The Effect of Different but Isoenergetic Breakfasts on Satiety

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Abstract

This master thesis aims to examine the effect of isoenergetic but different composed breakfasts on satiety and satiation in a Swedish context. Four isoenergetic breakfasts were composed: egg & bread, egg & fruits, yoghurt & müsli and jam & bread. The breakfasts were composed pairwise where the first two consisted of the same distribution of glycemic carbohydrates, fiber, protein and fat. The other two breakfast were similar with regards to glycemic carbohydrates but slightly different in other components. In combination with the breakfasts an *ad libitum* lunch was served to examine the effect on subsequent food intake. The breakfasts were served to 16 participants during four weeks, with one week between each study day. Participants were screened and had to attend an information meeting prior the meal study to ensure eligibility and compliance. Satiety was measured at set intervals, through a Visual Analogue Scale (VAS) to collect subjective ratings of satiety. The effect of the different breakfasts on subsequent energy intake was measured by the energy intake at lunch. In addition blood glucose levels were measured during the study day. This study found that the breakfasts affect satiety differently at different time points. Further this study showed that the jam & bread gave the highest feelings of hunger and also largest amount of energy eaten during lunch. Egg & bread and eggs & fruits resulted in the lowest amount of energy eaten during lunch. It was not possible to see a correlation between blood glucose level and satiety. The breakfasts were further evaluated based on their nutritional composition and environmental impact. The egg based breakfasts contained a larger amount of micronutrients which have shown to be deficient in parts of the Swedish population, and were a relative climate efficient alternative.

Sammanfattning

Denna masteruppsats hade som mål att undersöka hur mättnad och hunger påverkas av olika frukostar med samma energiinnehåll men med olika sammansättning, i en svensk kontext. Studien byggde på fyra frukostar: ägg & bröd, ägg & frukt, yoghurt & müsli och sylt & bröd. Frukostarna var komponerade parvis där de två första hade samma fördelning av glykemiska kolhydrater, fiber, protein och fett. De andra två bestod av samma fördelning av glykemiska kolhydrater men skilde sig något åt i förhållande till andra komponenter. Efter frukosten serverades en *ad libitum* lunch för att undersöka effekten på efterföljande energiintag. Studien gjordes med 16 deltagare, under fyra veckor med en vecka mellan studiedagarna. Deltagarna fick genomgå en kontroll och delta i ett informationsmöte innan studien startade för att säkerställa lämplighet och följsamhet. Vid fasta tidsintervaller fick försökspersonerna via en Visual Analogue Scale (VAS) skatta sin mättnad. Hur de olika frukostarna påverkade efterföljande energiintag mättes via lunchen. Även blodglukosnivåerna mättes under studiedagen. Studien fann att de olika frukostarna påverkar mättnad/hunger olika, beroende på tidpunkt. Vidare visade denna studie att sylt & bröd gav den största hungerkänslan och resulterade också i det högsta energiintaget vid lunch. Ägg & bröd och ägg & frukt resulterade i det lägsta energiintaget under efterföljande lunch. Studien såg ingen korrelation mellan blodglukosnivåer och mättnad/hunger. Frukostarna utvärderades även i förhållande till näringsinnehåll och miljöpåverkan. De båda äggfrukostarna innehöll mer av de mikronutrienter som det har visat sig vara en brist av i delar av den svenska befolkningen och var även relativt klimateffektiva.

Hungrig redan två timmar efter frukost?

En kalori är inte en kalori. Frukostar med olika komposition påverkar hungerkänslor på olika vis, trots att de innehåller samma mängd energi. Det är inte heller den frukost som du först känner dig mest mätt av som sedan gör att du äter minst till lunch.

Denna studie har undersökt fyra frukostar, Ägg & bröd, Ägg & frukt, Yoghurt & müsli och Syltsmörgås. Försökspersonerna fick äta frukost och sedan uppskatta sina hungerkänslor. Genom att sedan servera en stor mängd pytt i panna och i smyg väga hur mycket deltagarna åt, gick det även att studera hur mycket deltagarna senare åt till lunch.

Efter att deltagarna blivit serverade en syltsmörgås kände de sig väldigt hungriga och åt därför en stor portion vid lunchen. Det här är kanske inte så konstigt, däremot var det svårare att bedöma vilken frukost som var mest mättande. Resultatet visade nämligen att yoghurt & müsli gjorde att du rankade din mättnad högst, men samtidigt åt deltagarna mycket till lunchen. Medan de båda ägg frukostarna fick lite sämre ranking i mättnad åt deltagarna betydligt mindre till lunch! Om man då vill bedöma frukostarna med avseende på hur mycket lunch som konsumerades var en äggfrukost bäst. Ägg frukosten som även serverades med frukt innehöll dessutom mest av de vitaminer och mineraler som delar av befolkningen riskerar att äta för lite av.

Ett av de största hälsoproblemen idag är den ökade andelen personer som är överviktiga eller feta, 2014 var 52 % av världens befolkning antingen överviktig eller fet. Detta leder i sin tur till en ökad risk att drabbas av till exempel hjärt-kärl sjukdomar, stroke och typ 2 diabetes. Genom att öka kunskapen kring hur olika livsmedel påverkar mättnad finns möjlighet att bidra med kunskap som kan förhindra överätning, något som i sin tur kan förhindra övervikt.

Preface

The idea of constructing a cross-over meal study containing eggs was developed at the Food Technology Department at Lund University. This thesis aims to evaluate the satiating effect of isoenergetic but different composed breakfasts.

A meal study including 16 participants was held in the Chemistry Center at the Faculty of Engineering at Lund University. Both authors have contributed equally to the written report as well as the practical work included in the project.

This project has been very educating and we are thankful for getting this opportunity. First of all we would like to thank all the participants, if not for them this project would not have been possible. We would especially like to thank our supervisors Yvonne Granfeldt and Christer Rosén who have guided us through this process and shared their knowledge. We would further like to thank our examiner Kerstin Skog who has supported us with meaningful and educating comments on our report. Further, we want to thank Björn Bergenståhl for helping us understand the statistical analyses needed. Finally, we would like to thank Dan Johansson for support and guidance regarding the practical work, and all the other employees at the Food Technology Department for helping us in situations needed and for positive feedback and support.

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1.0 Background

One of the biggest public health challenges of today is the growing number of obese and overweight people (WHO, 2015). In 2014, 52 % of the world's adult population was classified as either overweight (Body Mass Index (BMI) ≥ 25) or obese (BMI ≥ 30) (WHO, 2015). This is a great public health challenge as being obese or overweight increases the risk of diseases, such as type 2 diabetes, cardiovascular disease and stroke (noncommunicable diseases), reducing the quality of life as well as causing premature death (WHO, 2015).

The most important cause to the growing number of overweight and obesity is thought to be our sedentary lifestyle combined with an increased consumption of high energy dense foods, causing weight gain (WHO, 2015). Eating is governed by the feeling of fullness and hunger, where the feeling of fullness can be divided into satiety and satiation (Blundell et al., 1987). If it is possible to identify what types of food and dietary patterns that causes the highest satiety and satiation it might be possible to use this knowledge to prevent overeating and through this battle the problem of overweight, obesity and noncommunicable diseases.

About 80 % of the Swedish population consume breakfast every day (CMA Research AB, 2016). The breakfast was recommended to provide 20 - 25 % of the daily recommended energy intake (NNR, 2004, p. 95). It is believed among the Swedish population to be the most important meal of the day and sandwiches, eggs or sour milk/yoghurt are the most popular items to consume in the morning (CMA Research AB, 2016). To battle the problem of obesity, and enhance the feeling of fullness, it is important to evaluate the satiating effect of different breakfasts. To our knowledge, no studies evaluating different breakfast's effect on satiety have been published in Sweden, on breakfasts with same macronutrient distribution (carbohydrates, protein, fat and fiber).

2.0 Aim

This project aims to construct four isoenergetic breakfasts to be evaluated in e meal study. Two breakfasts should be identical in amount of carbohydrates, protein, fat and fiber, and two should contain a larger, but identical amount of carbohydrates and differ in other components. The two groups of breakfast differ in macronutrient distribution.

This project also aims to examine the effect of:

- Carbohydrate source
- Carbohydrate amount

Satiety and satiation

- Evaluate breakfasts → Satiety and satiation
  → Blood glucose levels
- Breakfasts → Nutrient content
- Breakfasts → Climate impact

To reach the goals, four isoenergetic breakfasts will be studied.

3.0 Literature review

3.1 Satiety and Satiation

3.1.1 Appetite Regulation

Appetite regulation is a complex system governed by the brain, via either specific receptors or the nervous system (Benelam, 2009). Through the appetite regulation the body thrive to maintain energy homeostasis (Drewnowski & Bellisle, 2011). When food is ingested, several hormones and stretch signal are released (see satiety cascade below). The appetite regulation can be divided into episodic signals which act upon the ingestion of foods and tonic signals which are a response to the overall energy stores in the body (Benelam, 2009). In addition to the physical factors affecting appetite regulation, appetite is also highly affected by physiological and social factors (Badman et al., 2005; Blundell et al., 2010)

3.1.2 Hunger, Satiety and Satiation

Hunger is what drives us to seek and eat food, the opposite to hunger is satiety and satiation (Erlanson-Albertsson, 2007). Satiety is what keeps us from eating until next meal (defined by Blundell et al., 1987). Satiety allows us to store the energy we have received from the food, and to use that energy until hunger returns (Erlanson-Albertsson, 2007). Satiation is the response to a meal that inhibits further eating (defined by Blundell et al., 1987) Some of the most important hormones regulating appetite are described below, followed by the satiety cascade.

3.1.2.1 Gastric Stretch

Gastric stretch is when food reaches the stomach and acts as a feedback mechanism to promote satiation, and thus have an impact on meal size (Steinert et al., 2012).

3.1.2.2 Ghrelin

Ghrelin is the only known hormone circulating in the body that has been shown to promote hunger and food intake, ghrelin is mainly synthesized in the stomach (Wren et al., 2001). Ghrelin levels raises before a meal even when subjects are unaware of time, hence ghrelin seems to initiate eating (Cummings et al., 2004).

3.1.2.3 CCK

Cholecystokinin (CCK) is a satiation hormone produced in the duodenum and jejunum when nutrients enter the intestine (Benelam, 2009). CCK inhibits gastric emptying, movement of the intestine, and stimulates release of pancreatic enzymes and contraction of the gallbladder (Benelam, 2009). As a result, CCK decreases meal size and might together with leptin (see below) modulate energy intake over time (Moran, 2000; Wang et al, 2000)

3.1.2.4 GLP-1

Glucagon-like peptide 1 (GLP-1) is a protein transcripted from the proglucagon gene in the intestines, pancreas, brainstem and hypothalamus. After its release it has an effect on appetite by delaying gastric emptying and reducing the movements of the gut (Shah and Vella, 2014). GLP-1 is released in two intervals, one immediately after the eating session and for the next 30 minutes, another interval an additional hour later (Shah and Vella, 2014). Further GLP-1 is a highly effective incretin hormone (Wren & Bloom, 2007). Incretin hormones acts by increasing the amount of insulin in the blood (Fray, K & Akanji, A. 2011)

3.1.2.5 Insulin and Leptin

Insulin is produced in the pancreatic islets mainly as a response to the level of glucose in the bloodstream, which in turn is a response to the carbohydrates in a meal. Generally, when blood glucose levels are high, so are insulin levels and when blood glucose levels are low, so are insulin levels. As a response to the high blood glucose levels (and GLP-1 levels) after a meal insulin is produced. This encourage the liver and muscles to store glycogen, the adipocytes to store fat and initiates the synthesis of protein. By doing so the level of glucose and insulin will decrease (Fray, K & Akanji, A. 2011). Insulin is also a tonic signal that communicates the overall energy stores from adipocytes (Blundell et al., 2010), showed by obesity increases insulin levels (Bagdade, 1967). That insulin is a tonic signal is further supported by a more recent review by Benoit et al., (2004).

