** Neither like nor dislike	**6.** Like slightly	**7.** Like moderately	**8.** Like very much	**9.** Like extremely

Please smell the biscuit with fruit spread, and thick the box that best describes your opinion.

How much do you like or dislike the odour of the biscuit with fruit spread?

1. Dislike extremely	**2.** Dislike very much	**3.** Dislike moderately	**4.** Dislike slightly	**5.** Neither like nor dislike	**6.** Like slightly	**7.** Like moderately	**8.** Like very much	**9.** Like extremely

How would you describe the fruitiness of the odour of the fruit spread?

Not at all fruity enough	Not quite fruity enough	Just about right	Somewhat too fruity	Much too fruity

Please taste the biscuit with fruit spread, and thick the box that best describes your opinion.

How much do you like or dislike the taste of the biscuit with fruit spread?

1. Dislike extremely	**2.** Dislike very much	**3.** Dislike moderately	**4.** Dislike slightly	**5.** Neither like nor dislike	**6.** Like slightly	**7.** Like moderately	**8.** Like very much	**9.** Like extremely

How would you describe the fruitiness of the taste of the fruit spread?

Not at all fruity enough	Not quite fruity enough	Just about right	Somewhat too fruity	Much too fruity

How much do you like or dislike the biscuit with fruit spread overall?

1. Dislike extremely	**2.** Dislike very much	**3.** Dislike moderately	**4.** Dislike slightly	**5.** Neither like nor dislike	**6.** Like slightly	**7.** Like moderately	**8.** Like very much	**9.** Like extremely

Comments: ……

……

Thank you for your participation!

Appendix IV. Questionnaire of consumer study

Dear participant,

First I would like to thank you for participating in this research.

This research is about fruit spreads which can be spread on bread or Dutch toasts. You will receive 4 different fruit spreads and will evaluate these spreads. We are interested in your opinion, so all answers are correct. This research will take about 10-15 minutes.

Thank you for your cooperation!

Kind regards,

Laura

Participant number: …….. **Fruit spread number: …….**

Taste the Dutch toast with fruit spread and thick the box that best describes your opinion.

How much do you like the fruit spread?

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely

Why do you like or dislike the fruit spread?

……

……

Would you like to eat this fruit spread more often?

Yes	No

Take some sips of the water and raise your hand. After 2 minutes you will receive the next Dutch toast with fruit spread.

Participant number: ……

Finally, you will answer some general questions about yourself.

How old are you?

……

What is your gender?

Female	Male

How often do you consume jam?

Never	Once a month	More than twice a month	Once a week	More than twice a week	Daily

Thank you for participating in this research!

Appendix V. Forest fruit spreads with different amounts of sugar and/or sorbitol compensated for the relative sweetness

Quality attributes

As expected TSS increased with the amount of sorbitol (**Table 34**). As in the fruit spreads the relative sweetness indexof sorbitol was taken into account, the total sugar and sorbitol concentration increased and so TSS increased with the amount of sorbitol. When replacing sugar by sorbitol in the fruit spreads, the colour parameters (L*, a* and b*) increased which means that the fruit spreads became more white, yellow and red (**Table 34**).[87] Expected would be that L* and b* decreased and a* increased. Maillard reactions were taking place between the amino acids and reducing sugars. When the total amount of sugar and sorbitol increased, the water activity decreased. Decreasing water activity could lead to an increase in Maillard reactions and so in brown pigments.[61] Comparing the 100% sugar, 50% sorbitol and 100% sorbitol fruit spreads with the 25% sorbitol and 75% sorbitol fruit spreads, the textural parameters of the first three fruit spreads were lower than these parameters of the last mentioned fruit spreads (**Table 34**).

Table 34. Quality attributes (total soluble solids (TSS), colour and texture) of the fruit spreads with different amounts of sugar and/or sorbitol compensated for the relative sweetness (0.5).

