



Sveriges lantbruksuniversitet  
Swedish University of Agricultural Sciences

Faculty of Natural Resources and  
Agricultural Sciences  
Department of Food Science

# Consumer sensory science in product development

– A case study with a fermented rye product

*Cai Ruiling*

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**Supervisor:** Maud Langton, Institutionen för livsmedelsvetenskap, SLU

**Assistant Supervisor:** Line Holler Mielby, AU

**Examiner:** Rikard Landberg, Institutionen för livsmedelsvetenskap, SLU

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## **Popular scientific summary**

The current food market is dynamic and surrounded by numerous of new foods every year. Nevertheless, it is reported that more than 70% of new food products launched failed. Hence the study of the perceived satisfaction with new products in their product development process is critical.

This study aimed to develop methods to obtain consumers' response of on-going product development process with fermented rye products. Two methods were utilized in the study:

- The study of the prospective portion size aimed to measure the consumers' interest to food. The results showed that different food metrics of rye products had significant different prospective portion sizes. Across three rye products (i.e. rye grain, rye flake and rye puff), rye flake was chosen the largest portion (calorie for calorie), and rye puff was chosen the smallest portion. In addition, expected satiety was indicated to be negatively correlated with the prospective portion size; hence it can be used to a predictor of the prospective portion size. Moreover, individual difference of the feelings of hunger and satiety could have effects on making decisions about portion size.
- The study of collative motivation model aimed to predict long-term liking of fermented rye products by the relationship (i.e. the inverse U shape relationship) with collative properties (i.e. familiarity, novelty and complexity). This study was completed in two episodes. The results in the ESOF partially supported the inverse U shape relationship between liking and collative properties; and the results in the Food festival did not support this relationship. To sum up, the results of the study did not support the inverse U shape relationship. The reasons may be the products' quantity is not large enough and the range of the perceived inter-product difference is not large enough. Nevertheless, this study verified that food product preference/acceptance of were driven by the balance of familiarity and novelty/complexity. Meanwhile, the possibility to improve the fermented rye products existed; it depends on the balance of complexity and harmony (regarding the familiar need).

## **Abstract**

Consumers' perceived satisfaction with a new product is an important area of research in product development. The present study aimed to utilize two methods in order to understand consumers' perceived satisfaction in the product development process of a fermented rye-product. The consumer tests were held in two separate occasions: ESOF and the Food festival. The study of prospective portion size was carried out in ESOF and the study of collative motivation model was carried out in both occasions. In addition, a descriptive analysis was used to describe products used in the study of collative motivation model in the Food festival.

The study of prospective portion size was investigated both as the measurement of interest to food and as an important factor affecting short-term energy intake by visual stimuli. The results showed that different food metrics of rye products had significant different prospective portion sizes. The prospective portion size was negatively correlated with expected satiety; hence it can be predicted by expected satiety.

The study of collative motivation model aimed to predict long-term liking of fermented rye products by the relationship with collative properties (i.e. familiarity, novelty and complexity). The results from the ESOF showed a linear relationship between the hedonic response and complexity, which partially supported the inverse U shape relationship between liking and collative properties. It may be because the products' quantity was not large enough. And the results obtained at the Food festival did not support the inverse U shape relationship. This could be explained by the range of the perceived inter-product difference was not large enough, which was verified by the descriptive analysis. The result of the descriptive analysis verified the non-significant difference between two of five tested products. In conclusion, the results of the two collative motivation models did not support the inverse U shape relationship. Nevertheless, the rye products' preference/acceptance was proved to be driven by a concurrent need for familiar stimuli and novel/complex stimuli, and this could be a direction to further improve the acceptance of the fermented rye products. Two potential consumer groups were shown from the results. At last, among demographic factors, information levels and language versions were identified to have effects on the acceptance of the products.

*Keywords:* fermented rye bran, portion size, expected satiety, liking, collative properties

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# 1. Introduction

## 1.1 Introduction to the project and the product

The project of this thesis is a part of the research project – SENWELL, which aims to explore the role of sensory food satisfaction in promoting healthy and sustainable eating behavior. Senwell is a large collaborative project among Danish universities and industry partners including the food and agricultural company (i.e. Lantmännen and Aarhus Universtiy). The present study is also a part of the product development process of the new products – rye cereals containing fermented rye bran powder by Lantmännen.

Rye is a traditional staple food in Northern and Eastern Europe. The most common rye foods in these regions are rye bread and rye breakfast cereal. The most well-known benefits of consuming rye foods attributes to the dietary fiber (Åman et al., 2010), as well as to the phenolic compounds (e.g. phenolic acids, lignans) (Bondia-Pons et al., 2009). Rye contains about 20% dietary fiber. Approximately 40% of the dietary fiber is extractable, making it as an outstanding source of fiber compared to other commonly used cereals. However, due to food processing, such as milling, many components with established health benefits (e.g. dietary fiber, phenolic compounds, minerals, vitamins) deplete with the removing of the bran. Even though rye is consumed as whole grain, the molecular weight and properties of rye dietary fibers may be modified by food processing, such as baking (Bondia-Pons et al., 2009; Åman et al., 2010). Moreover, the bran of cereals contains cellulose and lignin, which influences both the taste and mouthfeel of cereal products, thus restricting the bran's full application in foods (Katina et al., 2007).

In order to improve the utilization of rye bran, studies are going on to make it as an ingredient for provision of dietary fiber and bioactive compounds. Owing to the fermentation process, the fermented bran would have more benefits compared to unfermented bran, such as enhanced bio-accessibility and conversion of phenolic acids into their microbial metabolites in a colon model. Hence, fermented bran is regarded as a nutritionally boosted cereal ingredient for many different foods (Katina et al., 2007). Under this assumption, the fermented rye bran as a good ingredient adding to different kinds of rye products (e.g. rye grain, rye flake, rye puff) will increase the value of common rye products.

When the fermented rye bran comes to application, consumers' perceived satisfaction with it should be studied along the product development process. There are two important processes in relation to food consumption should be taken into account: satiation regarded as the end point of eating, and satiety (physiological or sensory-specific) regarded as the inhibition of the feeling of hunger and wanting to eat ([www.senswell](http://www.senswell), 2014). In terms of satiety, both physiological and psychological have

been involved in researches. In addition, in the theory of Berlyne (1967), collative properties are regarded as a possibility to manipulate the capacity of foods to satiate a person; hence they are related to the consumption and the satisfaction of foods. Therefore, studies in terms of satiety and collative properties ought to be further explored to get perceived satisfaction of consumers with fermented rye products.

The focus of this work is firstly to utilize and verify sensory and consumer methods in the process of food product development, and secondly help to develop new products – fermented rye bran products.

## 1.2 Theoretical background

### 1.2.1 Sensory science

Sensory evaluation is a method that uses human senses (e.g. sight, hearing, smell, taste and touch) as instruments of measurements, so it has its own incomparable advantages than modern instruments, such as gas chromatography (Bech et al., 1994). Sensory evaluation traditionally plays a critical and prominent role in food industry, as it isolates the sensory properties of foods from other exterior properties (e.g. brands, prices, packages) and provides food practitioners with information regarding sensory characteristics (Lawless & Heymann, 2010).