Another tonic signal is leptin and it has been shown that the level of leptin in the blood stream is correlated to the amount of body fat and that leptin levels will decrease as a response to body weight reduction (Maffei et al., 1995). Hence leptin can be seen as an indication of the overall energy storage within the body. There are also evidence for a possible correlation between leptin and CCK, with indications that CCK triggers release of leptin and that they together have a stronger appetite reducing effect than when CCK or leptin is present without the other (Wang et al., 2000). Leptin maintains homeostasis of the body, and during weight loss leptin level decrease, signaling decreasing energy storage, causing hunger (Leibel, 2014).

3.1.2.6 The Satiety Cascade

The satiety cascade is a complex framework describing the effects on the body after ingestion of food, and how the ingestion leads to satiety (Blundell et al., 2010; Bellisle, 2008), see Figure 1. It was first developed in 1987 by Blundell, Rogers and Hill (Blundell et al., 1987), but has later been modified by Mela (2006). The satiety cascade can be divided into three parts: *i*) before the eating has started, here expectations on the food as well as odor and sight affects satiation and satiety *ii)* the postingestive phase when the food enters the stomach *iii)* the postabsorptive phase where the nutrients are released into the body. Lastly satiety will be affected by the total energy storage within the body (Benelam, 2009; Blundell et al., 2010).

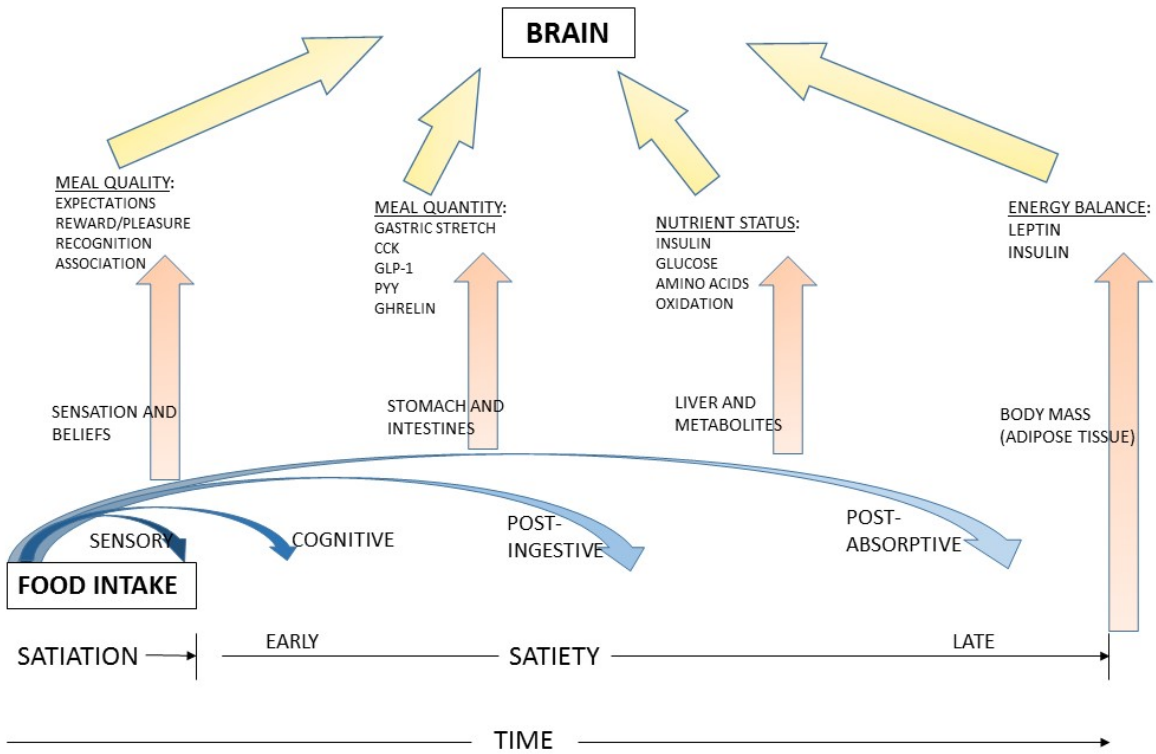

Figure 1. A schematic figure describing the different components released by the body after food intake affecting the brain resulting in satiation and/or satiety. The satiety cascade is based on Blundell et al. (2010). (CCK = cholecystokinin, GLP-1 = glucagon-like peptide-1, PYY = peptide YY)

All components in the ingested food contribute to satiation (Blundell et al., 1987; 2010). When the food enters the mouth, the olfactory sensation triggers the reward system in the brain marking the beginning of the satiation process. When the ingested food reaches the stomach the gastric wall stretches, stimulating stretch receptors providing a neural signal of fullness (Blundell et al., 2010). The gastric wall is also responsible for the production of ghrelin, the hunger hormone, which production is diminished by the gastric stretch (Badman et al., 2005). Further in the gastrointestinal tract, in the small intestine, the ingested food inflicts the release of satiation and satiety hormones such as CCK and GLP-1 (Blundell et al., 2010).

When nutrients are absorbed into the blood further satiety signals are released (Blundell et al., 2010). Insulin is released from the pancreatic islets as a response to increased glucose levels in the blood stream. The hormone also has the possibility to stimulate the secretion of CCK, enhancing the satiety effect (Badman et al., 2005). The last part of the satiety cascade, affecting the long term satiety, is the body's energy balance signaled by insulin and leptin (Blundell et al., 2010).

3.1.3 How Different Foods Affect Satiety and Satiation

Different macronutrients and diets have proved to increase satiety. Protein is believed to cause the highest satiety response among all macronutrients, Benelam (2009) has done a review of studies and found that protein is more satiating than the other macronutrients, also Leidy et al. (2015) found protein to be most satiating. However, the state of the food also affects how much energy is consumed, liquid foods have been found to be less satiating per energy unit, than solid foods (Bellisle, 2008).

A food consisting of a higher energy density has been shown to lead to a larger amount of energy consumed at a meal, compared to a food of lower energy density. This is because the volume of the food/portion size is more important than the energy the portion consists of in determining meal size. For this reason we consume more energy when the energy density is high (Bellisle, 2008).The importance of the energy density and volume of foods on energy intake was also shown by Rolls et al. (1998) in their study where the volume of a milk drink was changed while macronutrients and energy content was kept constant, the result showed the larger volume provided higher satiety. A high fat and sugar content is believed to be more palatable, and result in a larger meal size as well as subsequent greater food intake (Holt et al., 1995).

Capsaicin has revealed a correlation with satiety. However, it is shown that the pungent molecule is not responsible for the release of satiety hormones, but gastrointestinal stress causing the feeling of satiety (van Avesaat et al., 2016). Holt et al., (1995) created a “satiety index” by testing the satiating effect from a variety of foods given in the same energy amount. In the different food groups tested, fruits had the highest satiating effect whereas bakery products (cakes, cookies, not including bread) had the least satiating effect.

3.1.3.1 Glycemic Index Affecting Satiety

Glycemic carbohydrates are digested in the small intestine and absorbed by the blood. The rate of the absorbed carbohydrates differs between varieties and will affect the blood glucose response, and therefore also the Glycemic Index (GI), differently, see Figure 2 (Abrahamsson et al., 2006, p.87). Studies concerning if the GI of foods affects satiety is contradictory. It has been shown that diets including low GI foods will provide a larger weight loss over time. However, the weight lost is not due to a stronger feeling of satiation or satiety (Juanola-Falgarona et al., 2014). Holt (1996) believes that there is no correlation between GI and satiety. On the other hand, in the review article by Ludwig (2000) several authors have found a correlation between GI and satiety (see section "measuring blood glucose" for a further discussion regarding blood glucose and satiety).

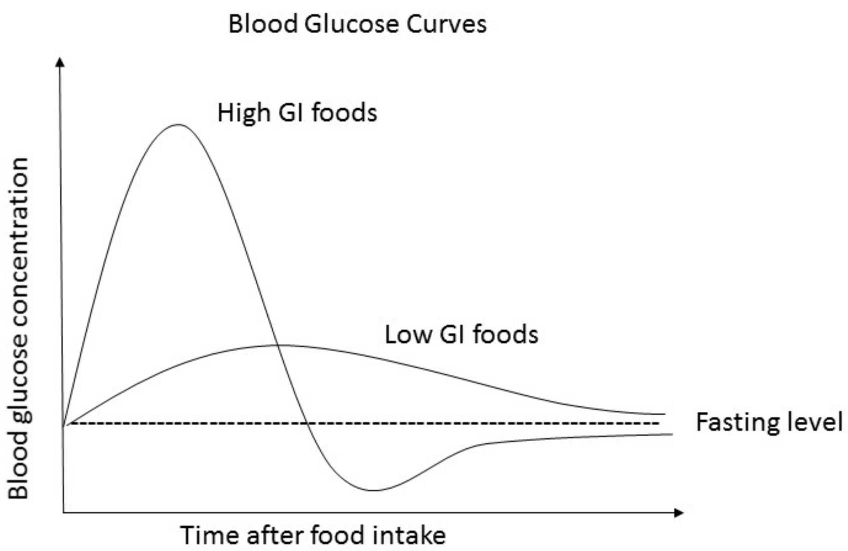

Figure 2. The figure is describing the different blood glucose responses depending on high or low GI foods. When insulin is produced the glucose is absorbed, marking the decrease in blood glucose concentration (Abrahamsson et al. 2006, p. 87). The figure is based on Abrahamsson et al. (2006, p.87).

3.1.3.2 Paleolithic Diet and Satiety

A Paleolithic diet (also referred to as a hunter-gatherer diet) is meant to simulate the food eaten by humans during “the Old Stone Age 2.6 million - 10,000 years ago” (Jönsson, 2007). It is thought by some to be the diet that our bodies are adapted to eat (Lindberg et al. 2003; Jönsson, 2007). The Paleolithic diet is based on foods obtained from “hunting, fishing and gathering of wild plants and insects” (Jönsson, 2007) in opposite to the agrarian diet which is largely based on cereals. Gowlett

(2003) suggest that there was no single hunter-gatherer diet, but that they all had some aspects in common; the diets did not include dairy products, nor did they include one single cereal in any large amount, instead the most important source of carbohydrates was fruit and to some extent roots. Jönsson et al (2010) refers to a Paleolithic diet as a diet which is “based on lean meat, fish, fruits, vegetables, root vegetables eggs and nuts”, and found the Paleolithic diet to be “more satiating per calorie than a Mediterranean-like diet”. Bligh et al. (2015) compared two Paleolithic meals to a reference meal (the reference was based on the guidelines from World Health Organization and contained cereals). They found the two to be more satiating than the reference meal, even though one of the Paleolithic meals contained the same amount of protein as the reference meal. Jönsson et al. (2010), but also Kuipers et al. (2010), used more protein in the compared Paleolithic meals. However, Bligh et al. (2015) suggest that the protein content in a Paleolithic diet is not the reason behind the satiating effect. Jönsson et al., (2010) believe that one explanation for the higher satiating effect of a Paleolithic diet is a decrease in leptin resistance compared to an agrarian diet.

3.1.4 Blood Glucose and Insulin

When food is ingested the body enters an absorptive state where nutrients are absorbed from the gastrointestinal tract to provide energy to cells (Widmaier et al., 2014). The abundance of glucose is stored in the liver, muscles and adipose tissue, where it is converted into either glycogen or triglycerides. Subsequently, about four hours since ingestion, the body enters the postabsorptive state. In the postabsorptive state there is no glucose to be absorbed by the gastrointestinal tract, therefore some of the stored glycogen and triglycerides are catabolized back into glucose and excreted into the bloodstream. The glucose is absorbed by cells and used as energy. The postabsorptive state is important for maintaining the blood glucose level in balance (Widmaier et al., 2014). The same phenomenon also occurs if too much insulin is produced, in response to a high concentration of blood glucose. When this happens the glucose level will drop to a negative delta value (see Figure 2 for a high GI food), and the glycogen and triglycerides are catabolized back into glucose to increase the blood glucose level (Abrahamsson et al., 2006, p. 86; Widmaier et al., 2014).