Fruit spread	TSS (°Brix)	L*	a*	b*
100% sugar	44.80 ± 1.35^{c}	3.87 ± 0.09^{b}	8.77 ± 0.12^{c}	0.41 ± 0.26^{c}
25% sorbitol	48.50 ± 0.10^{b}	4.61 ± 0.11^{c}	13.25 ± 0.12^{b}	1.74 ± 0.19^{b}
50% sorbitol	51.97 ± 1.94^{a}	5.05 ± 0.12^{a}	14.32 ± 0.53^{b}	2.04 ± 0.05^{ab}
75% sorbitol	53.00 ± 0.85^{a}	5.32 ± 0.05^{a}	15.75 ± 0.34^{a}	2.44 ± 0.11^{a}
100% sorbitol	54.20 ± 1.57^{a}	5.08 ± 0.16^{a}	14.18 ± 0.50^{b}	1.70 ± 0.01^{b}
Fruit spread	**Positive area (N·s)**	**Negative area (N·s)**	**Maximum force (N)**	**Minimum force (N)**
100% sugar	13.06 ± 2.00^{c}	-0.49 ± 0.05^{a}	1.00 ± 0.04^{c}	-0.34 ± 0.06^{a}
25% sorbitol	26.23 ± 1.76^{a}	-0.86 ± 0.20^{b}	1.65 ± 0.13^{a}	-0.57 ± 0.08^{b}
50% sorbitol	13.88 ± 2.00^{c}	-0.47 ± 0.04^{a}	1.00 ± 0.02^{c}	-0.37 ± 0.05^{a}
75% sorbitol	20.34 ± 1.69^{b}	-0.95 ± 0.21^{b}	1.21 ± 0.07^{b}	-0.60 ± 0.04^{b}
100% sorbitol	13.47 ± 2.44^{c}	-0.50 ± 0.11^{a}	1.11 ± 0.10^{bc}	-0.40 ± 0.07^{a}

Different letters within a column indicate significant differences according to the Tukey test ($p < 0.05$).

Appendix VI. Optimisation of low sugar forest fruit spreads enriched with 7.5% WPI

Recipe

The fruit spreads enriched with 7.5% WPI were made with 2.27% GP (**Table 35**). This amount was chosen based on the results of the fruit spreads enriched with 5% WPI.

Table 35. Ingredients and composition (%) of the fruit spreads enriched with 7.5% whey protein isolate (WPI), made with 2.27% *Geleipoeder* (GP) and with different sugar and sorbitol concentrations (0%, 25%, 50%, 75% and 100%).

Ingredients	Composition (%)
Fruit	71.46
Sugar/sorbitol	18.76
GP	2.27
WPI	7.51

Quality attributes

The average TSS of the fruit spreads equalled 49.71 (± 2.45) °Brix. The colour parameter L* increased with the amount of sorbitol, so the fruit spreads became whiter.[87] The absolute values of the textural parameters were the highest for the fruit spread with 100% sugar which means that this fruit spread was less spreadable (**Table 36**).[9]

Compared to the fruit spreads enriched with 5% WPI, L* increased, a* slightly decreased and b* became negative. Thus due to addition of extra 2.5% WPI, the fruit spreads became whiter, less red and more blue.[87] When increasing the amount of WPI, the absolute values of all parameters increased and thus the fruit spreads enriched with 7.5% WPI were less spreadable than the fruit spreads enriched with 5% WPI (**Table 9** and **Table 36**).[9]

Sensory

The fruit spread with 25% sorbitol was overall the most liked of the fruit spreads enriched with 7.5% WPI (**Table 37**). The fruit spreads were all rated as not fruity enough for taste and odour by the majority of the participants (**Figure 21**). The addition of extra 2.5% WPI led to a decrease in liking scores (**Table 10** and **Table 37**).

Table 36. Quality attributes (total soluble solids (TSS), colour and texture) of the fruit spreads with different amounts of sugar and/or sorbitol enriched with 7.5% whey protein isolate and made with 2.27% *Geleipoeder*.