Lawless and Heymann (2010) divided sensory evaluation techniques into three categories according to different goals and to the criteria demanded for participants' selection:

- Discrimination analysis: it aims to detect difference in any way between products. Participants in a discrimination test do not need any training or sometimes just need to be partly trained. Examples of discrimination analysis are triangle test, Duo-trio test and paired comparison tests.
- Descriptive analysis: it aims to detect difference in specific sensory characteristics between products. Participants in a panel should be trained or highly trained. Classic examples of descriptive analysis are Flavor Profile (FP), Quantitative descriptive analysis (QDA), and Sensory Spectrum etc.
- Affective analysis (consumer sensory analysis): it aims to evaluate the personal response to preference or acceptance from consumers concerning a product idea, existing product or some specific product characteristics. Affective analysis usually focuses on investigating “whether the consumer like the product, prefer it over another product or find the product acceptable based on its sensory characteristics” (Lawless and Heymann, 2010). The most common used methods of consumer sensory evaluations are the simple paired preference testing, the 9-point hedonic scale, and the labeled affective magnitude scale (LAM), just about

right scales (JAR), ranking test, and best-worst-scaling (BWS) etc. In consumer sensory tests, it is crucial to use consumers rather than trained panelists to answer questions. It is because consumers often react immediate and perceive the product as a whole pattern, without considering specific attributes of a product. Moreover participants in a consumer sensory test should be regular users of a product or at a minimum like this type of the product and be familiar with similar products. The reasons are make sure that participants have a frame of reference and can compare the product with similar products that they have experienced, as well as participants can possess reasonable expectations on the product (Lawless and Heymann, 2010).

In this thesis, two of the three categories will be used: descriptive analysis and affective analysis.

#### 1.2.1.1 Descriptive analysis

Descriptive analysis is regarded to be the most sophisticated tool in sensory science. There are different descriptive analysis methods, differing in more or less objective, qualitative or quantitative. The methods induce complete sensory descriptions of products in both qualitative and quantitative aspects. The use of descriptive analysis is comprehensive in food science and food industry (Lawless and Heymann, 2010):

- In product development, it can be used to characterize a detailed specification of the sensory attributes of a single product, and comparisons among several products in order to distinguish the difference of comparative products. Moreover, it can measure how close an on-going product is to the target or to prototype products in the different stages of a product development process.
- In quality assurance, it can be used in quality control tests when quality problems occur in terms of sensory aspects.
- In academic context, descriptive methods can be used to define sensory-instrumental relationship. Last but not least, the data and information collected by descriptive analysis can be related to information regarding consumer preference through consumer tests.

Regarding the type of panelist, both descriptive analysis and discrimination analysis are the analytical tests, which are based on the assumption that panelists are interchangeable, namely sensory acuity and performance are the only things that should be monitored. As a result, a small panel of trained panelists is appropriate in terms of an internal validity perspective (Giacalone et al, 2013). A generic descriptive analysis usually has 8 – 12 trained panelists. The methods consist of generating and using a list of sensory attributes and their intensity with the use of reference standards. When performing descriptive analysis the panelists must focus on specifying what

attributes are present and at what level rather than their personal preferences; in other words, the panelists would not be asked for their hedonic responses to a product. To perform a descriptive analysis study, three steps are usually implemented: training the panelists, determining panelist reproducibility and evaluating samples (Lawless and Heymann, 2010).

#### 1.2.1.2 Affective analysis

During the food products development processes, consumer sensory tests are usually used in the early stage (e.g. the study of consumer trends) and in the end of the stage (e.g. final product prototype determination). It may be the cost of a consumer test or the insufficiency in methods to induce information for the sake of product development.

Giacalone et al (2013) advocated the use of consumer data in analytical analysis. He distinguished data from consumer sensory test and analytical test were different in two ways: attribute meaning and discriminative ability (Giacalone et al., 2013). Regarding to attribute meaning, sensory attributes developed by trained panels are regarded to have a higher degree connection to physical product characteristics; in comparison, consumers would probably express their opinion on non-technical and non-characteristic attributes (Giacalone et al., 2013). In terms of discriminative ability, trained panels are usually able to detect small differences between products rather than consumers (Hough, 1998). Researchers (Ares et al., 2010; Giacalone et al., 2013) argued that consumer data based on simple sensory concepts would ensure a better understanding of the end-consumer's perception to the sensory characteristics of food products, rather than data from sensory panel with variables that are may be irrelevant to the end-consumer. Moreover, discriminative ability is argued to be important for quality control and for maintaining product integrity, but not for getting a direct feedback on sensory characteristics of food products as developmental guidance for product developers (Moskowitz, 1998). Bech et al. (1994) thus indicated that when determining the optimal design of food products, consumer data such as acceptability information can be combined with other sensory analysis, knowledge of consumer expectations, and product formulation constraints. In this work, we are trying to involve consumer sensory tests and consumer data in an on-going product development process.

In general, there are two main methods for consumer sensory analysis: preference testing and acceptance testing. In a preference testing, the consumer assessor has a choice between products; and in an acceptance testing, acceptability scaling can be scored for scaling the degree of acceptability.

On the contrary to analytical test, affective test involves an external validity perspective. It maintains that people differ fundamentally in their perception, and hence requires larger amount of participants to ensure that data are projectable and

that the characteristics of specific segments can be observed (Giacalone et al, 2013). Lawless and Heymann (2010) indicated an adequate numbers of consumers in a consumer sensory test should be around 75-150, or even larger. The reason is that individual preference has a high variability; it varies in personal background, experiences, culture, attitudes, habits and personal interests that have effects on individual's preference regarding appearance, texture, smell and taste of a food. Moreover, individual's preference may be affected by the time of the day for consumption, the number of times the food has been consumed recently and the serving condition of the food etc. hence, the amount of participants is critical for sensitivity and statistical power.

### 1.2.1.3 Questionnaire design in sensory consumer evaluation

The questionnaire is one of the most important parts in sensory consumer evaluation. It is the mean of communication between respondents and sensory professionals by providing response to stimuli. In general, the questionnaire should be easy to understand by respondents, and avoid any biases. A pre-testing hence is necessary to expose faulty assumptions. Lawless & Heymann (2010) suggested a variety of principles for questionnaire design. They are: brevity; use plain language; do not ask what they do not know; avoid vague, ambiguity and double-barreled questions; check for overlap and completeness; avoid questions that suggest a correct or desirable answer; beware of halos and horns; and be as short and concise as possible.

There is no definitive answer for the sequence of questions. Regarding the place of the general acceptance question, although many sensory professionals prefer to place it as the first question, others argue this decision (Moskowitz et al., 2008). Lawless & Heymann (2010) indicated that the primary rule for questionnaire design is to make the questionnaire flow go from general to specific. In general, in food and consumer product testing, it starts with:

- Screening questions to qualify the respondent;
- Followed by a general acceptable question for liking or disliking the product;
- After that, open-ended reasons for liking and disliking would be asked;
- The questions with relation to more specific attributes are presented to respondents. The reason of the sequence of general acceptable question and specific attribute questions is to avoid respondents trying to figure out the aim of the test and giving the right answer or trying to please the interviewer, because questions related to specific attributes may lead to unrealistically analyze in respondents;
- Claims, opinions and issues are mentioned. The information can be important for subsequent advertising and label information;
- Overall satisfaction or some other correlated index of liking would be asked at this time. Satisfaction is more related to performance relative to expectations than it is to acceptability;

- Sensitive personal demographics such as income are better to be disclosed at last, because participants should feel comfortable and familiar with the interview process.