3.1.4.1 Digestion of Carbohydrates

Complex carbohydrates need to be broken down into monomers to be absorbed and utilized by the body. Starch consists of monomers of glucose. The starch is broken down in the mouth and in the small intestine. From the small intestine the glucose is transported to the liver and further circulated out in the bloodstream raising blood glucose levels (Abrahamson et al., 2006, p. 85). Fructose need to be transformed into glucose in the liver thereby causing a slower effect on blood glucose levels (Abrahamson et al., 2006, p. 85).

3.1.4.2 Measuring Blood Glucose

In a healthy fasting adult, the plasma glucose (P-glucose) levels are usually at 6.00 mmol/L or below and for a non-fasting healthy adult the value is usually below 8.7 mmol/L (Enander, 2013). Brand-Miller et al., (2009) have studied the effect on the glycemic index (GI) of different foods and the shape of the following blood glucose curve, see Figure 2. It was found that the blood glucose usually peaked about 30 minutes after eating.

To evaluate the postprandial effect of different foods on the blood glucose levels, the blood glucose can be tested four hours after a meal. If blood glucose levels are lower after four hours than before a meal, this can be due to an elevated amount of insulin secreted, decreasing the blood glucose level to a negative value (Liljeberg et al., 1999), see Figure 2 for a high GI food.

The correlation between the blood glucose level and satiety is contradictory. Depending on how the different carbohydrates, high- or low-glycemic carbohydrates, affect the blood glucose level, the carbohydrates will suppress energy intake at different time. Low-glycemic carbohydrates suppress energy intake after a longer time than high glycemic carbohydrates, at the same time it is not concluded whether this effect is due to the difference in the blood glucose response (Anderson and Woodend, 2003). Holt (1996) believes that there is no correlation between blood glucose concentration and feelings of satiety. However, a relation was found between the amount of food consumed *ad libitum* and the insulin response, implying a relation between the insulin concentration and satiety. Flint et al (2007) also suggest a relation between insulin and satiety, and not between blood glucose and satiety, though an insulin response is partly dependent on blood glucose concentration.

3.1.5 Nonphysiological Factors when Assessing Satiety and Satiation

Eating behaviors are affected by both cognitive, physiological and environmental factors, for example the expectations of the satiating effect a particular food has (Blundell et al., 2010). Chambers et al. (2015) states that when we first eat something the “appearance and sensory profile” of that food highly affect the satiating effect.

As the nonphysiological factors can have a large effect on the result when assessing satiety, a way to reduce this impact when providing an *ad libitum* meal is to give a portion that far exceed what can possibly be eaten, by doing so it will be harder for the participant to determine how much of the food has been consumed (Gibbson et al., 2014). According to Blundell et al. (2010) when measuring satiation, it is better to provide subjects with a single *ad libitum* meal rather than a buffet, as the buffet itself promote overeating. Another factor that affect eating behavior is the knowledge about when we will eat the next time (De Graaf et al., 1999). Further social aspects and environmental aspects can influence eating behaviors, therefore these should be controlled as much as possible, for example through separating participants in cubicles (Gibbson et al., 2014). Other aspects influencing appetite control is alcohol and obesity. Previously consumed alcohol can increase energy intake over a 24 h period (Westerterp-Plantenga & Verwegen, 1999), whereas obesity can disturb satiety, satiation and hunger feelings (Halford & Harrold, 2012).

3.2 Meal Study

When constructing a meal study the trials need to be randomized where all participants will eat every meal once (Blundell et al., 2010), with four meals this becomes a four-way cross-over study. The study days need to be strict and instructions are made on the exact amount of liquid that needs to be consumed with each meal, for example 150 ml water together with each breakfast (Östman et al., 2005). Further tea or coffee can be offered after a meal, but the same drink needs to be consumed in the same amount on each study day (Östman et al., 2005). To rate the satiety a booklet containing questions concerning hunger and fullness is given (Flint et al., 2000). A standardized meal the day before each study day is not needed in order to get reliable results (Flint et al., 2000). The gender of the participants might affect the result as women seem to increase their energy consumption during some parts of the menstrual cycle (Lissner et al., 1988). In this essay a meal study will be based on Fallaize at al. (2013) with a few alterations.

3.3 Nordic Nutrition Recommendations

The Nordic Nutrition Recommendations (NNR) (2012) sets the base for the dietary guidelines within the Nordic countries. According to NNR 2012 (p. 25-27) the recommended macronutrient distribution should be as stated in Table 1. The energy percentage (E%) stated in the Table 1 is not meant to be interpreted as the recommendations for each meal, they are rather the recommendations regarding food intake over a longer period of time (NNR, 2012, p. 16).

Table 1. The recommended distribution of macronutrients according to NNR 2012 (p. 25-27), (E% = energy percentage)

Macronutrient	Amount of energy intake expressed as E %
Total amount of fatty acids:	**25 - 40**
Monounsaturated fatty acids	10 -20
Polyunsaturated fatty acids	5 - 20, where of ≥ 1 n-3 fatty acids
Linoleic (n-6) and alpha linolenic acid (n-3)	≥ 3 where of at least 0.5 alpha linolenic acid
Saturated fatty acids	< 10
Total amount of protein	**10-20**
Total amount of carbohydrates	**45 - 60**
Added sugar less than	< 10
Dietary fiber	2-3g /MJ or 25-36g/day

3.3.1 Energy Requirements - Breakfast

The energy requirements needed in a breakfast, is based on the recommendations given by NNR (2004, p. 95) and was 20 - 25 E % of the daily energy consumed (20 E % was used in the calculations below). Using the daily recommendations for consumed energy from NNR 2012 (p. 34), an adult male, 18-30 years old with a daily physical activity level (PAL) of 1.6, breakfast should provide 2340 kJ of energy, for women in the same age group and PAL, the breakfast should provide 1880 kJ of energy. For the same PAL but age group 31- 60 the energy need for men is 2200 kJ and 1760 kJ for women.

3.3.2 Micronutrients - Deficiencies within the Population

According to NNR 2012 (p. 625) a balanced and varied diet with enough energy will cover the need of all nutrients for the majority of the population. However for some subgroups the need for vitamin D, folate, iron and iodine might not be covered (NNR, 2012, p. 625).

3.3.2.1 Vitamin D

Vitamin D is a fat soluble vitamin found as Vitamin D_3 (cholecalciferol) in oily fish, fats, milk products and to some extent in meat and eggs, and in mushrooms as D_2 (ergocalciferol). The possible more potent metabolite 25-hydroxyvitamin D_3 (25OHD) is found in eggs and meat (NNR, 2012, p. 350). Vitamin D can also be produced in the skin when exposed to the sun (NNR, 2012, p. 349). Due to the low sun exposure in the Nordic countries, food play an important role in covering the need for vitamin D. Elderly, infants and people with low sun exposure are regarded as groups of the population with largest risk of developing deficiency in vitamin D. Deficiency in vitamin D has been associated with rickets, higher mortality rates and cardiovascular disease (NNR, 2012, p. 349).

The metabolite of vitamin D, 25OHD 25-hydroxyvitamin D_3 has in some studies been found to be 5 times more potent than D_3 (cholecalciferol) in raising serum levels of 25OHD (Cashman et al., 2012) 25OHD is used as a marker of the vitamin D levels in the body (NNR, 2012, p. 350) Due to the possible more potent effect of 25-hydroxyvitamin D_3, the amount of vitamin D in some products is assessed differently in different countries. In the nutritional database of Public Health England the vitamin D content of meat, fish and eggs is calculated as D_3 (cholecalciferol) + 5* 25-hydroxyvitamin D_3 + D_2 (ergocalciferol) (Finglas et al., 2015; Public Health England: Institute of Food Research, 2015). Whereas in the Swedish National Food Agency food database (SLV, 2015), the vitamin D content in the foods is calculated as D_3 (cholecalciferol) + D_2 (ergocalciferol) which gives a lower value for foods high in 25-hydroxyvitamin D_3.

3.3.2.2 Folate

In the Swedish diet the food groups providing the most folate are cereals and vegetables (Riksmaten, 2010-11), Folate is found in high amounts in green leafs, legumes and liver (NNR, 2012, p. 435). The vitamin is important for pregnant women as a low level of folate has been connected with neural tube defects (NNR, 2012, p. 438).

3.3.2.3 Iron

In the Swedish diet the most important sources of iron are cereals, meat, fish and eggs (Riksmaten, 2010-11). How much of the iron in the diet that is absorbed is highly affected both by the type of iron, as it is present in two forms, haem iron and non heam iron where haem iron is easier absorbed. The absorption of non haem iron is highly affected by other components present in the food, phytate lower the absorption of iron whereas vitamin C enhances absorption (Abrahamsson et al., 2006, p. 225-229). Fertile women, pregnant women and infants are regarded as being at risk for iron deficiency (Abrahamsson et al., 2006, p. 230). The average intake of iron for fertile women in Sweden is below the recommended daily intake (Riksmaten, 2010-11).

3.3.2.4 Iodine

Sources of iodine are saltwater fish, milk, egg, water and fortified table salt. The iodine content of foods is highly dependent on where it has been grown, or what feed has been given to the animals

(NNR, 2012, p. 584) Deficiency in iodine is rare within the Swedish population (Abrahamsson et al., 2006, p. 244) but it is still mentioned by NNR (2012, p. 625) as one of the minerals that can be deficient in subgroups of the population.

3.3.2.5 Eggs and Cholesterol

There used to be a recommendation from the National Food Agency in Sweden to not eat too many eggs. This was due to the large cholesterol content in eggs which was thought to increase the cholesterol level in the body. This recommendation has now been removed as it has been found that in a healthy person when eating food containing cholesterol, the amount produced by the body is lowered hence the cholesterol levels are kept constant (SLV, 2015).

3.4 Environmental Impact

Global warming occurs when greenhouse gases (GHGs), such as nitrous oxide, methane and carbon dioxide (Garnett, 2011) are trapped in the atmosphere, increasing the temperature (California institute of technology, 2016). Human produced GHG are responsible for the accelerated temperature increase (California institute of technology, 2016). Meanwhile, food is responsible for 25 % of the GHG emissions in Sweden (Naturvårdsverket, 2011) at the same time as one third of the globally produced food is wasted (FAO, 2011). Further, food production have additional impact on the environment through the effect on biodiversity and animal welfare (WWF, 2016).

It has been concluded that meat and dairy production is one of the largest GHG emitters (Garnett, 2011; WWF, 2016). In 2015 the World Wide Fund For Nature (WWF) established a guide containing environmental recommendations regarding protein sources (WWF, 2015), which was updated in May 2016 (WWF, 2016). Different meats, eggs, cheeses and pulses were evaluated on behalf of biological diversity, animal welfare, chemical pesticides, climate and antibiotics (WWF, 2016). Röös (2014) has in the report "Mat-klimat-listan" estimated the emissions of GHG:s from different foods, in order to facilitate estimations of GHG:s emissions of different types of foods and food groups, in this study GHG emission are presented as carbon dioxide equivalents (CO_2e) in kg per kg of product . A summary of different foods environmental impact is described below:

- Eggs: According to NNR (2012, p. 148-151) eggs are "climate effective" and are recommended to increase in consumption, compared to other animal products. However, soy is sometimes used as feed which in turn has been connected with problems of deforestation. World Wide Fund for Nature (WWF, 2016) rank different eggs on behalf of biological diversity, animal welfare, chemical pesticides, climate and antibiotics. The Swedish KRAV-certified eggs and the Swedish EU-organic eggs are ranked the best, due to the higher demands on animal welfare. Eggs is estimated to produce an average of 2 kg CO_2e/ kg product which can be compared with other sources of protein: Beef is estimated to result in 26 kg CO_2e / kg product, pork 6 kg CO_2e / kg product, chicken 3 CO_2e / kg product, Quorn 4 kg CO_2e / kg product, and legumes 0.7 kg CO_2e / kg product (Röös, 2014).