Fruit spread	TSS (°Brix)	L*	a*	b*
100% sugar	53.03 ± 0.93[a]	26.76 ± 0.09[d]	26.29 ± 0.05[b]	-2.00 ± 0.03[a]
25% sorbitol	46.33 ± 0.15[c]	26.82 ± 0.01[d]	25.73 ± 0.06[d]	-1.86 ± 0.07[a]
50% sorbitol	49.57 ± 2.06[b]	27.88 ± 0.01[c]	25.99 ± 0.08[c]	-1.57 ± 0.05[a]
75% sorbitol	48.80 ± 0.20[bc]	28.35 ± 0.08[b]	26.81 ± 0.14[a]	-0.87 ± 2.88[a]
100% sorbitol	50.80 ± 0.20[ab]	30.20 ± 0.02[a]	25.78 ± 0.06[cd]	-2.92 ± 0.13[a]
Fruit spread	**Positive area (N·s)**	**Negative area (N·s)**	**Maximum force (N)**	**Minimum force (N)**
100% sugar	19.59 ± 0.18[a]	-1.27 ± 0.02[c]	1.58 ± 0.02[a]	-0.93 ± 0.04[c]
25% sorbitol	10.28 ± 0.39[d]	-0.63 ± 0.06[a]	0.96 ± 0.04[b]	-0.49 ± 0.04[a]
50% sorbitol	12.08 ± 0.50[bc]	-0.76 ± 0.04[a]	1.00 ± 0.03[b]	-0.56 ± 0.03[ab]
75% sorbitol	13.53 ± 0.52[b]	-0.89 ± 0.03[b]	1.04 ± 0.08[b]	-0.65 ± 0.03[b]
100% sorbitol	11.09 ± 1.01[cd]	-0.73 ± 0.07[a]	0.86 ± 0.13[b]	-0.53 ± 0.04[a]

Different letters within a column indicate significant differences according to the Tukey test ($p < 0.05$).

Table 37. Liking of the attributes (spreadability, appearance, odour and taste) and the overall liking of the fruit spreads with different amounts of sugar and sorbitol enriched with 7.5% whey protein isolate and made with 2.27% *Geleipoeder*, evaluated on a nine-point hedonic scale.

Fruit spread	Spreadability	Appearance	Odour	Taste	Overall liking
25% sorbitol	6.6 ± 0.6	6.2 ± 0.8	4.0 ± 0.7	5.4 ± 0.9	5.6 ± 0.6
50% sorbitol	5.2 ± 0.8	6.2 ± 0.5	3.6 ± 1.1	5.0 ± 0.7	4.8 ± 0.8
75% sorbitol	4.4 ± 1.1	5.8 ± 0.5	4.0 ± 0.7	4.4 ± 0.9	4.4 ± 0.9

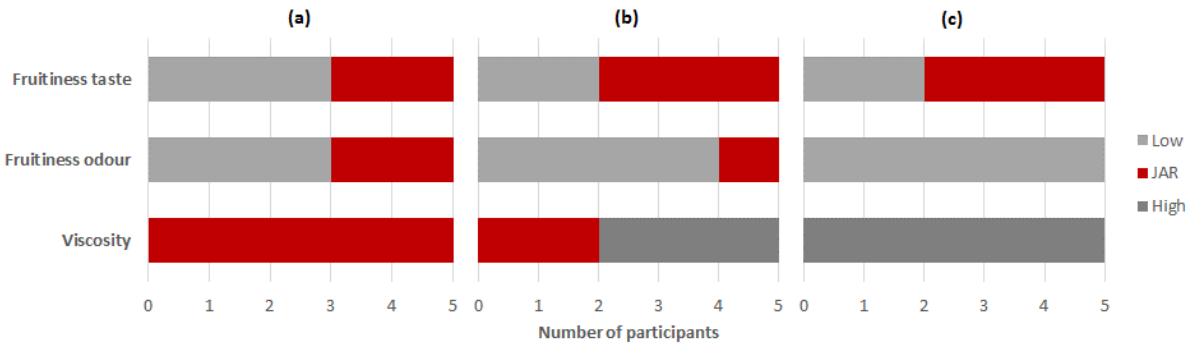

Figure 21. Number of participants that rated the fruit spreads with **(a)** 25% sorbitol, **(b)** 50% sorbitol and **(c)** 75% sorbitol enriched with 7.5% whey protein isolate and made with 2.27% *Geleipoeder* on a just-about-right (JAR) scale as low, JAR or high for the attributes fruitiness taste, fruitiness odour and viscosity.

Appendix VII. Optimisation of low sugar forest fruit spreads enriched with 5% Simplesse®100 and WPI

Recipe

Because fruit spreads enriched with Simplesse®100 gave a fruitier flavour and fruit spreads enriched with WPI were more attractive, a combination of both proteins was added to the fruit spreads in a total concentration of 5% (**Table 38**). The white clumps were less visible in these fruit spreads compared with those enriched with 5% Simplesse®100 (**Figure 21**).