When sensory professional wants to test comprehensive sensory attributes of a food, in order to minimize re-tasting and maximize the quality of the data obtained, two key points should be taken into account: the order in which attributes are perceived and their importance to the product. In general, the recommended sequence is visual appearance, aroma, taste/ flavor, texture, and aftertaste (Moskowitz et al., 2008).

### 1.2.2 Food choice

Food choice - choices people make among food - influences food production systems through consumer demands. In the last several decades, researchers in different disciplines (e.g. in consumer science and psychology) have indicated some aspects of food choice (Tanis et al., 1996). Köster (2007) advocated an exhaustive overview of food choice, which is influenced by many interacting factors belonging to a variety of scientific disciplines. They are biology, physiology, psychology and sociology. They all attempt to answer at least partially of the central question of food choice: “Why does who eat what, when, and where?” In the paper, Köster (2007) indicated the different responsibilities of the disciplines:

- Biology regarding energy balance, physiology regarding oro-, gastro-, and intestinal mechanisms, as well as psychology regarding motivation and decision making on food answer the “why” question;
- Biology with relation to genetic factors and gender, sociology about culture, tradition and social status and psychology regarding group formation, age and learning and personality trait attempt to answer the “who” question.
- Sensory, consumer and food science (e.g. sensory attributes, food chemistry, nutritional value), marketing (e.g. consumer attitudes, beliefs and brands), psychology regarding sensory interaction, learning and expectations, and economics (e.g. price and benefit) may answer the “what” question.
- At last, almost all of the above disciplines have answers to the “where” and “when” questions.

This work focuses on answers regarding the “what” question through sensory and consumer methods.

#### 1.2.2.1 The portion size of foods

The portion size of foods has usually been investigated as an important environmental

factor affecting short-term energy intake (Kral, 2006) and as the dependent measure of interest to food (Brunstrom et al., 2008). Kral (2006) indicated that besides the physiological mechanisms on energy intake, it is possible that psychological events, such as sensory influences (e.g. visual cues, olfactory cues), cognitive factors (e.g. learning, social norms), and post-ingestive consequences (e.g. sensation of hunger and fullness) related to the portion size of foods altogether contribute to the amount of food consumed by people.

When Kral (2006) summarized the works on the portion size of foods, three factors are usually used to investigate the subjects' cognition: hunger and fullness, perceived/prospective portion size, and pleasantness of taste. Researchers found that it is possible that the type of food served (e.g. amorphous or discrete), the size of portion and the increment by which portion size was increased may influence subjects' individual ratings of after-meal hunger across experiments. Meanwhile, regarding prospective portion size, it may be perceived differently in a single food or in a combination of foods, and by the different size of portion, as well as the pleasantness of taste of foods.

Brunstrom and Shakeshaft (2009) emphasized the importance of one of the cognitive factors – self- selected portion size - in decision about meal size, underlying the fact that the control of meal size in human being is learned and expressed in the cognitive activity (Brunstrom, 2011). In history, portion size is typically studied by observing *ad libitum* food intake (Kral, 2006; Wilkinson et al., 2012), which is regarded as a costly, time consuming and uncompleted approach (Wilkinson et al., 2012). The authors in the paper (Brunstrom & Shakeshaft, 2009) focus on the role of three factors (i.e. expected satiety, liking and intention to restrict dietary) that might influence the individual prospective portion size, and then indicated that the prospective portion size can be predicted by liking (affective factor) and expected satiety (non-affective factor). Moreover, these two factors are unrelated; in other words, they can be the predictors to predict prospective portion size independently. A further research (Wilkinson et al., 2012) showed that expected satiety was a better predictor than liking; hence its role in making decision of portion size had been verified.

Questions regarding satiety in literatures usually asked “the extent to which a food staves off hunger”. It is noted that there is another concept “satiating”, which asked “the amount of food that is needed in order to bring about meal termination” (Brunstrom et al., 2008). Brunstrom et al (2008) argued that it has greater validity to use satiety rather than satiation when asking meal size, because satiation (i.e. amount eaten) was influenced by a range of extrinsic factors (e.g. serving size).

Earlier Lantmännen has been involved in researches on satiety in terms of physiological mechanisms (Isaksson et al, 2012). In this work, the focus is on psychological events, in order to explore the relationship of expected satiety and prospective portion size by visual stimuli. In addition, in previous literatures,

researches were based on different food categories, such as crackers, nuts, and chocolates at the same tests. This study focuses on different food metrics regarding one certain food – rye products.

#### 1.2.2.2 The collative motivation model

Over the last twenty years, the use of initial hedonic responses of a food product for predicting long-term preference has been argued a lot, as criticisms indicated that preference and choice behavior can change with experience (i.e. repeated exposures to stimuli) (Lévy et al., 2006). In numerous relative literatures, the arousal theories of Berlyne (1967) and the Dember and Earl (1957), and the concept - sensory specific satiety (SSS) (Rolls et al., 1981) have been applied widespread to understand the mechanisms involved in the dynamics of food preference change.

According to the arousal theory of Berlyne (1967), all stimuli can induce “arousal”, which is a state of psychobiological alertness related to physiological changes (e.g. grain stem activity) and behavioral processes (e.g. attention and drive). The relationship between arousal potential and hedonic responses takes the shape of an inverted U (Figure 1). Figure 1 indicates that for each individual there is an optimal arousal potential level, below and above which stimuli are liked less. The optimal level depends on individuals and can be influenced by learning and experience. Berlyne also defined a set of properties that determine the individual’s arousal potential: psychophysical properties (e.g. stimulus intensity, stimulus quality), ecological properties (e.g. individual’s biological functions: thirst, hunger, sex and fear), and collative properties (properties that affect the arousal level via the attention process: novelty, familiarity and perceived complexity). The collative properties emphasize a comparison between previous experiences and incoming perception of a stimulus (Giacalone et al., 2014).

Among the collative properties, novelty is a property attempting to investigate the distance between expectation and perception. Berlyne (1950) explained that in the measurement of novelty, positive hedonic response (i.e. curiosity and exploratory behavior) was at one side of the scaling, and negative hedonic response (i.e. fear and withdrawal) was at the other side. Individual would give a positive response when novelty refers to some unexpected feature in familiar material. Familiarity means whether the product has been seen before. In other words, how well a product fits previously encountered products in the category regarding sensory characteristics. Novelty and familiarity are slightly different in perceptual dimensions, as novelty try to measure some surprising elements, and not necessarily has to be encountered before by individual. Hence, these two concepts should be measured separately (Giacalone et al., 2014). Perceived complexity refers to the number of discernible elements within a stimulus and on the degree to which these elements coexist or conflict (Berlyne, 1967). Perceived complexity is different from chemical complexity, as chemical complexity means the number of different compounds actually present in

a product. Researches showed that the relationship between perceived complexity and chemical complexity in a flavor study is not straightforward (Giacalone et al., 2014; Jellinek & Köster, 1979, 1983). Many researchers have identified the inverted U shape model between preference and collative properties. For instance, Mielby et al. (2012) has explored the relationship between preference and perceived complexity by visual stimuli. Hence it makes sense to study perceived complexity of any target food products. In this thesis, complexity always refers to perceived complexity.