- Dairy: Dairy products contribute to eutrophication and GHG emissions and are recommended to eat less of (NNR, 2012, p. 148-151). Milk and yoghurt is estimated to produce an average of 1 kg CO_2e / kg of product whereas cheese and butter on an average emit 8 kg CO_2e / kg of product (Röös, 2014).

- Fruit: Fruit have a low climate impact and NNR (2012, p. 148-151) recommend that people consume more fruit. However, fruit is often treated with pesticides and some are transported on airplanes (NNR, 2012, p. 148-151), affecting the climate and environment negatively. Fruits from Sweden results in an average emission of 0.2 kg CO_2e / kg product. For imported fruits this value is 0.6kg CO_2e / kg product and for fruits and vegetables transported by airplane 11 kg CO_2e / kg, airplane transported fruits and vegetable are however rare and only used for very sensitive products (Röös, 2014).

- Cereal: Cereal have an overall low impact on the environment and climate (NNR, 2012, p.148-151). On the other hand, fertilizers are often used in the production of cereals. They are responsible for eutrophication and emission of GHG:s and pesticides are often used (NNR, 2012, p. 148-151). Bread is estimated to produce an average of 0.8 kg CO_2e / kg product and cereals 0.6 kg CO_2e / kg product (Röös, 2014).

4.0 Material and Method

A randomized four-way cross-over study based on four isoenergetic breakfasts was completed. Two breakfasts consisted of the same mass (g) and energy percent of carbohydrate, protein, fat and fiber, and two were equal in the ~~same~~ amount of carbohydrates but differed in other components.

4.1 Participants Selection Process

The participants were recruited from different courses at Lund University, such as Biotechnology and Chemical Engineering year one at the Faculty of Engineering and students from the first year of the master's program Food Technology and Nutrition. Both men and women were requited for the study.

4.2 Test Foods

Four different breakfasts, egg & bread, egg & fruits, yoghurt & müsli and jam & bread, were chosen based on their popularity among the Swedish population. The breakfasts were composed as Table 2 by using the SLV food database and packaging information to achieve the same energy content and wanted macronutrient distribution. The first breakfasts composed were 1) an egg & bread breakfast and 2) an egg & fruits breakfast. These two breakfasts were designed to examine the effect of the carbohydrate source by comparing bread with fruits. The egg & fruits breakfast, topped with a few walnuts, was chosen to represent a Paleolithic breakfast. The protein content in both breakfasts was mainly from the eggs.

Table 2. Detailed composition of breakfasts for men and women. The products used were conventional, and both imported as well as Swedish. The women were given 20 % less energy than men (NNR, 2012).

	Men Weight (g)	***Women*** Weight (g)
Breakfast 1. Egg & bread	175	140
Egg conventional boiled (Ägg 15-pack, Garant, Axfood, Stockholm, Sweden)	100	80
Bread, fiber 6 % (Lingogrova, Pågen, Malmö, Sweden)	65	52
Margarine 40 % fat (Lätt&Lagom, Arla Foods, Stockholm, Sweden)	10	8
Breakfast 2. Egg & fruits	315	252
Egg conventional boiled (Ägg 15-pack, Garant, Axfood, Stockholm, Sweden)	120	96
Walnuts (Naturella valnötter, Garant, Axfood, Stockholm, Sweden)	5	4
Orange (Conventional)	50	40
Apple with peel (Granny Smith, Conventional)	50	40
Banana (Conventional)	90	72
Breakfast 3. Yoghurt & müsli	295	236
Müsli (Sunt & Gott, Finax, Helsingborg, Sweden)	40	32
Yoghurt Natural 3 % (Naturell yoghurt 3%, Garant, Axfood, Stockholm, Sweden)	150	120
Banana (Conventional)	45	36
Orange juice (Apelsinjuice, Bravo, Tomelilla, Sweden)	50	40
Sugar white (Strösocker, Dansukker, Copenhagen, Dennmark)	10	8
Breakfast 4. Jam & bread	200	160
White wheat bread, fiber 3 % (JätteFranska, Pågen, Malmö, Sweden)	80	64
Margarine 40 % fat (Lätt&Lagom, Arla Foods, Stockholm, Sweden)	15	12
Apricot jam (Aprikosmarmelad, Bob, Orkla, Malmö, Sweden)	15	12
Orange juice (Apelsinjuice, Bravo, Tomelilla, Sweden)	90	72

The main ingredient in the bread, in the egg & bread breakfast, was wheat flour (also some whole wheat and rye flour) (Lingongrova, Pågen, Malmö, Sweden) and therefore mainly consisted of “rapidly digestible starch” (Coultate, 2009, p. 57) providing a high GI. In the egg & fruits breakfast the carbohydrates derived from the monosaccharides, consisting of glucose and fructose, as all of the fruits contained both glucose and fructose in varied proportions (Coultate, 2009, p.8), see Figure 3 for a description of the carbohydrates.

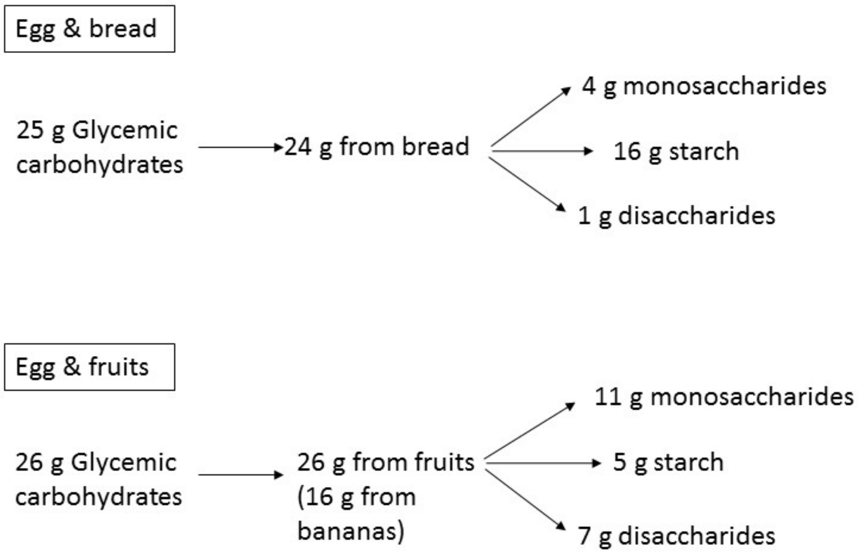

Figure 3. The different components are based on the SLV food database (2016), the amount of starch was calculated as the total glycemic carbohydrates subtracted by mono- and disaccharides. The calculations are based on the amount given to women.

The second group of breakfasts contained a larger amount of carbohydrates (see Table 2 for description of the breakfasts). The composed breakfasts were 3) the yoghurt & müsli and 4) the jam & bread breakfast, both provided with a glass of orange juice. The jam & bread was chosen since it is a common breakfast. The yoghurt was a neutral yoghurt (3 % fat) and the müsli was Russin & Nötter with some table sugar added on top. The jam & bread breakfast was a white wheat bread with some apricot jam on top. The amount of carbohydrates in the two breakfasts are equal, however the protein, fat and fiber content varies slightly between the breakfasts.

For both sandwich breakfasts a margarine was used. The bread used in the meal study was always bought on the Friday, the week before the study week, and was put into the freezer to prevent retrogradation (Cauvain, 1998). The bread was taken out from the freezer in the afternoon the day before each study day.

The nutritional calculations are based on the Swedish National Food agency database (2016) and packaging information. When the nutritional value for the müsli was calculated a similar (but not the same) müsli was used to calculate micronutrients and mono/poly/ n-3 fatty acid content whereas the packaging information was used to calculate the macronutrients.

4.2.1 Conversion Factors

The conversion factors used for the different macronutrients was according to NNR 2012 (p. 186-187) and presented in Table 3 below.

Table 3. Conversion factors for macronutrients from NNR (2012, p. 186-187).

Macronutrient	*Conversion factor (kJ/g)*
Glycemic carbohydrates	17
Protein	17
Fat	37
Fiber	8

4.3 Eligibility

The participants' general health and eating habits were screened prior ~~to~~ the study. The participants were also asked whether they had any intolerance or dislike to any of the food components included in the study, to ensure compatibility. The screening questions can be seen in appendix 1 Table 1. The inclusion and exclusion criteria for the study can be seen in Table 4 below.

Table 4. Inclusion and exclusion criteria. The criteria are modified from Fallaize at al. (2013) and Pombo-Rodrigues et al. (2011). Eligibility was controlled by a questionnaire.

Inclusion criteria	**Exclusion criteria**
Healthy adults (over 18 years old) men or women	Dislike or intolerance to any of the components in the breakfast
BMI between 18.5 – 30 [1]	Not accustomed to eat three meals a day
Habitual breakfast eaters	Eating disorder or restricted eating behavior
Less than 10 h/week of intense exercise	Pregnancy or lactation
Consume less than 21 units of alcohol per week for women and 28 units of alcohol per week for men	On medication that might affect satiety

[1] Information about the height and weight was collected before the study

4.4 Information Meeting

Participants interested in the study were invited to a meeting. They were in addition asked to sign a consent form. They received a visual analog scale (VAS) and were instructed how to use it (see section "experimental day").

Prior the test day, the participants were asked to assess their satiety on a random weekday. They were asked to rank their satiety before and after their breakfast at home, as well as four hours later (before they had eaten any lunch). No snacking was allowed between breakfast and lunch, and the participants were instructed to record what they eat for breakfast (no weights) as well as time for breakfast and satiety measurements. This was to ensure that the participants knew how and were comfortable with using the VAS.

The participants were asked for their weight and their height. If it was not known, they were measured and weighed either during the first day of the study or before the study started.

Participants were instructed not to drink any alcohol or perform any physical exercise, except for walking the day before the study day. The evening meal was not to be consumed later than 20.00 h, and all foods and drinks ingested between 18.00 to 20.00 h were to be documented. Apart from these instructions, participants were told to maintain a normal lifestyle before each study day. At home in the morning, the participants were allowed to drink 150 ml water before the study began. The same instructions were given for each study day.

4.5 Experimental Day

Each participant was randomly assigned an order in which the breakfast was to be served during the following weeks. The study days were assigned based on availability.

The breakfasts were served together with 150 ml of water and the participants were instructed to consume their assigned breakfast in silence within 10 min. The participants were seated individually facing the wall, to reduce external impacts. Coffee, tea or water (150 ml) was served after the breakfast, the participants were told to consume the same beverage and the same amount after each assigned breakfast for all test days. The same instructions were given to smokers who were allowed to smoke the same amount of cigarettes between breakfast and lunch for each study day. Between breakfast and lunch, the participants were allowed to consume water, tea or coffee (150 ml) and engage in regular activities such as studying or working, but they were not allowed any physical exercise and were told to refrain from talking about food.

4.5.1 Measurements of Satiety and Satiation

The participants were instructed to use a VAS provided in a booklet, to rate their satiety, see Figure 4. The questions included in the VAS can be seen in appendix 1 Table 2. Each question was provided with a scale of 100 mm. Instructions were to answer the questions without any hesitation by marking the horizontal line with a dash. The first VAS was filled out before the breakfast was distributed among the participants. Another VAS was filled out again directly after consumption, and in every hour until lunch was served. All VAS were collected at the end of the study day.