Table 38. Ingredients and composition (%) of the fruit spreads enriched with 5% Simplesse®100 and whey protein isolate (WPI), made with *Geleipoeder* (GP) and with different sugar and sorbitol concentrations (0%, 25%, 50%, 75% and 100%).

Ingredients	Composition (%)
Fruit	73.15
Sugar/sorbitol	19.20
GP	2.66
WPI	2.49
Simplesse®100	2.49

Figure 2. Fruit spread with 25% sorbitol and enriched with 5% Simplesse®100 and whey protein isolate.

Quality attributes

The average TSS of the five fruit spreads was 48.09 (± 1.56) °Brix. The colour parameter L* increased, a* stayed more or less constant and b* decreased with the replacement of sugar by higher concentrations of sorbitol (**Table 39**). This means that the fruit spreads became whiter and less yellow.[87] No systematic differences were seen for the textural parameters of the fruit spreads enriched with 5% Simplesse®100 and WPI when increasing the amount of sorbitol (**Table 39**).

When comparing the fruit spreads enriched with 5% Simplesse®100 and WPI with those enriched with 5% WPI, L* and a* stayed constant and b* increased. The textural parameters of those fruit spreads did not vary from each other (**Table 9** and **Table 39**). On the other hand, when comparing with the fruit spreads enriched with 5% Simplesse®100, L* increased, a* stayed constant and b* decreased. No systematic differences were found when comparing the textural parameters of the fruit spreads enriched with 5% Simplesse®100 and WPI with those parameters of the fruit spreads enriched with 5% Simplesse®100 (**Table 12** and **Table 39**).

Table 39. Textural parameters (positive area, negative area, maximum force and minimum force) of the fruit spreads with different amounts of sugar and/or sorbitol enriched with 5% Simplesse®100 and whey protein isolate.

Fruit spread	TSS (°Brix)	L*	a*	b*
100% sugar	47.33 ± 1.04^{ab}	19.05 ± 0.03^{d}	28.62 ± 0.09^{b}	3.12 ± 0.18^{a}
25% sorbitol	49.30 ± 0.82^{a}	19.22 ± 0.08^{c}	27.58 ± 0.05^{d}	2.94 ± 0.11^{ab}
50% sorbitol	48.70 ± 0.26^{a}	17.90 ± 0.05^{e}	27.36 ± 0.10^{e}	2.73 ± 0.09^{b}
75% sorbitol	49.00 ± 2.09^{a}	19.41 ± 0.02^{b}	28.33 ± 0.07^{c}	2.22 ± 0.13^{c}
100% sorbitol	46.10 ± 0.26^{b}	21.53 ± 0.09^{a}	29.55 ± 0.05^{a}	3.01 ± 0.07^{ab}
Fruit spread	**Positive area (N·s)**	**Negative area (N·s)**	**Maximum force (N)**	**Minimum force (N)**
100% sugar	12.64 ± 0.64^{cd}	-0.59 ± 0.08^{a}	0.87 ± 0.04^{c}	-0.42 ± 0.04^{a}
25% sorbitol	12.41 ± 0.58^{d}	-0.59 ± 0.07^{a}	0.90 ± 0.01^{c}	-0.42 ± 0.03^{a}
50% sorbitol	18.26 ± 0.72^{a}	-0.82 ± 0.01^{b}	1.42 ± 0.06^{a}	-0.56 ± 0.04^{b}
75% sorbitol	14.48 ± 0.48^{b}	-0.64 ± 0.05^{a}	1.10 ± 0.09^{b}	-0.48 ± 0.02^{ab}
100% sorbitol	13.92 ± 0.39^{bc}	-0.56 ± 0.07^{a}	1.19 ± 0.09^{b}	-0.45 ± 0.04^{a}

Different letters within a column indicate significant differences according to the Tukey test ($p < 0.05$).

Sensory

For all attributes and overall liking, the fruit spread with 25% sorbitol had the highest scores (**Table 40**). The fruitiness odour of this fruit spread was evaluated as JAR by the majority of the participants (**Figure 22**). The liking scores of all fruit spreads decreased compared to those scores of the fruit spreads enriched with 5% WPI, but slightly increased compared to the fruit spreads enriched with 5% Simplesse®100 (**Table 10**, **Table 13** and **Table 40**). Thus, the fruit spreads enriched with 5% WPI were the most liked.