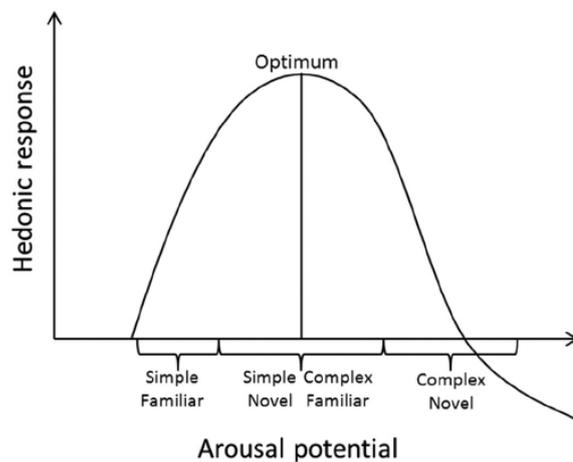


Fig. 1. Relationship between arousal potential and hedonic response (Berlyne, 1967).

Dember and Earl (1957) regarded perceived complexity as the most important collative properties dominating the arousal potential of stimuli. They developed a theory claiming that the individual's optimal level of complexity could be changed by exposure to stimuli of higher complexity. Weijzen et al. (2008) further identified three items to measure complexity: complex, number of ingredients perceived and difficulty to describe the product. Giacalone et al. (2014) indicated that complexity depends not only on the detectability of individual elements of the product, but also on the degree of harmony or congruity of these elements.

Based on the above mentioned older theories, Walker (1980) developed a method to predict long-term hedonic response of foods. In his theory, stimuli that are initially less than optimally liked, but are more complex than the optimally-liked stimulus would be liked for a much longer time than the originally most-liked stimulus. Lévy et al. (2006) further indicated that repeated exposure to simple products does not influence the perceived complexity of simple and complex products, but leads to a significant decrease in liking for both simple and complex products. On the other hand, repeated exposure to a complex product causes a significant decrease of the perceived complexity of complex products, but not of simple products; repeated exposure to complex products leads to a significant increase of liking for complex products, and some decrease of liking for simple products.

Sulmont-Rosse et al. (2008) concluded that two psychological mechanisms are

processing: repeated exposure would lead to an increase in appreciation for a stimulus by giving the individual an opportunity to decrease his/her uncertainty about the safety and the identity of the stimulus; meanwhile repeated exposure would also lead to an increasing feeling of boredom. Sulmont-Rosse et al. (2008) argued that the balance between these two psychological mechanisms depend on the initial arousal potential of stimulus. That means when the individual is exposed to a stimulus with an arousal potential that is higher than his/her arousal optimum, the uncertainty reducing effect surpasses the other one; when the arousal potential is at the right place of the individual's arousal optimum, the two effects are presumably equivalent; and when expose to a lower arousal potential than the individual's arousal optimum, the boredom effect wins. Moreover Sulmont-Rosse et al. (2008) identified the collative property "familiarity" as a key property having effect on the liking score in repeated exposure.

The current food market is dynamic and surrounded by numerous of new foods every year. Nevertheless, it is reported that more than 70% of new food products failed. Lévy et al. (2006) therefore come up with a suggestion: if the less-liked but more complex product can be a candidate to be marketed in food NPD projects?

### 1.3 Hypothesis

The hypothesis of this study is based on the two theories in terms of the collative motivation model and the prospective portion size, they can be elucidated by:

- H<sub>1</sub>: The prospective portion size can be related to expected satiety of one certain food and individual factors.
- H<sub>2</sub>: The prospective portion size is different in different food metrics of one certain food.
- H<sub>3</sub>: The arousal potential of a product can be determined by its combined degree of collative properties, and will be in an inverse U shaped relation with hedonic response.

### 1.4 Aims

The main objective of this thesis is to develop and implement consumer sensory methodologies that can be used to understand consumers' perceived satisfaction with the fermented rye products in product development process. In order to achieve this aim, four aims will be investigated:

- Investigate the relationship between prospective portion size and expected satiety regarding three rye metrics (i.e. rye grain, rye flake and rye puff) by consumer test.

- Distinguish the prospective portion size of the above three rye metrics by consumer test
- Investigate the hedonic quality (e.g. liking and satisfaction) of fermented rye puff in different stages of the product development process by consumer test, and its relation to their collative properties (i.e. novelty, familiarity, complexity etc.).
- Describe and distinguish fermented rye puff by analytical analysis and development relationship between data from consumer test and sensory descriptive analysis.

Appendix 1 presented the overview of the study. In order to achieve the aims mentioned above, three episodes were set up. The first one was held in the ESOF, which involved two tests: the study of prospective portion size and the study of the collative motivation model. The second one was held in the Food festival, which involved one test: the study of the collative motivation model. The products used in the two studies of the collative motivation model were different; they were the on-processing products in the product development process. The final one was the descriptive analysis held in Aarhus University.

### 1.5 Delimitations

There are restrictions in a consumer test, namely the length of the questionnaire could not be a burden of respondents; in other words, tested products and attributes could not be too many to be the burden. Moreover, the project is a part of a new project in Lantmännen, there are also restrictions in the production regarding the mixture of the fermented rye bran and other rye products, and hence the selected levels of stimulus are limited. As a result, for the study of the collative motivation model, the tested levels of stimulus (i.e. tested products in a specific test) are insufficient to retrieve individual curves as the theory states.

## 2 Material and methods

### 2.1 The study of prospective portion size in ESOF

ESOF was held in June of 2014 in Copenhagen. The participants were asked if they would like to take part in either both of the tests or just one of them. If they were interested in both, the sequence was always from the study of prospective portion size to the study of the collative motivation model. Because the fermented rye bran is new to consumers and we could just provide the uncompleted product (i.e. rye flake + fermented rye bran powder) rather than all three rye products to consumers, and we were afraid this would influence the acceptance of the products in the test, and thus making an effect on the selection of expected satiety and prospective portion size.

The products used in the test were rye grain, rye flake and rye puff. Measuring expected satiety and prospective portion size involved showing pictures of three kinds of rye products to participants. 12 pictures are designed to each food metrics, and they varied in the designed portion sizes. Pictures were taken by a Canon EOS 20D camera, with an aperture value of F20, a shutter speed of 1/200, and a focal length of 100 mm; a constant lighting condition in the room was used by taking on a white uniform background and using of photo flash. Each food was photographed on the same white plate (255 mm diameter). For each food, picture number one showed a 50 ml portion, picture two showed a 100 ml portion, and so on. The last one of each food showed a 600 ml portion. All photos in fixed volume were converted into their energy content (kcal).

The measure of expected satiety was based on a “method of constant stimuli” (Brunstrom et al., 2008; Brunstrom & Shakeshaft, 2009). In our test, twelve pictures (230×152 mm) of one food were arrayed page by page from the smallest portion size to the largest portion size (Fig.2, Fig.3, Fig.4). One food of fixed and known energy content is displayed in a picture in Fig. 2, 3, 4. The energy contents were not shown on pictures in the questionnaire. Totally thirty-six pictures were bound into one folder with the “standard picture” in the first page of the folder. The sequence for evaluating three foods was randomized. The “standard” food in our test was “half a rye bun with butter and cheese” and it was converted into its energy content. The reason to choose this standard food is because they are common breakfast on Danish’s table. The amount of the standard food (194.052 kcal) is decided by being comparative with the three foods. During the test, the participants were asked to look through the twelve pictures one food, and indicate which portion size of the food (which picture) would make them have the same fullness as with the standard food. And then did the same procedures with the other two foods.