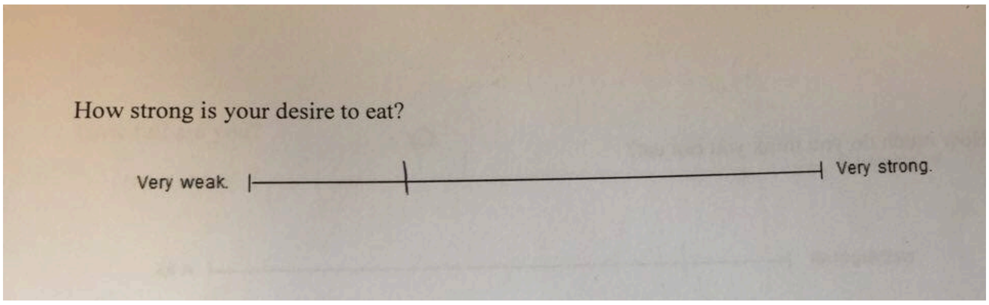

Figure 4. A question from a VAS-booklet where the feeling is marked with a dash. The distance between the left end to the mark was measured in mm.

A lunch (about 800 g = 4728 kJ, based on a pre-measured volume) of "PyttiPanna" (Oxpytt, Findus, Bjuv, Sweden) (meat and potato pieces heated in an oven, 35 E% fat, 46 E % carbohydrate, 16 E % protein, 3 E % fiber) was served *ad libitum* with 200 ml water, four hours after breakfast was consumed. The plate was weighed after the participants had finished eating, to measure the amount of ingested energy. The portion given to the participants were large and they were instructed to eat until they felt "comfortably full". The energy provided by the lunch was calculated using the information provided by the food manufacturer (Oxpytt, Findus, Bjuv, Sweden). A vegetarian option was also provided (Quorn Pyttipanna, Qourn, England).

Each breakfast as well as the *ad libitum* meal was tested for palatability by questions included in the VAS, see appendix 1 Table 2.

4.6 Blood Glucose

Blood samples were taken by the participants themselves with blood glucose test stripes (Contour next, Bayer, Solna, Sweden) and a blood glucose meter to measure the P-glucose levels (Contour XT, Bayer, Solna, Sweden). The participants were helped to correctly read the result from the blood glucose meter. Samples were taken before the breakfast, 30 min after breakfast and before the lunch was served.

4.7 Assessment of the Breakfasts in Relation to Nutrients and Climate

Each breakfast was assessed in relation to their content of vitamin D, iron, iodine, folate and vitamin C by comparing the content in the breakfast with the recommendations in NNR 2012. The macronutrient distribution was also evaluated based on the NNR (2012) recommendations. The breakfasts were examined in relation to their climate impact, by comparing the breakfasts with assessments already made by NNR (2012), Röös (2014) and WWF (2016).

4.8 Statistical Analysis

For an example of calculations see appendix 2.

4.8.1 Appetite Score from VAS

An appetite score was calculated for every individual VAS (in mm) using the questions regarding hunger and fullness:
Appetite score = [Fullness + (100-Desire to eat) + (100-Hunger) + (100-How much you think you can eat)] / 4 (Abou-Samra et al., 2011)

A score of 100 mm indicates maximum fullness and a score of 0 mm indicates maximum hunger. The total peak area under the curve (AUC) for every individual appetite score from before breakfast until lunch was calculated based on the delta values (the fasting morning value from the first appetite score was regarded as the 0 value), using the trapezoidal method through the Graphpad Prism ver. 7.0 program. The time between breakfast and lunch (0-240 min) was broken down into segments based on when the participants filled out the VAS scales. The mean AUC results ± standard deviation (SD) for each time segment was calculated. The AUC were centralized and normalized for each individual. One-way analysis of variance (ANOVA) with a significance set to $p < 0.05$ and post hoc Tukey test with a significance set to $p < 0.05$ was used to examine the difference between the breakfasts. When no significance was found, Student's t-test with a significance set to $p < 0.1$ was used to examine the results.

The baseline for each participants' appetite score was centralized and normalized to be examined for variance in satiety using ANOVA with a significance set to $p < 0.05$.

The delta mean results from the appetite scores were calculated and presented graphically. The delta mean appetite score before lunch (240 min) was centralized and normalized and analyzed using ANOVA with a significance set to $p < 0.05$ and post hoc Tukey test with a significance set to $p < 0.05$ to find significant differences in satiety before lunch between the breakfasts.

4.8.2 Energy from Lunch

The consumed energy from the *ad libitum* lunch was determined for both men and women, only men and only women. The mean amount of consumed energy was calculated for all breakfasts for the three "groups". The energy amounts consumed by each participant were centralized, normalized and analyzed using ANOVA. A difference was considered significant when $p < 0.05$. Pairwise differences between the consumed energy were analyzed using the post hoc Tukey test with a significance of $p < 0.05$. If no significance could be found using ANOVA, Student's t-test of pairwise differences was used with a significance set to $p < 0.05$.

When combining the mean consumed energy for both men and women the standard deviation were large since the men ate more. For this reason, the results were also divided between men and women separately.

4.8.3 Blood Glucose

The delta mean results of the blood glucose measurements were calculated for each time point, the blood glucose value before breakfast was used as the zero value. The peak values for the delta blood glucose was analyzed using ANOVA with a significance set to $p < 0.05$, and Tukey test with significance set to $p < 0.05$ was used for pairwise differences. An assumption was made that the blood glucose decrease was linear, therefore AUCs were calculated for the entire morning, for every breakfast using the trapezoidal method with the Graphpad Prism ver. 7.0 program. The results were centralized, normalized and analyzed using ANOVA with a significance set to $p < 0.05$. The results were further analyzed using the post hoc Tukey test with a significance set to $p < 0.05$.

4.8.4 Confounders

4.8.4.1 Palatability

A palatability score for each participant was calculated based on the answers given from the VAS. The score was based on the questions from the segment "questions about the food".

Palatability score: (Appearance + Taste + How palatable was the food?) / 3

The palatability scores were centralized, normalized and analyzed using ANOVA with significance set to $p < 0.05$.

A value was considered an outlier if it was >/< ± SD*2

4.8.4.2 Thirst

The answers regarding the participants thirst, which were collected at different time points during the morning was calculated as AUC using the trapezoidal method through the Graphpad Prism ver. 7.0 program. The AUCs for each individual was centralized and normalized before analyzed by ANOVA with a significance set to $p < 0.05$.

5.0 Results

5.1 Participants

A total of 22 subjects were interested in participating in the study but 5 were not included since they did not pass the “Eligibility”. One person dropped out after the first breakfast due to discomfort and hunger. A total of 16 participants (12 women and 4 men) were able to complete the study. The mean age of the participants was 30.6 ± 12.0 years (21-71 years), and the mean BMI was 22.8 ± 2.42 kg/m^2 (18.7-27.3 kg/m^2).

When energy intake was calculated during the result was based on 14 participants since two (one man and one woman) ate a vegetarian alternative and could therefore not be included (the vegetarian option consisted of a different energy density and had a slightly different taste which could impact the amount consumed, for this reason the two participants choosing this option are not included).

5.2 Appetite Score from VAS

No significant difference at baseline in satiety was found between the different breakfasts (p value: 0.8073).

5.2.1 Delta Mean Appetite Scores

The delta mean value of the appetite score for each breakfast is presented graphically in Figure 5. Time 0 min represent the appetite score before the breakfast was served, and 15 min represent the value directly after consumption. As demonstrated in the figure all breakfasts provide a feeling of fullness, but the egg & fruits breakfast and the yoghurt & müsli breakfast gave the highest delta mean score of 47 and 48 mm respectively.

The egg & fruits breakfast and the yoghurt & müsli breakfast provide the highest feeling of fullness until about 45 min. Beyond this point, the yoghurt & müsli breakfast provides the largest feeling of fullness where the decrease in fullness is close to linear. The egg & bread breakfast provides its highest delta mean score of 40 mm, 15 and 45 min after consumption. The decrease in satiety is more rapid between 45 min to 120 min. After 120 min the decrease in satiety is not as steep, and reaches the appetite score of -4 mm before lunch. Compared to all the other breakfasts (egg &

fruits: -6 mm, yoghurt & müsli: -7 mm, jam & bread: -16 mm) this mean score is the highest delta appetite score before lunch, which correlate well with its significance when compared to the jam & bread (see above). The jam & bread breakfast provides the lowest delta mean appetite score during the recorded time period. The highest value the jam & bread breakfast reaches is after 45 min with a peak appetite score of 34 mm. After 45 min, an almost linear decrease in satiety can be seen. As displayed in Figure 5 the standard deviations are large.

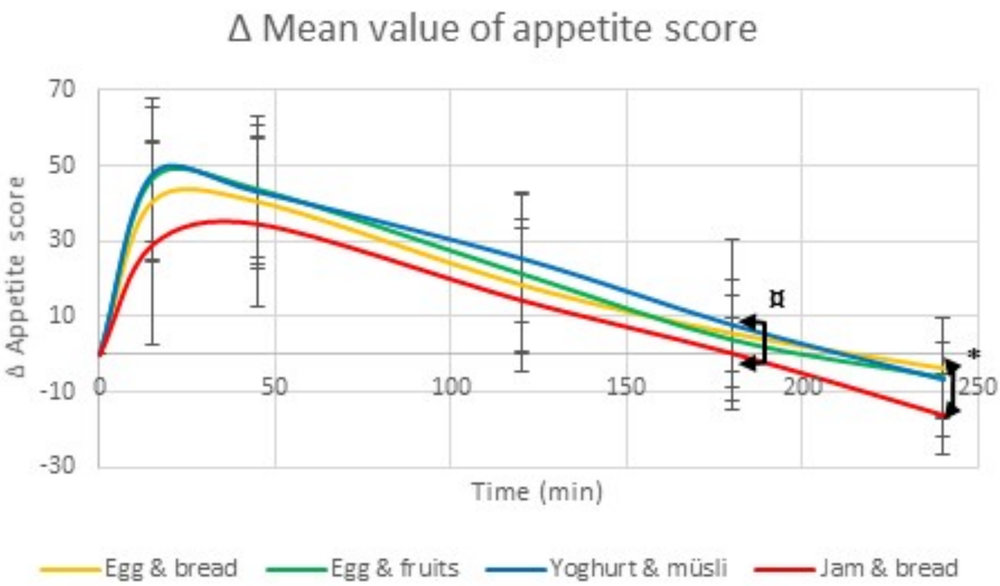

*Figure 5. The graph displays the delta mean appetite score for each breakfast in mm versus time in min during the morning of the test day. The symbol ¤ display significance in AUC until 180 min (¤=p<0.05), and the symbol * display significance in the snapshot of the delta appetite scores at 240 min (*p<0.05), the significance is based on Tukey.*
(Values have been centralized and normalized before calculating differences, n=16).

5.2.2 Appetite Score at 240 min – Individual Time Point

Just before lunch (at 240 min) the egg & bread breakfast was significantly more satiating than the jam & bread (p=0.0405).

5.2.3 Appetite Score - Area Under the Curve (AUC)

The results of the “Statistical analysis” can be seen in Table 5. At different time intervals there is a significant difference between the yoghurt & müsli and the jam & bread as well as the egg & fruit and the jam & bread breakfast, where the significance differs depending on time (see Table 5).

Table 5. The mean AUC ± SD are presented in the table below, divided into time segments of the test morning. The significance is based on each row and between a and b the significance is based on Student's t-test and p<0.1, and the significance between c and d is based on Tukey and p<0.05 (n=16).

Time interval (min)	***Egg & bread***	***Egg & fruits***	***Yoghurt & müsli***	***Jam & bread***	***Missing values***
0-15	303.5 ± 118	348.8 ± 159	358.0 ± 134[a]	249.5 ± 167[b]	4
0-45	1517 ± 577	1647 ± 777[a]	1719 ± 641[a]	1238 ± 821[b]	2
0-120	3743 ± 1660	4117 ± 2090	4283 ± 1670[a]	3096 ± 2230[b]	2
0-180	4511 ± 2220	4975 ± 2920	5408 ± 2260[c]	3652 ± 2800[d]	2
0-240	4765 ± 2470	5309 ± 3390	5804 ± 2580[a]	3870 ± 2780[b]	2

5.3 Energy from Lunch

It was found, when combining the consumed energy for both men and women, that significantly less energy was consumed after the egg based breakfasts compared to the jam & bread (egg & bread p=0.0057, egg & fruits p=0.0099).