Table 40. Liking of the attributes (spreadability, appearance, odour and taste) and the overall liking of the fruit spreads with different amounts of sugar and/or sorbitol enriched with 5% Simplesse®100 and whey protein isolate.

Fruit spread	Spreadability	Appearance	Odour	Taste	Overall liking
25% sorbitol	5.4 ± 1.3	5.4 ± 0.9	5.2 ± 1.3	6.2 ± 0.8	6.0 ± 1.2
50% sorbitol	4.4 ± 1.1	5.0 ± 0.7	4.2 ± 0.8	5.2 ± 0.8	4.6 ± 0.9
75% sorbitol	4.6 ± 1.1	5.4 ± 0.9	4.4 ± 1.3	4.8 ± 1.3	5.0 ± 1.4

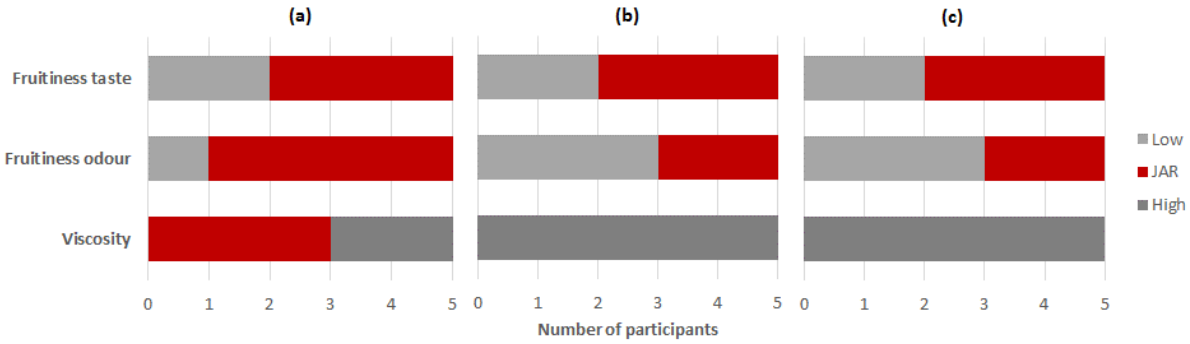

Figure 22. Number of participants that rated the fruit spreads with **(a)** 25% sorbitol, **(b)** 50% sorbitol and **(c)** 75% sorbitol enriched with 5% Simplesse®100 and whey protein isolate on a just-about-right (JAR) scale as low, JAR or high for the attributes fruitiness taste, fruitiness odour and viscosity.

Appendix VIII. Optimisation of low sugar forest fruit spreads enriched with 10% Simplesse®100 and WPI

Recipe

The combination of Simplesse®100 and WPI was also added to the fruit spread in a total concentration of 10% (**Table 41**). In these fruit spreads less white clumps were visible than in the fruit spreads enriched with 10% Simplesse®100 (**Figure 23**). These fruit spreads were also less glossy than those enriched with 10% Simplesse®100 or 5% Simplesse®100 and WPI.

Table 41. Ingredients and composition (%) of the fruit spreads enriched with 10% Simplesse®100 and whey protein isolate (WPI), made with *Geleipoeder* (GP) and with different sugar and sorbitol concentrations (0%, 25%, 50%, 75% and 100%).

Ingredients	Composition (%)
Fruit	69.78
Sugar/sorbitol	18.32
GP	1.90
WPI	5.00
Simplesse®100	5.00

Figure 23. Fruit spread with 25% sorbitol and enriched with 10% Simplesse®100 and whey protein isolate.

Quality attributes

The average TSS of the five fruit spreads equalled 50.37 (± 1.54) °Brix. The colour parameters L* and b* did not show systematic differences and a* decreased with increasing concentrations of sorbitol. Also for the textural parameters no systematic differences were found with increasing amounts of sorbitol (**Table 42**).

Compared to the fruit spreads enriched with 5% Simplesse®100 and WPI, L* increased, a* slightly decreased and b* became negative. Thus the fruit spreads became whiter, less red and more blue

when the concentration of Simplesse®100 and WPI was increased.[87] This colour change was also seen when adding higher concentration of Simplesse®100 or WPI. No systematic differences were found when comparing the textural parameters of the fruit spreads enriched with 5% Simplesse®100 and WPI with those parameters of the fruit spreads enriched with 10% Simplesse®100 and WPI (**Table 39** and **Table 42**).