In the participant recruitment, we told them which kind of food was involved in the test, as we assumed that this consumer group was interested in cereals and variety seeking with regards to cereals. Consumers aged above 15-year-old in the ESOF were all welcomed to our tests.

The measure of prospective portion size was carried out by asking the participants to look through all twelve pictures of one of the three tested foods again, and select the individual prospective portion sizes. Participants were instructed to “imagine it was 8 o’clock in the morning, and you were going to take your breakfast, so which portion size of this food would you like to choose to consume?” The questionnaire part included questions about participants’ age, gender, how hungry they were at the beginning of the questionnaire, and weight and height at last (Appendix 2).



Fig. 2. Thumbnail images of rye grain with energy contents.

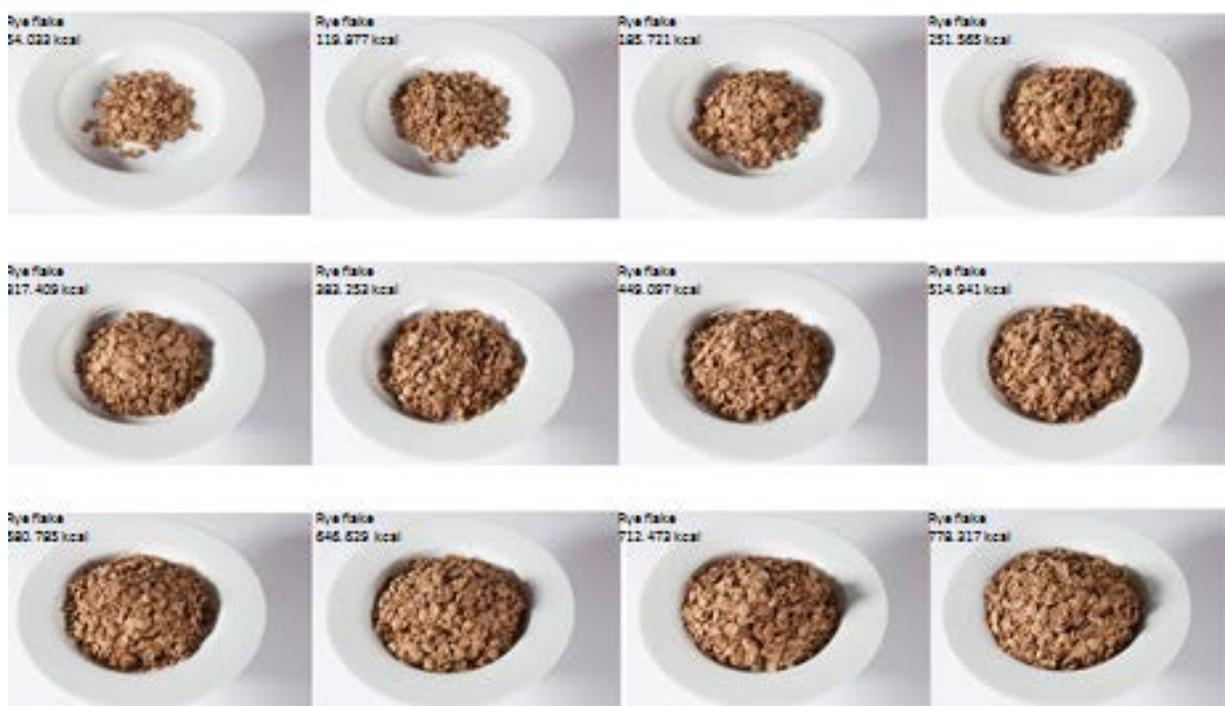


Fig. 3. Thumbnail images of rye flake with energy contents.

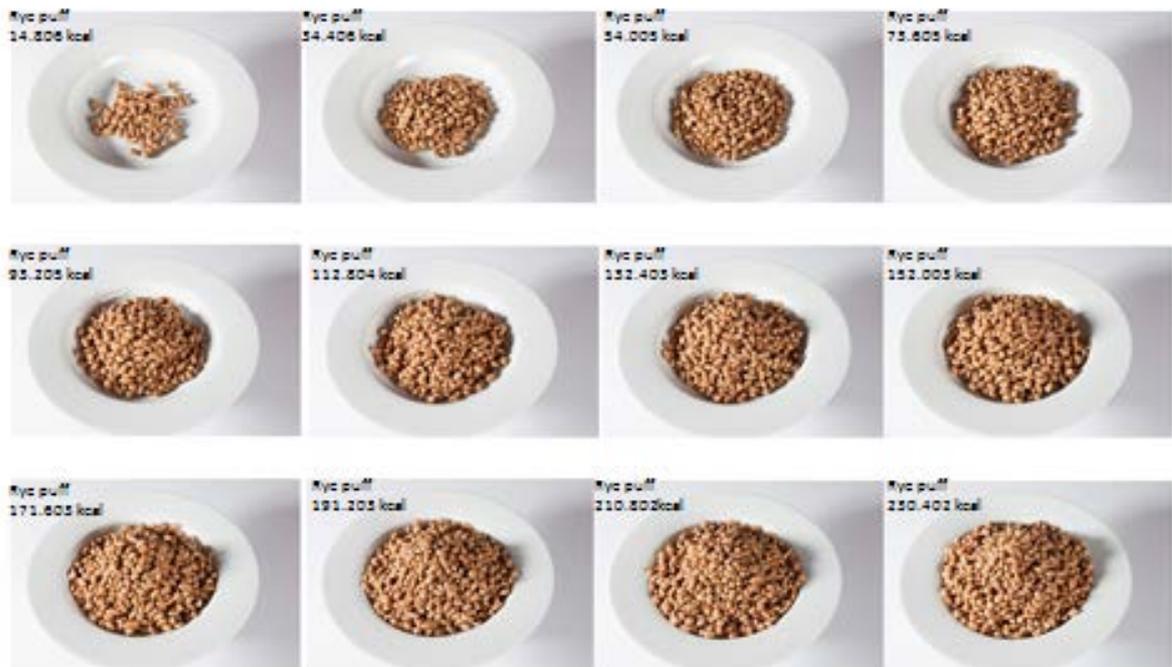


Fig. 4. Thumbnail images of rye puff with energy contents.

For data analysis, the mean (S.E.M.) portions of three rye products were calculated for prospective portion size. For expected satiety, it was converted into a ratio by dividing the standard (194.052 kcal) by the value of the expected satiety. Means and Standard Error of Mean (S.E.M.) of the ratios were calculated. From the ratio, it can be inferred that when the ration is greater than 1.0, the compared rye product is expected to deliver greater satiety than the standard (calorie for calorie), and vice versa. To find significant effects of response variables on expected satiety, univariate data analysis in Generalized Linear Models (GLM) (IBM SPSS Statistics, version 20) was performed. Expected satiety was used as dependent variables; fixed factors are products and background factors of participants: hunger, satiety, desire to eat, BMI groups, and language versions. ID (the ID of participants) was regarded as Randomized factor. Fixed factors that identified to have main effects were analyzed with *Post-hoc* tests. At last, Factors will be plotted in a PCA (SIMCA, version 13.5) to explore their relationships with prospective portion size. All data were auto-scaled and the model was full cross validated.