The mean amount of energy eaten *ad libitum* for both men and women can be seen in Figure 6. When served the egg & fruits breakfast, the least amount of energy was consumed, whereas the jam & bread breakfast results in the largest ingested energy during lunch. The difference in mean energy between egg & fruits and jam & bread breakfast is approximately 500 kJ.

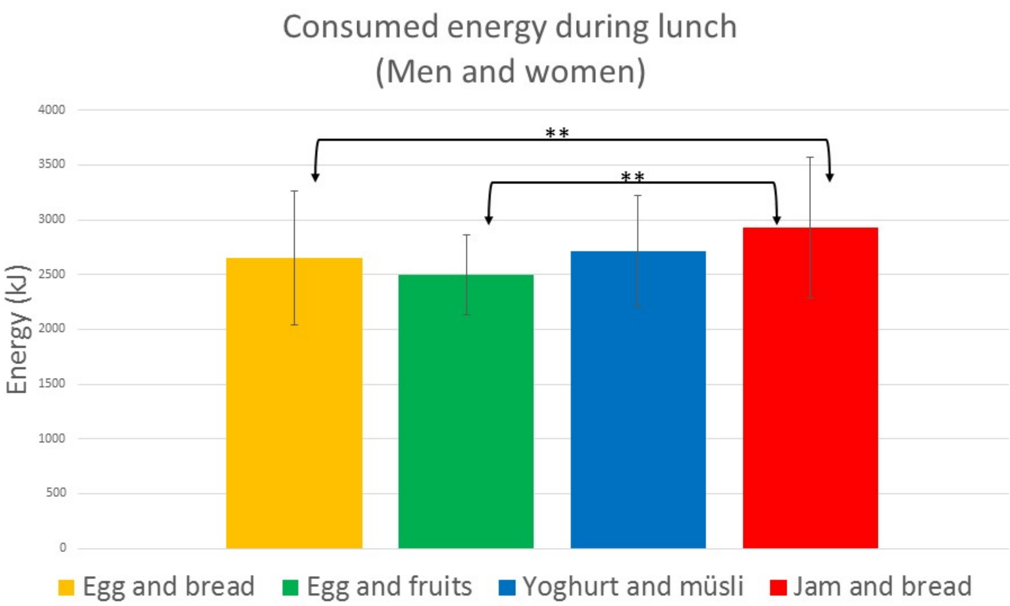

*Figure 6. Mean consumed energy for the ad libitum lunch 4 hours after the provided breakfast. The results displayed are for both men and women combined. The significance shown in the figure is based on the centralized and normalized values for the different breakfasts (Tukey, **p<0.01, n=14).*

The results are divided between men and women separately, see Table 6. The results for men include three participants, while the results for women contain eleven participants. For the men, no significance was found using ANOVA, however Student's t-test found a significance between the egg & fruits breakfast versus the jam & bread breakfast (p=0.0032). The jam & bread breakfast resulted in the most ingested energy during the ad libitum lunch, 3990 kJ. The largest difference in consumed lunch is between the egg & fruits breakfast and the jam & bread breakfast, where a difference of 1200 kJ is observed.

Table 6 also displays the consumed energy for the women. The result differs from the men and is not showing the same mean difference between the breakfasts. The egg & bread breakfast was significantly more satiating than the jam & bread (p=0.0140). The largest difference in mean consumed lunch for women is between the egg & bread breakfast and the jam & bread breakfast, 320 kJ.

Table 6. The table displays the ingestion of energy after the ad libitum lunch 4 hours after the provided breakfast. Three men and eleven women are included. The significance between a and b shown is based on the results from Student's t-test (p<0.05), and the significance between c and d is based on Tukey (p<0.05).

	Egg & bread	***Egg & fruits***	***Yoghurt & müsli***	***Jam & bread***
Men - Consumed energy during lunch (kJ)	3590 ± 200	2820 ± 282[a]	3460 ± 501	3990 ± 430[b]
Women - Consumed energy during lunch (kJ)	2390 ± 397[c]	2410 ± 337	2510 ± 257	2710 ± 282[d]

5.4 Blood Glucose

When measuring blood glucose 15 participants were included in the result since one person did not want to take blood samples. At two occasions two participants had a higher delta blood glucose level before lunch than at 30 min after breakfast. These two values were discarded, and a mean of the three other occasions was used instead.

A significant difference in peak blood glucose was found between the two breakfasts with different carbohydrate source (egg & fruits versus egg & bread, p=0.0121) where the egg & fruits breakfast gave a lower blood glucose response. There was also a significant difference between the breakfasts comparing carbohydrate amounts, see Table 7.

*Table 7. The table displays the pairwise differences using Tukey (p<0.05) between the peak delta blood glucose for every breakfast, (*p<0.05, ****p<0.0001, n=15). Egg based breakfast glycemic carbohydrates 25-26g, Yoghurt &* müsli and jam & bread *glycemic carbohydrates 47-46g*

Breakfast	*Vs.*	*Tukey (p<0.05)*
Egg & bread	**Egg & fruits**	0.0121 (*)
	Yoghurt & müsli	<0.0001 (****)
	Jam & bread	<0.0001 (****)
Egg & fruits	**Yoghurt & müsli**	<0.0001 (****)
	Jam & bread	<0.0001 (****)
Yoghurt müsli	**Jam & bread**	0.9938

The delta mean results are shown in Figure 7. The egg & bread breakfast gives a peak mean value of 1.0 mmol/L glucose 30 min after ingestion and decreases to 0.10 mmol/L 4 h after breakfast. The egg & fruits breakfast displays the lowest result in peak delta mean blood glucose value, 0.51 mmol/L after 30 min, but decreases to -0.15 mmol/L 4 hours after breakfast.

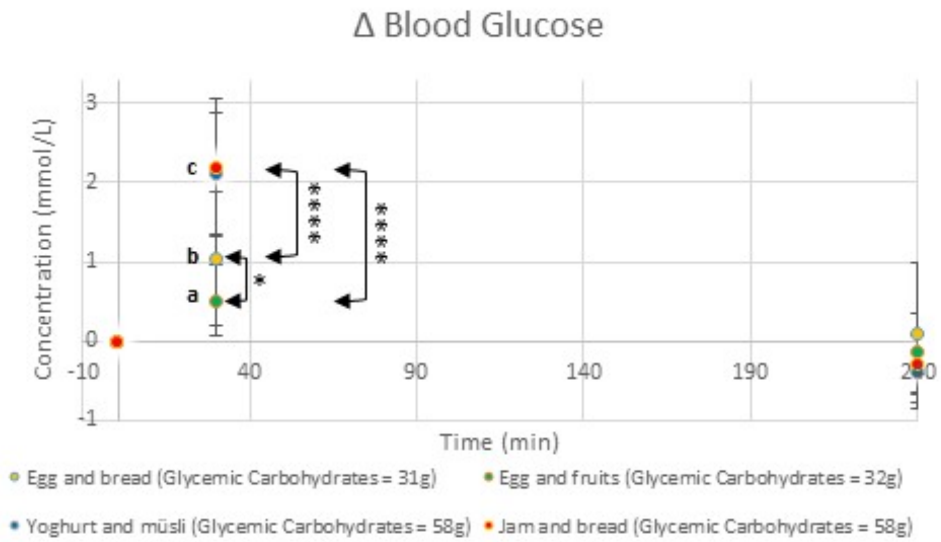

*Figure 7. The graph displays the mean concentration of delta blood glucose in mmol/L for every breakfast versus time in min. a) Egg & fruits b) Egg & bread c) Yoghurt & müsli and Jam & bread. The significance shown in the figure is based on the peak blood glucose level for the different breakfasts, *p<0.05, ****p<0.0001 (n=15). Egg based breakfast glycemic carbohydrates 25-26g, Yoghurt &* müsli and jam & bread *glycemic carbohydrates 47-46g*

The yoghurt & müsli and jam & bread breakfast consisted of a larger amount of carbohydrates, which also can be seen in Figure 7, displaying larger peak values for the two breakfasts compared to the egg & bread breakfast and the egg & fruits breakfast. The yoghurt breakfast gives a peak value of 2.1 mmol/L glucose 30 min after breakfast and -0.39 mmol/L glucose 4 hours after breakfast. The jam & bread breakfast gives the largest peak of 2.2 mmol/L glucose and decreases to -0.29 mmol/L glucose 4 hours after breakfast.

The only breakfast not providing negative delta results is the egg & bread breakfast, however no significance was found between the breakfasts 4 h after consumption (p value: 0.8425) . As can be seen in Figure 7 the standard deviations are large, this is due to the values not being centralized and normalized.

When analyzing the AUC for the blood glucose during the morning, significance was found between the carbohydrate amounts, see Table 8.

*Table 8. The table displays the pairwise differences using Tukey ($p<0.05$) between the AUC counted from the delta blood glucose for every breakfast, *$p<0.05$, ****$p<0.0001$ ($n=15$). Egg based breakfast glycemic carbohydrates 25-26g, Yoghurt &* müsli and jam & bread *glycemic carbohydrates 47-46g.*

Breakfast	*Vs.*	*Tukey (p<0.05)*
Egg & bread	**Egg & fruits**	0.0761
	Yoghurt & müsli	0.0143 (*)
	Jam & bread	0.0148 (*)
Egg & fruits	**Yoghurt & müsli**	<0.0001 (****)
	Jam & bread	<0.0001 (****)
Yoghurt & müsli	**Jam & bread**	0.9999

5.5 Confounders

5.5.1 Palatability

No significant difference in palatability between the breakfasts was found (p value: 0.0557, 5 outliers). In addition no significant difference in palatability of the lunch, was found between the different study weeks (p value: 0.2525, 1 outlier).

5.5.2 Thirst

No significant difference in thirst was found between the participants AUC during the morning (p value: 0.9780).

5.6 Assessment of the Breakfasts in Relation to NNR

A comparison between the different breakfasts nutritional composition was made below and is summarized in Table 9. Since the largest amount of participants in this study were women, the comparison is based on the amount given to women.

5.6.1 Egg & bread and Egg & fruits

The egg & bread and the egg & fruits breakfast is both within the range of NNR (2012, p. 25-27) recommendations with regards to carbohydrate and total fat content, as well as for monounsaturated fatty acids. The two breakfasts are just slightly above the recommendations for protein and somewhat above the recommendations regarding saturated fats (NNR, 2012, p. 25-27). The fiber content in both breakfasts is a bit on the low side (3 g in each breakfast). The fiber content is about

13 % of the lower limit of the daily recommended amount of 23 - 36g fiber /day (NNR, 2012, p. 25-27). Both breakfasts are also lower in N-3 fatty acids than recommended (NNR, 2012, p. 25-27).

The Vitamin D content is about equal in the two breakfast but slightly higher for the egg & bread as vitamin D is provided by both eggs and margarine. The vitamin C content is higher in the egg & fruits as the egg & bread contained no vitamin C. The content of iron is the same in both breakfasts. Folate and iodine is somewhat higher in the egg & fruits breakfast compared to the egg & bread breakfast, see Table 9.

5.6.2 Yoghurt & müsli and Jam & bread

The yoghurt & müsli and jam & bread breakfasts are both somewhat high in total carbohydrates in relation to the recommendations (NNR, 2012, p. 25-27), see Table 9. Whereas total amount of fatty acids and saturated fatty acids are within the range of the recommendations. Monounsaturated, polyunsaturated fatty acids and fiber is somewhat low in both breakfasts in comparison to the recommendations of NNR (2012, p. 25-27). The fiber content (3g in the yoghurt & müsli, 2 g in the jam & bread) is equal to 13 % and 8.7 % of the lower limit of the daily recommended amount of 23 -36g fiber /day (NNR, 2012, p. 25-27). The protein content is within the recommended range for the yoghurt & müsli but below recommendations for the jam & bread (NNR, 2012, p. 25-27). Both breakfast are lower in N-3 fatty acids than the recommendations (NNR, 2012, p. 25-27). The vitamin D and the vitamin C content is higher in the jam & bread than in the yoghurt & müsli. The content of iron is the same in both breakfast, the content of folate and iodine is a little bit higher in the yoghurt & müsli than in the jam & bread.