Table 42. Textural parameters (positive area, negative area, maximum force and minimum force) of the fruit spreads with different amounts of sugar and/or sorbitol enriched with 10% Simplesse®100 and whey protein isolate.

Fruit spread	TSS (°Brix)	L*	a*	b*
100% sugar	50.93 ± 0.31[a]	26.20 ± 0.10[c]	25.62 ± 0.13[a]	-2.59 ± 0.04[ab]
25% sorbitol	52.30 ± 1.20[a]	26.84 ± 0.12[b]	24.46 ± 0.05[c]	-2.14 ± 0.12[ab]
50% sorbitol	51.00 ± 0.78[a]	24.83 ± 0.02[d]	24.47 ± 0.21[c]	-0.63 ± 2.13[a]
75% sorbitol	48.73 ± 0.23[b]	29.03 ± 0.16[a]	24.10 ± 0.10[d]	-3.96 ± 0.09[b]
100% sorbitol	48.87 ± 0.55[b]	26.93 ± 0.05[b]	24.88 ± 0.09[b]	-2.84 ± 0.06[ab]
Fruit spread	**Positive area (N·s)**	**Negative area (N·s)**	**Maximum force (N)**	**Minimum force (N)**
100% sugar	10.45 ± 0.19[c]	-0.70 ± 0.04[a]	0.86 ± 0.03[c]	-0.51 ± 0.01[a]
25% sorbitol	16.94 ± 0.63[b]	-0.98 ± 0.03[b]	1.33 ± 0.04[b]	-0.71 ± 0.03[b]
50% sorbitol	19.58 ± 1.12[a]	-1.07 ± 0.07[b]	1.56 ± 0.05[a]	-0.82 ± 0.05[c]
75% sorbitol	15.35 ± 0.86[b]	-0.93 ± 0.06[b]	1.27 ± 0.04[b]	-0.67 ± 0.03[b]
100% sorbitol	9.07 ± 0.27[c]	-0.59 ± 0.02[a]	0.76 ± 0.02[c]	-0.46 ± 0.02[a]

Different letters within a column indicate significant differences according to the Tukey test ($p < 0.05$).

Sensory

The fruit spreads with 25% and 75% sorbitol were both overall the most liked, but the fruit spread with 75% sorbitol had the highest liking scores for the attributes odour and taste (**Table 43**). However, the fruit spread with 75% sorbitol was evaluated as too thick (**Figure 24**). Four of the five participants complained about white clumps in the fruit spreads, so a combination of Simplesse®100 and WPI could not prevent this problem. Therefore, the further optimisation and development was only done with WPI.

Table 43. Liking of the attributes (spreadability, appearance, odour and taste) and the overall liking of the fruit spreads with different amounts of sugar and/or sorbitol enriched with 10% Simplesse®100 and whey protein isolate.

Fruit spread	Spreadability	Appearance	Odour	Taste	Overall liking
25% sorbitol	5.0 ± 1.9	5.2 ± 0.8	4.2 ± 1.3	4.4 ± 1.1	5.0 ± 0.7
50% sorbitol	3.4 ± 1.3	4.8 ± 1.6	4.6 ± 1.7	4.4 ± 1.1	3.8 ± 0.8
75% sorbitol	4.4 ± 1.5	4.8 ± 1.1	5.4 ± 0.9	4.8 ± 1.3	5.0 ± 1.0