## 2.2 The study of the collative motivation model in ESOF

In the study of the collative motivation model, products were rye flake mixed with four different dosages of fermented rye bran (0%, 20%, 33% and 43%). The dosages were developed based on the authors' own perception of the level to which was not acceptable. That means the level of 43% was absolutely unacceptable. 20% and 33% were the intervals between the minimal level (0%) and the maximal level (43%). In

the thesis, they are presented as rye flake 1, 2, 3, and 4, respectively. The products used in this test were the uncompleted products in the product development process, so the rye flake and the fermented rye bran were mixed by hand and it resulted in a detached appearance. The products were served with yoghurt (20g, Klover Sodmalksyoghurt Naturel, Arla), because it would be mixed better with fermented rye bran powder than milk.

The questionnaire of the study (Appendix 3) started with participants' demographical information: age, gender and how hungry they were. In order to investigate the difference regarding individual elements, Danish and English questionnaires were prepared. In addition, expectations may influence consumers' perception (Deliza & Macfie, 1996; Mielby & Frøst, 2010), so participants were instructed to scale acceptance and collative properties under three information levels to test if there was any influence:

- Level one: the product is noted as a breakfast cereal;
- Level two: the product is noted as rye flake + fermented rye bran.
- Level three: the product is noted as rye flake + fermented rye bran with potential benefit of consuming it.

The three information levels were conducted separately, in other words, in three consecutive periods with the increase of the information level. The reason is to avoid any communication between participants doing the different levels of questionnaire.

According to the instruction in the questionnaire, participants were asked to rate their liking to the product on a 9 point hedonic scale with the following semantic anchors: 1 = no, not at all, 5 = Neither yes nor no, 9 = Yes, extremely. Rating on familiarity, novelty, complexity, and harmony were elicited via questions, such as "Do you think the cereal is familiar?" and also scaled on the 9 point hedonic scale. The question regarding harmony was under the consideration that the products were on-going products, rather than finished products; hence it might be necessary to investigate the balance of products' tastes and flavors. It followed by a question asking satisfaction based on considering the appearance, aroma, taste and texture of the cereal. Four products were instructed to taste and rate on monadically. At the end of the questionnaire, a question in terms of product knowledge was asked: how much they were familiar with rye-based breakfast cereal. And then two sensitive personal information regarding weight and height were asked.

For data analysis, descriptive statistics (IBM SPSS Statistics 20) was carried to calculate the means and standard deviations of six response variables: liking, familiarity, novelty, complexity, harmony and satisfaction to four products. To find significant effects of background factors on the six response variable, univariate data analysis in Generalized Linear Models (GLM) (IBM SPSS Statistics, version 20) was performed. Variables (liking, familiarity, novelty, complexity, harmony and

satisfaction) are used as dependent variables; fixed factors are products and demographic factors of consumers: products, information level, gender, age groups, BMI groups, language, hunger and rye familiarity. ID was regarded as Randomized factor. The mixed models were performed for the main effects and for the two-way interaction effects between products and other factors. Models were iteratively reduced in case of non-significant interactions, in order to produce more stable models. Subsequently, principal component analysis (PCA) was performed to detect relationships between all variables (SIMCA, version 13.5). Product name (RF), gender (G), information level (Info), age group, BMI, language version (LA) were carried out as quantitative variables; and liking (LN), familiarity (FA), novelty (N), complexity (C), harmony (HA), satisfaction (S), hunger (HU), rye familiarity (RFA) were used as qualitative variables (x variables). All data were auto-scaled and the model was full cross validated.

### 2.3 The study of the collative motivation model in Food Festival

The Food festival was held in September of 2014 in Aarhus. One study - the study of the collative motivation model was completed. There are five products provided by Lantmännen. After considering the length of the questionnaire, four products were used, which were fermented rye puffs (the rye puff was addition of 25% fermented rye bran). They were different in the additional ingredients that added to improve the flavor and the taste of the products:

- a. No additions. In the thesis, it is named RP (N);
- b. Amino acid mix without reducing sugar. It is named RP (A);
- c. Amino acid mix + mix of reducing sugar. It is named RP (AS);
- d. Amino acid mix + mix of reducing sugar + vanillin. It is named RP (ASV).

The same procedure of the study in ESOF was performed. The products (5 grams for each) were served with milk (20g, Arla Mini mælk, 0.5% fat content). The decision of using milk was because milk was one of the most common foods to be served with cereals, and it was based on the authors' judgments that milk could provide better aftertaste to the rye products than yoghurt. Only Danish questionnaire was used because it was estimated most of visitors to the Food festival were Danish; and two information levels were used:

- Level one: the product is noted as rye puff + fermented rye bran
- Level two: the product is noted as rye puff + fermented rye bran with potential benefit of consuming it.

The data analysis was performed in the same way as in the study of ESOF.

### 2.4 The descriptive analysis

The descriptive analysis was held in October of 2014 in Aarhus University (Årsløv). All five products mentioned above were used. The one excluded in the Food festival was:

- e. Vanillin mix without precursor aroma. In the thesis, it is named RP (V).

The generic sensory descriptive analysis (Mielby et al., 2013; Lawless and Heymann, 2010; Murray et al., 2001) was performed by a panel to describe and distinguish products. The panel consisted of 8 assessors. Before the evaluation, the panel went through two training sessions, which lasted for about 2 h separately. With the help of reference samples, assessors developed and made consensus on a list of sensory attributes. The training was conducted using three products of five. After the training sessions, the panel evaluated the five products in two main sessions on two consecutive days:

- In the first session, the five products (4 grams for each) were served without milk. All products were evaluated in triplicates.
- In the second session, the five products (6 grams for each) were served with milk (20g, Arla Mini mælk, 0.5% fat content). All products were evaluated in triplicates.

For data analysis, the software PanelCheck (1.4.0) was used. Consensus and Standardized in the program were used and 3-way ANOVA (products, assessors and replicates) was used to assess the importance of attributes.

### 3 Results and discussions

#### 3.1 The study of prospective portion size in ESOF

267 consumers took part in the test, and 244 consumers finished the questionnaires. Table 1 shows the description of participants in the study.

Table 1. Description of participants in the study of prospective portion size in ESOF

Age groups					Language version	
≤20	20-30	30-40	40-50	≥60	Danish	English
14	78	53	43	56	198	46
BMI groups				Gender		
≤18.5	18.6-24.9	25-29.9	≥30	Male		Female
9	165	57	13	112		132

Regarding relationship between expected satiety (ratio) and prospective portion size, Fig.5 and Fig.6 show the mean prospective portion size and expected satiety for three rye products. Data shows that expected satiety is significantly associated with

prospective portion size ( $r = -.519, p = .000$ ). From the data, product that has high expected satiety is chosen in smaller portions. In our case, Rye puff is regarded to have the highest expected satiety among three products and is chosen the smallest portion when consuming it; and rye flake has the smallest expected satiety and is chosen the largest portion.