Table 9. The nutritional components in each breakfast. All values based on the Nutritional database of SLV and packaging information of the müsli, and calculated on the amount given to women.

Nutritional components	***Egg & bread (1129 kJ)***	***Egg & fruits (1144 kJ)***	***Yoghurt & müsli (1141 kJ)***	***Jam & bread (1139kJ)***	***NNR 2012 RDI for women***
Glycemic carbohydrates, E% (g)	38 (25)	39 (26)	70 (47) [1]	69 (46)	
Fiber, E% (g)	2.2 (3)	2.1 (3)	2.1 (3) [1]	1.4 (2)	25-36 g/day
Total carbohydrate, E% (g)	40 (28)	41 (29)	72 (50) [1]	70 (48)	45-60
Of which sugars, E% (g)	7.5 (5)	27 (18)	33 (22) [1]	21 (14)	
Protein, E% (g)	21 (14)	21 (14)	12 (8) [1]	9.0 (6)	10-20
Fat, E% (g)	39 (12)	39 (12)	16 (5) [1]	19.5 (6)	25-40
Saturated fatty acids, E% (g)	13 (4)	10 (3)	7.1 (2) [1]	9.8 (3)	<10
Monounsaturated fatty acids, E% (g)	16 (5)	13 (4)	3.2 (1) [2]	6.5 (2)	10-20
Polyunsaturated fatty acids, E% (g)	6.6 (2)	9.7 (3)	3.2 (1) [2]	3.3 (1)	5-20
N-3 fatty acids, E% (g)	0 (0)	0 (0)	0 (0) [2]	0 (0)	≥1
Vitamin D, µg	2	1	0 [2]	1	10
Vitamin C, mg	0	33	17 [2]	26	75
Folate, µg	62	87	39 [2]	30	400 [3]
Iron, mg	2	2	1 [2]	1	15.9 [4]
Iodine, µg	24	28	1 [2]	0	150

[1] For the müsli the values are calculated from the packaging information [2] Calculated from the database of SLV for a similar müsli. [3] For women of reproductive age, otherwise 300 µg [4] 9 mg for men.

5.6.3 Comparison of Micronutrients in all Four Breakfasts

In total the egg & fruits and egg & bread breakfast provided a larger amount of folate, and iodine than the yoghurt and jam & bread breakfast. The vitamin D content is highest in the egg & bread and equal in the eggs & fruits and jam & bread. The vitamin C content is highest in the egg & fruits, and lowest in the egg & bread. The vitamin D content in the egg & bread correspond to 20 % of the daily recommended intake for women, and in the egg & fruits and jam & bread to 10 % of the daily recommended intake for women (NNR, 2012, p. 349). The vitamin C content in the egg & fruits corresponds to 44 % of the daily recommended intake (NNR, 2012, p. 465). Folate corresponds to 16 % for the egg & bread breakfast and 22 % for the egg & fruits breakfast of the daily recommended intake for women of reproductive age respectively, see Table 9 (NNR, 2012, p. 435). Iodine corresponds to 16 % and 19 % respectively for egg & bread and egg & fruits, of the daily recommended intake (NNR, 2012, p. 583).

5.7 Environmental Impact

The four breakfasts included in the study have been analyzed based on their environmental impact, with regards to the main components, which are: eggs, dairy, fruit and cereal, see Table 10.

The main components in the egg & bread breakfast are eggs and cereal. There is some dairy in the margarine which is recommended to eat less of since it is responsible for eutrophication and GHG emissions (NNR, 2012, p.148-151). But since the amount of dairy in the margarine is such a small amount it will not be considered.

The egg & fruits breakfast is considered environmentally efficient since it consists mainly of egg and fruits (NNR, 2012, p.148-151; Röös, 2014).

The yoghurt breakfasts, consist mostly of dairy products. The müsli added to the yoghurt is a mixture of mainly cereals which also contribute to the emission of GHG and eutrophication, although in a lower amount compared to dairy (NNR, 2012, p.148-151).

The jam & bread breakfast is mostly an environmentally friendly breakfast. It contains margarine which has a low concentration of dairy. The bread, a white wheat bread, contains cereal and contributes to the emission of GHG and eutrophication (NNR, 2012, p.148-151; Röös, 2014).

All breakfasts were composed using conventional ingredients, this means that chemical pesticides and fertilizers have been used in the primary production, something that have a negative impact on the environment (Röös, 2014). If organic ingredients had been used this impact would have been less, on the other hand the emission of greenhouse gases per kg of product is sometime higher for organic products than for conventional products (Röös, 2014).

Table 10. The table is describing the amount of the environmentally examined products in each breakfast.

Breakfast	***Egg (g)***	***Dairy (g)***	***Fruit (g)***	***Cereal (g)***
Egg & bread	80			52
Egg & fruits	96		152	
Yoghurt & müsli		120	36	32
Jam & bread				64

6.0 Discussion

Overweight and obesity is increasing, causing a growing problem with noncommunicable diseases (WHO, 2015). With an increased knowledge about satiety this development might be hindered. Breakfast is eaten by most people in Sweden and therefore contribute to the total energy intake (CMA Research AB, 2016). By evaluating the satiating effect of different breakfasts we might be able to enhance the feeling of fullness in order to prevent overeating.

Our study has provided many interesting results. The breakfasts were appreciated and were based on common ingredients. Four isoenergetic breakfasts were constructed where two breakfasts were identical in amount of macronutrients, and two breakfasts were identical in amount of carbohydrates, which was in a larger concentration compared to the other two breakfasts. The results showed that the breakfasts affect satiety and subsequent energy intake differently.

6.1 Test Foods

The egg & bread was chosen since it is popular to consume sandwiches and eggs for breakfast in Sweden (CMA Research AB, 2016) and egg based breakfasts have shown to have a satiating effect (Fallaize et al., 2013). The amount of energy in each breakfast was 40% lower than the 20 E % of the daily requirement (NNR, 2004, p. 95; NNR, 2012, p. 34), in order to ensure detection in differences in satiety/satiation between the breakfasts. The breakfasts were served in two different energy amounts depending on gender (as calculated from the mean energy requirements based on PAL 1.6 age 18 - 60 NNR, 2012, p. 34). We did not measure the volume of the different breakfasts, but instead weight. In the discussions being made below we will however consider their effect on satiety as the same. A similar comparison has been made by Rolls et al., (1998).

6.2 Study Day

The perceived satiety was measured using a VAS, which was later transformed into an appetite score to be able to calculate the AUC of the breakfasts. The participants completed the VAS at specific time points, more or different time points might have resulted in a slightly different AUC values. For example, one VAS was collected right before and after consumption of the breakfast whereas the next was collected at 45 min (from the first VAS). Later in the morning, when the participants were free to join classes or work, the VAS was completed once an hour. This was due to practical reasons as we expected it to be harder for the participants to adhere to the study protocol if having to complete more VAS at the same time as attending classes, instead the time intervals were adjusted to fit with the brakes usually given between classes. Additional VAS during the early morning could possibly result in higher AUC scores as the decrease in feelings of satiety might not have been as rapid as presented in our graph.

6.3 Satiety and Blood Glucose

The delta mean appetite scores showed that the yoghurt & müsli breakfast provided the largest feelings of satiety (with regards to the total AUC) and it was significantly more satiating compared to the jam & bread (not significantly more satiating compared to any other breakfast). Egg & fruits are very close to the yoghurt in terms of satiety.

However, when looking at specific time points, right before lunch the egg & bread was significantly more satiating compared to the jam & bread. When measuring energy intake during lunch for women the egg & bread resulted in significantly less energy consumed than the jam & bread. On the other hand, if combining men and women a difference was found between egg & bread and jam & bread but also between the egg & fruits and the jam & bread. If only men were studied, a difference was found between the egg & fruits and the jam & bread, no such difference in consumed energy could be found for the yoghurt & müsli even though it provided the overall highest appetite score. The reason for this could be that the initial satiating effect of the yoghurt & müsli results in a large AUC compared to the other breakfast. However this satiating feeling seem not to last until lunch which might be the reason that no correlation was seen between the total AUC and energy ingested during lunch.

We believe that initially the weight of the foods is what determine satiety and here the egg & fruits (252g, women) as well as yoghurt & müsli (236g, women) has the highest weight providing the largest feeling of satiety. With time, the components of the breakfast become more important than the weight and therefore both egg & bread (140g, women) and egg & fruits which have the same macronutrient distribution, result in the lowest value of ingested energy during lunch. The importance of volume and weight over macronutrient composition has also been found in the study by Rolls et al. (1998) where a larger pre-load in volume resulted in a decrease in energy intake during lunch given 30 minutes later even if the macronutrients and energy content was kept constant.

The jam & bread (160g) resulted in the lowest perceived satiety and most energy ingested during lunch while having about the same weight as the egg & bread (140g). This could be due to that jam

& bread had its largest share of energy deriving from liquid (orange juice) and energy coming from liquid has shown to be less satiating than solid food (Bellisle, 2008). Further, the amount of energy from protein in this breakfast (9 E%) is the lowest compared to the other breakfasts, and the half amount of protein compared to the egg & bread.

The two egg containing breakfasts results in the least energy consumed during lunch which correlates with a similar study done by Fallaize at al., (2012). Here the authors saw a decrease in appetite ratings and subsequent energy intake during lunch when an egg containing breakfast was eaten in comparison to cereals or croissant. These two studies are similar by both providing about the same amount of eggs in the egg based breakfasts (Fallaize, 2012), 2 eggs, in our 100 g egg & bread 120 g egg & fruits (values for men). Our study does however also examine the effect on appetite and energy intake of two breakfasts that are not only similar in energy content but also in macronutrient distribution.

In our study no significant difference in satiety was found between the two egg containing breakfasts. This does not correlate with Holt et al. (1995) where in her study fruits had the largest satiating effect as a food group. According to Holt within this food group bananas had the lowest satiety index score. It might be possible that this trend would have been different if bananas were not included. Further this trend does not correlate with some studies on Paleolithic diet which has found to be very satiating (Bligh et al. 2015; Jönsson et al., 2010). However, in the study by Jönsson et al., (2010) the reasons why the Paleolithic diet was more satiating is explained due to a decrease in leptin resistance, something that we were not be able to see within our short study time.

Though no significance could be found in the delta blood glucose response before lunch, a tendency suggests that the egg & bread not providing a negative delta value, as for the egg & fruits providing the second highest delta value (though below zero), could be the reason for significantly less energy consumed during lunch. The result may be due to the secreted insulin which might affect the satiety response and not the glucose level. The insulin's effect on satiety would correlate with both Holt et al. (1996) and Flint et al (2007). Due to limitations in the study the insulin level in the participants was not examined.

In this study there was a significant difference in how the carbohydrate source affected the peak delta blood glucose level. The egg & bread and egg & fruits contain the same amount of carbohydrates but the egg & bread contains "rapidly digestible starch" (Coultate, 2008, p. 57) whereas the egg & fruits contain fructose, which have a lower effect on the blood glucose level as it needs to transform into glucose in the liver before giving a response (Abrahamson et al., 2006, p. 85).

6.4 Participants and Confounders

One factor that could affect the result could be the number of participants. Recruiting participants was difficult since many found it problematic to be available once a week for four weeks. Others had allergies to components in the breakfasts, or did not pass the screening procedure for other reasons, for example they were not used to consume breakfast during the morning. In our study both men and women were included, which is different from for example the study by Fallize (2013). This can be regarded as problematic as the menstrual cycle can affect energy intake, which might have an effect on the result (Lissner et al., 1998). On the other hand this can also be regarded as a strength since when both men and women are included the study better reflects the population. The age span of the participants was rather large, but with the majority of the participants being below 30. This was due to most of the recruitment was done within Lund University and because it might have been easier for students to be available during the morning.