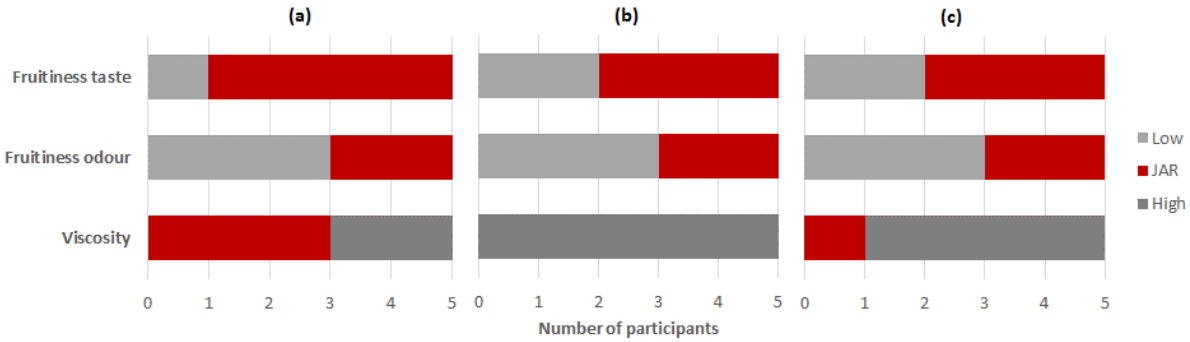

Figure 24. Number of participants that rated the fruit spreads with **(a)** 25% sorbitol, **(b)** 50% sorbitol and **(c)** 75% sorbitol enriched with 10% Simplesse®100 and whey protein isolate on a just-about-right (JAR) scale as low, JAR or high for the attributes fruitiness taste, fruitiness odour and viscosity.

Appendix IX. Dry matter content of the ingredients

The dry matter content of the ingredients which were used to make the fruit spreads for the consumer study was determined (**Table 44**).

Table 44. Dry matter content (%) of the ingredients used to make the fruit spreads (GP: *Geleipoeder* and WPI: whey protein isolate).

Ingredient	Dry matter content (%)
Strawberry	8.40 ± 0.68
Blueberry	13.95 ± 3.55
Blackberry juice	9.02 ± 0.38
Raspberry juice	10.97 ± 0.12
Lemon juice	7.74 ± 0.28
Sugar	99.86 ± 0.23
Sorbitol	99.56 ± 0.06
GP	95.76 ± 0.18
WPI	96.48 ± 0.44

Appendix X. Nutritional information of fruit spreads in consumer study

The nutritional information of the four fruit spreads that were evaluated in the consumer study, was calculated with taking into account the calories per g (**Table 45** and **Table 46**). The nutritional values of the fruits were found on the packages and assumptions were made to get these values for the raspberry and blackberry juice. The first assumption was that the juices did not contain fat or fibre as the seeds were rich in both components. Secondly, the juice only consisted of sugars and not of carbohydrates.[44,56] Because the seeds are rich in polyunsaturated fatty acids and antioxidants, they can be used as dietary supplements or in cosmetics.[44]

Table 45. Kcal per g of nutrients.

Nutrients	Kcal per g
Fat	9
Protein	4
Carbohydrate	4
Fibre	2
Sorbitol	2.4

Table 46. Nutritional information of 100 g of each fruit spread chosen for the consumer study; reference fruit spreads: 100% sugar and 25% sorbitol, and protein-enriched fruit spreads: 5% and 11.25% whey protein isolate (WPI).

	100% sugar	25% sorbitol	5% WPI	11.25% WPI
Energy	105 kcal 440 kJ	105 kcal 440 kJ	120 kcal 502 kJ	138 kcal 577 kJ
Fats	0.42 g	0.41 g	0.38 g	0.36 g
Of which saturated	0 g	0 g	0 g	0 g
Carbohydrates	31.37 g	33.17 g	31.50 g	29.44 g
Of which sugars	23.19 g	20.29 g	19.31 g	17.95 g
Fibres	0.76 g	0.74 g	0.70 g	0.66 g
Proteins	0.62 g	0.61 g	5.57 g	11.76 g
Salt	0 g	0 g	0 g	0 g

Appendix XI. Characteristics of the participants in the consumer study

The participants could be divided in different groups according to certain characteristics (**Table 47**).

Table 47. Percentage (%) of certain characteristics of the 84 participants who were above 65 years old and completed the questionnaire.

Characteristics		Participants (%)
Butter		44.05
Face-to-face interview		27.38
Gender	Female	73.81
	Male	26.19
Age	65-69	14.29
	70-74	27.38
	75-79	23.81
	80-84	17.86
	85+	16.67
Consumption frequency	Never	10.71
	Once a month	17.86
	More than twice a month	5.95
	Once a week	9.52
	More than twice a week	21.43
	Daily	34.52
Place	65+ Werkgroep Noordwest	14.29
	AB Zuylenstede	11.90
	Beatrix	9.52
	Bij Bosshardt	1.19
	De Speler	26.19
	Odensehuis	10.71
	Oog voor Utrecht	9.52
	Roosebrink	2.38
	Senioren Ontmoetingspunt Doetinchem	14.29