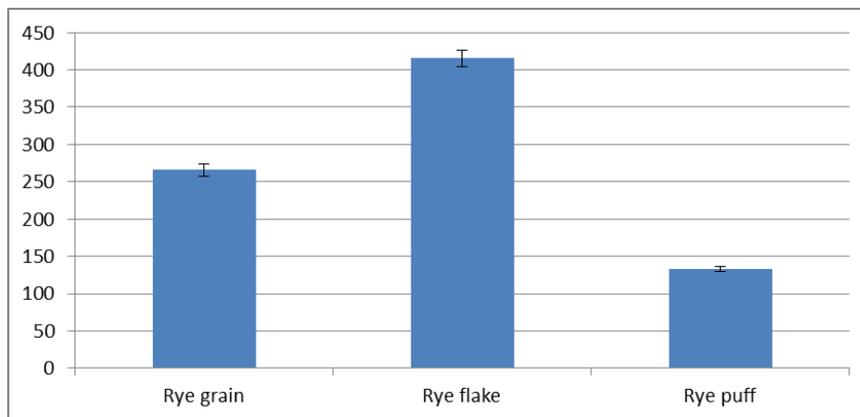


Fig. 5. The average prospective portion size for three rye products.

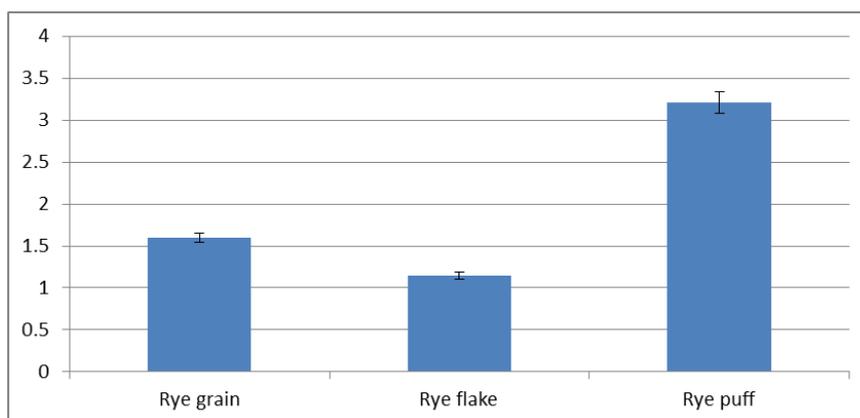


Fig. 6. The average expected satiety (ratio) for three rye products.

Three products are found to significantly differ from each other ( $p=.000$ ) by *Post-hoc* tests regarding prospective portion size.

In order to explore individual differences in the extent to which expected-satiety predicts prospective portion size, a mixed model was developed for the relationship between expected-satiety and individual differences (language version (LA), hunger, satiety, desire and BMI). The mixed model (GLM) (Table 2) shows that only hunger, satiety and products have main effects on expected satiety (ratio). The *post-hoc* test shows that there is significance between the pair who felt extremely hunger and extremely non-hunger. Participants who felt extremely non-hunger has a higher expected-satiety than participants who felt extremely hungry. That means participants who feel extremely hunger or non-hunger are more likely to base decisions about

portion size on the relative satiety that a food portion is expected to generate. For satiety, significant differences exist between some pairs. The trend is that the rated expected-satiety increases with the increase in satiety.

Table 2. p-values for the mixed model of the study

Model	LA	Hunger	Satiety	Desire	BMI	Products
.000	.828	.001	.001	.147	.687	.000

In order to explore the relationships between these response variables and prospective portion size, a PCA (Fig.7) is showed. The PCA model is in line with the mixed model. From Fig.7, Expected satiety (ES (ratio)) is obviously negatively correlated with prospective portion size (PP). Product PF (rye flake) is positively related with PP, and product RP (rye puff) is positively related with ES. Moreover, regarding the relationship between hunger and satiety, they are literally synonymous and they showed obviously negatively with each other, hence they would be the alternative to each other in questionnaires.

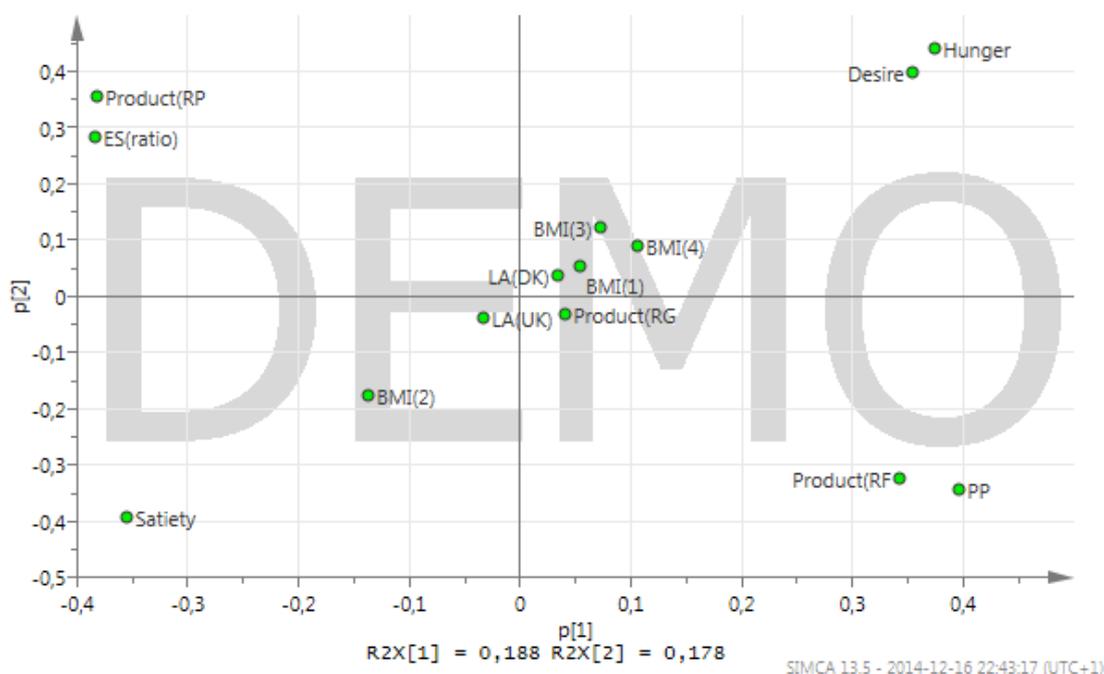


Fig. 7. Principal Component Analysis (PCA) loading on response variables of the study of prospective portion size (PC 1 and PC 2 explained 18.8% and 17.8% of the variance, respectively).

### 3.2 The study of the collative motivation model in ESOF

384 participants took part in the test, and 341 participants finished the questionnaires. Table 3 shows the description of participants in the study.

The results of univariate data analysis (GLM) are shown in Table 4. The model is used to explore relationships between demographic factors and the six response variables

(liking, familiarity, novelty, complexity, harmony and satisfaction). Moreover, Post Hoc Tests are performed to detect significance ( $p < 0.05$ ) for every fixed factors. Descriptive statistics was performed and the means and standard deviations of the six response variables to four products are presented in Table 5.

Table 3. Description of participants in the study of the collative motivation model in ESOF

Information level				Gender		Language version		
Info(1)	Info(2)	Info(3)		G0(Male)	G1(Female)	LA(DK) (Danish)	LA (UK) English	
105	102	134		144	197	275	66	
Age groups					BMI groups			
1 (≤20)	2 (20-30)	3 (30-40)	4 (40-50)	5 (≥60)	1 (≤18.5)	2 (18.6-24.9)	3 (25-29.9)	4 (≥30)
13	112	74	65	77	9	242	73	17

As shown in Table 4, significant main effects of age group and the rating of hunger on six attributes were found. The significant main effects of other demographic factors were found on specific attributes. For example, BMI, language version, the rating on rye familiarity have significant main effects on liking. A significant two-way interaction was found on “Products \* Gender” on novelty, which indicates that males and females evaluated the different products with regards to the response variable novelty.