According to the study by Flint et al., (2000) our number of participants (16) would be enough to with a power of 0.8 detect a 10 mm difference in appetite score for mean values (4.5 h) and in the fasting appetite rating for hunger, fullness and prospective food consumption, however for fasting values of satiety and peak/nadir values a larger sample size would be required to detect a difference of 10 mm (18 and 12- 32 participants). Some of the results above might have been different if we would have had a larger sample size. Another factor that might have affected the result is that VAS-scales in both English and Swedish were used as we had both English and Swedish speaking participants. It can also be difficult to translate a feeling into a scale which is the reason for the large standard deviations.

Something that might have further affected the result is the perceived satiating effect of a specific breakfast as it was not for practical reason possible to blind the participants towards what kind of food they were given nor to the serving sizes (Badman et al., 2005; Blundell et al., 2010).

The breakfasts given contained about 40 % less energy than what would be estimated as the need of the participants (NNR, 2004, p. 95; NNR, 2012, p. 34), in order to ensure detection of differences in satiety between the breakfasts. This can also have affected the result as if the participants were very hungry we expect it to be harder to see a difference between the breakfasts.

6.5 Nutrients

Not all macronutrients were within the NNR recommendations. However, the energy percent is regarding the food intake over a longer period of time rather than just one meal (NNR, 2012, p. 16).

As can be seen in Table 9 the yoghurt & müsli and jam & bread do not contain a large amount of the micronutrients parts of the population are lacking. This might be a problem for the people suffering from deficiencies, since the yoghurt breakfast is considered a popular breakfast (CMA Research AB, 2016). The egg based breakfasts do contain a larger amount of micronutrients, however the egg & bread breakfast does not contain any vitamin C which can cause a problem regarding the iron uptake. On the other hand, the egg & fruits breakfast contains the largest amount of vitamin C which will enhance the iron absorption (Abrahamsson et al., 2006, p. 227-229).

The vitamin D content in the breakfasts is based on the Swedish National Food Agency food database (SLV, 2015) which gives a value of 1.29 μg per 100 of boiled eggs. If the 25-hydroxyvitamin D_3 would be taken into account as in the database of Public Health England, this value would have been 3.2 μg per 100g of boiled eggs (Finglas et al., 2015: Public Health England: Institute of Food Research, 2015) as eggs have been found to have a relatively high level of 25-hydroxyvitamin D (Finglas et al., 2015: Public Health England: Institute of Food Research, 2015; Bildoeau et al., 2011).

6.6 Environmental Impact

The debate about climate and environmental impact is complicated to cover and a complete investigation of the climate impact is outside the scope of this essay. Due to time shortage the breakfasts were discussed based on the evaluation above deriving from the NNR (2012), WWF (2016) and Röös (2014) regarding the components used in the largest quantities. According to this investigation, animal products had the largest negative environment and climate impact, whereas plant based foods show a lower impact (NNR 2012 p.148-151; Röös, 2014). Fruits are environmentally friendly and even more so if no pesticides and long transportations are used (NNR, 2012, p.148-151). Eggs, as described above, are also an environmentally friendly protein option

(WWF, 2016). Dairy production is believed to be one of the worse alternatives (after meat) regarding climate (Garnett, 2011) since it contributes abundantly to the emission of GHG:s and eutrophication (NNR, 2012, p.148-151). However when examining the GHG emissions for yoghurt it contributes less to GHG emissions per kg product than other dairy products such as cheese or butter and also less than eggs (Röös, 2014). Even if the emissions of GHG:s is slightly higher per kg of product for egg than for yoghurt (Röös, 2014), the protein content per 100 g is higher in eggs than in yoghurt (Natural yoghurt plain 3 % fat contains 3.42 g protein/ 100g and eggs boiled 12.25 g protein /100g according to SLV food database (2016)) and eggs could therefore be regarded as a more efficient source of protein. Important to consider is also the different serving sizes between the amounts consumed eggs compared to yoghurt. On the other hand, from an environment and climate point of view the best option would be a completely plant based meal (NNR, 2012, p.148-151; Röös, 2014).

7.0 Conclusion

We constructed four isoenergetic breakfasts where two were identical in carbohydrates, protein, fat and fiber, and two contained a larger, but identical amount of carbohydrates and differed in other components. The isoenergetic breakfasts affected the perceived satiety, subsequent energy intake and blood glucose response differently.

The results of our study showed:

- It is more important that the breakfasts provide the largest satiety over several hours rather than straight after consumption to prevent overeating.

- No significant difference in satiety was found between the bread and fruits as carbohydrate source.

- The yogurt & müsli breakfast was most satiating with regards to total area under the curve (AUC) of the appetite scores. Jam & bread was found to be the least satiating with regards to total AUC of the appetite scores.

- No significant difference in satiety was found between the egg & fruits and the egg & bread breakfast.

- The least amount of energy consumed at lunch was after the egg based breakfasts.

- The egg & fruits breakfast gave a lower blood glucose response than the egg & bread breakfast, both containing the same amount of carbohydrates.

- No correlation was observed between blood glucose level and satiety.

- The egg based breakfasts contain a larger amount of the micronutrients which have shown to be deficient in parts of the population. The egg & fruits contain more of vitamin C, folate and iodine than the egg & bread.

- The jam & bread breakfast had the least environmental impact, however this breakfast was the least satiating alternative.

- With regard to energy ingested during following lunch, evaluated micronutrient content and the relative low climate impact the best breakfast option is egg & fruits.

8.0 Future Outlook

There are more interesting areas to examine when it comes to different breakfasts effect on satiety and satiation. A correlation between volume of the food and satiety would have been interesting. It would also be interesting to compare the volume of the food with the weight of the food to examine if there is a difference in satiety. It would further be interesting to continue the investigation on how different breakfasts affect satiety at different time points, as our study showed different results in total AUC and the snapshot in satiety before lunch. Another composition of breakfasts could be studied to evaluate the possible effect warm or cold foods have on satiety. A warm porridge for example, could be compared to müsli.

To improve the understanding of the different satiety responses different breakfasts have, information need to be shared with the population. An example would be to print posters to put up at the Chemical Center for students to read, or to add the information in a magazine.

To improve the results a more closed setting during the meal study would be preferable, since external inputs may affect the result. It would also be possible to make sure that the participants were following the instructions as told. More blood samples could have been taken and more VAS could have been filled out to receive additional information during the day to increase the validity of the results. More participants would also have improved the results.

9.0 Abbreviations

AUC – Area Under the Curve

BMI – Body Mass Index

CCK – Cholecystokinin

$C0_2e$ – Carbon dioxide equivalents

E % – Energy percentage

FAO – Food and agriculture Organization of the United Nations

GHGs – Greenhouse gases

GI – Glycemic Index

GLP-1 – Glucagon-like peptide 1

NNR – Nordic Nutrition Recommendations

PAL – Physical activity level

P-glucose – Plasma glucose

RDI - Recommended daily intake

SLV – National Food Agency, Sweden

WHO – World Health Organization

WWF - World Wide Fund For Nature

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11.0 Appendix

Appendix 1.

Table 1. Screening questions asked to participants.

Namn:		
Födelsedatum:		
Telefonnummer:		
Mejl-adress:		
	Man	**Kvinna**
Kön:		
Hälsa	**Ja**	**Nej**
Har du diabetes?		
Har du ett BMI mellan 18.5 - 30?*		
Har du högt kolesterol?		
Har du högt blodtryck?		
Är du gravid/ammar du?		
Tar du någon medicin som kan påverka mättnad/hungerkänslor?		
Anser du dig som frisk?		
Tränar du mer än 10 timmar i veckan?		
Röker du?		
** BMI=vikt i kg / (längden i meter)^2*		
Matvanor:		
Äter du vanligtvis frukost?		
Äter du minst tre måltider om dagen?		
Om du är man dricker du mer än 28 enheter alkohol i veckan? Om du är kvinna dricker du mer än 21 enheter alkohol i veckan?*		
Går du på någon diet?		
Bantar du för tillfället?		

Deffar du?		
*Exempel på en enhet är: 33 cl starköl alternativt 12 cl 13 % vin, eller 4 cl sprit.		

Allergier:		
Har du någon matallergi/intolerans? I så fall vilken?		
Är det något av följande du inte tycker om? Kokt ägg, äggsmörgås, yoghurt, aprikosmarmelad, müsli, apelsinjuice, banan, äpple, apelsin, Pyttipanna		

Tillgänglighet		
Du kommer att behöva vara tillgänglig för en frukost samt en lunch en dag i veckan (tisdag, onsdag eller torsdag) från och med vecka 14 till och med vecka 17. Är detta ett hinder för dig?		
I studien kommer det eventuellt ingå blodsockermätningar genom att du själv sticker dig i fingret, detta är frivilligt. Går du med på att göra det här?		

Table 2. VAS questions provided to the participants in a booklet.

Questions regarding fullness and hunger: (Frågor angående mättnad och hunger)	How hungry do you feel? (Hur hungrig känner du dig?) (Fallaize et al., 2013)
	How much do you think you could eat? (Hur mycket tror du att du skulle kunna äta?) (Fallaize et al., 2013)
	How full are you? (Hur mätt är du?) (Fallaize et al., 2013)
	How strong is your desire to eat? (Hur stor är din önskan att äta?) (Pombo-Rogrigues et al., 2011)
	How thirsty do you feel? (Hur törstig är du?) (Abou-Samra et al., 2011)
Questions about the meal: (Frågor angående måltiden)	Appearance (Utseende)
	Odor (Doft)[1]
	Taste (Smak)
	How palatable was the food? (Hur god var maten?)

[1] The question regarding odor was later discarded since the participants did not experience it.

Appendix 2.

Example of how the satiety was calculated for the entire study day, based on one participant and the Egg & bread breakfast:

1. VAS booklets were collected and the distance from the left end to the mark made by the participant was measured using a ruler (mm) for each question.

2. An appetite score was calculated from the questions from VAS regarding satiety and hunger for each time point:
   Appetite score = [Fullness + (100-Desire to eat) + (100-Hunger) + (100-How much you think you can eat)] / 4
   34 = 30+(100-61)+(100-65)+(100-68)

Time (min)	Appetite score
0	34
15	62
45	57.75
120	59
180	36.5
240	16.5

The delta value for each person was calculated based on the baseline value of the appetite score:

Appetite score	Subtract baseline value	Delta value appetite score
34	34	0
62	34	28
57.75	34	23.75
59	34	25
36.5	34	2.5
16.5	34	-17.5

3. The delta value for each appetite score vs time was entered into the Graphpad Prism ver. 7.0 program to calculate the peak area under the curve (AUC) for every person. This areas is only based on the positive appetite score values.
   = 3649

4. The AUC for each breakfast and person was centralized and normalized:

	Egg & bread	Egg & fruits	Yoghurt & müsli	Jam & bread	Mean
Delta AUC	3649	4836	3631	4278	4098.5

Centering using mean of evaluator: $X_{n,i}=x_i/(\text{mean of } x)-1$

-0.11 =3649/4098.5 – 1

	Egg & bread	Egg & fruits	Yoghurt & müsli	Jam & bread	SD
Centralized	-0.11	0.18	-0.12	0.04	0.12

Normalized using the centralized value divided by the standard deviation: $X_{n,i}/SD$

	Egg & bread	Egg & fruits	Yoghurt & müsli	Jam & bread
Normalized	-0.90	1.48	-0.94	0.36

5. The centralized and normalized values for each person were placed in Graphpad Prism ver. 7.0 program to calculate the significant difference using ANOVA or Student's T-test. For post hoc Tukey test was used in the same program.

The same calculations were made for the three blood glucose values received during the day.