For the age groups, group 5 (aged above 50) shows significant difference with other age groups by post-hoc tests. Participants in age group 5 have rated significantly higher than other groups on liking. For BMI, participants with BMI in group 2 and 3 have higher ratings on liking than those of in group 1 and 4. Regarding hunger and rye familiarity, although both of them have main effects on liking, but the post-hoc tests show the differences are not regular.

Table 4. p-values for the main effects and two-way interactions, for the six variables.

	Liking	Familiarity	Novelty	complexity	Harmony	Satisfaction
Model	0.000	0.000	0.000	0.000	0.000	0.000
products	0.000	0.000	0.001	0.000	0.000	0.000
Information level	0.797	0.415	0.723	0.068	0.014	0.471
Gender	0.647	0.353	0.670	0.933	0.028	0.707
Age groups	0.005	0.000	0.000	0.003	0.015	0.043
BMI	0.021	0.017	0.013	0.321	0.006	0.230
Language version	0.011	0.000	0.153	0.224	0.594	0.157
Hunger	0.001	0.010	0.005	0.002	0.000	0.001
Rye familiarity	0.000	0.000	0.159	0.013	0.005	0.000

Products * Information level	-	-	-	-	-	-
Products * Gender	-	-	0.019	-	-	-
Products * Age groups	-	-	-	-	-	-
Products * BMI	-	-	-	-	-	-
Products * Language version	-	-	-	-	-	-
Products * Hunger	-	-	-	-	-	-
Products * Rye familiarity	-	-	-	-	-	-

The “-” denotes non-significant interactions removed from the model to produce a more stable model.

Regarding the hedonic response (liking), the rating decreases with the increase of the dosage of fermented rye bran (Table 5). The difference between products is significant ( $p=0.000$ ), as well as the difference are also significant between every pairs of the products by post-hoc tests ( $p=.000$  for all pairs). The ratings of familiarity, harmony and satisfaction show decrease with the increase of the fermented rye bran powder, and the difference between products are significant. In the contrast, the rating of novelty and complexity shows an increase. The harmony and the satisfaction to the products show the same trend with the hedonic response.

The reasons for liking decreasing with an increase of fermented rye on the rye flakes may due to the appearance of the mixture between the rye flake and the fermented rye powder and the taste of the fermented rye powder. Nevertheless, it can be deduced that the fermented rye bran is regarded to be “novel” and “unfamiliar”; it influences the rating of complexity, familiarity, novelty of products, thus further affecting the hedonic response to the products.

Table 5. Mean overall ratings ( $\pm$  standard deviation) for six response variables.

	Rye flake 1	Rye flake 2	Rye flake 3	Rye flake 4
Liking	5.73 $\pm$ 1.799	5.01 $\pm$ 1.888	3.85 $\pm$ 2.127	2.83 $\pm$ 2.131
Familiarity	5.67 $\pm$ 2.093	4.73 $\pm$ 2.036	3.95 $\pm$ 2.191	3.23 $\pm$ 2.152
Novel	3.65 $\pm$ 1.978	3.99 $\pm$ 2.022	4.12 $\pm$ 2.149	4.17 $\pm$ 2.432
Complexity	3.68 $\pm$ 1.929	4.15 $\pm$ 2.014	4.29 $\pm$ 2.138	4.42 $\pm$ 2.242

Harmony	5.37±2.053	4.82±2.053	4.00±2.067	3.11±2.020
Satisfaction	5.44±1.977	4.53±2.040	3.55±2.167	2.80±2.062

In order to explore relationships between hedonic response (i.e. liking, satisfaction, harmony) and collative properties (i.e. familiarity, novel, complexity), and relationships between demographic factors and the six response variables, all variables are included in a PCA (Fig. 8). Harmony (HA) and satisfaction (S) are positively related with liking (LN). Regarding collative properties (i.e. familiarity, novelty and complexity), PC 2 separates familiarity (F) from novelty (N) and complexity (C). Among them, familiarity is closer to liking than the other two properties, which means familiarity has contribution to liking in these products.

As can be seen from Fig.8, PC 1 separates Rye flake 1 and 2 from Rye flake 3 and 4. That means rye flake 1 and 2 are more positive related to liking (LN) than rye flake 3 and 4. That means regarding the dosage of fermented rye bran, rye flake 2 (20% fermented rye bran) still contributes to liking, although its rating in liking is not the highest. If Walkers' theory (1980) is used here, Rye flake 2 would be the less-liked but more complex product that will bring long-term liking to this new product type under the assumption that rye flake 1 is at the top of the inverse U shape.

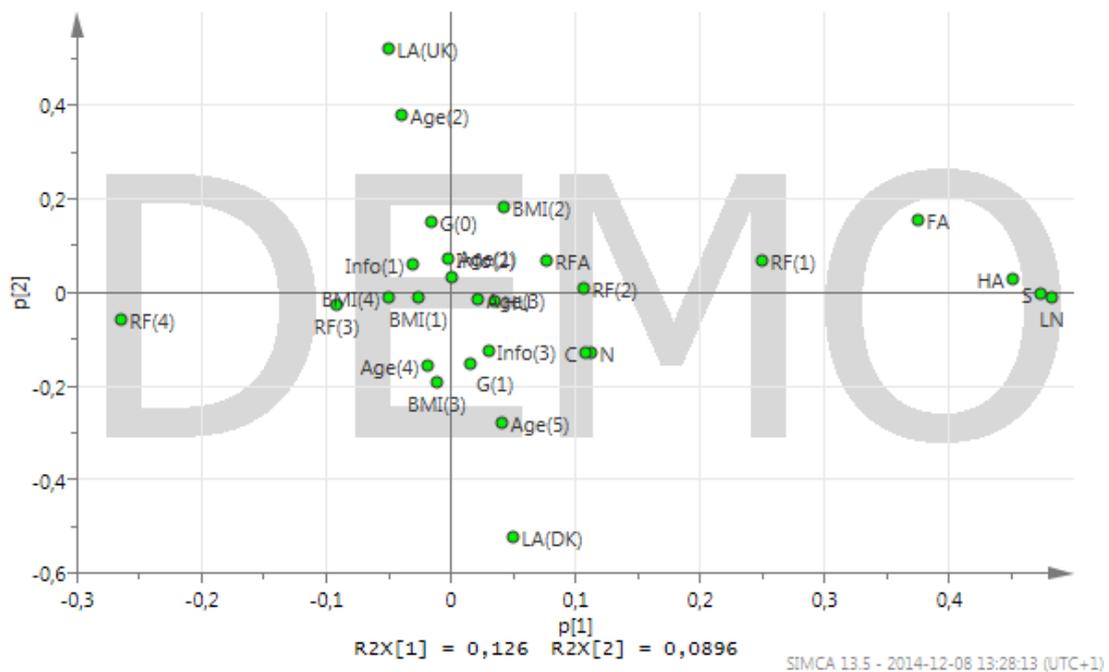


Fig.8. Principal Component Analysis (PCA) loading on all variables of the study on ESOF.

In terms of the demographic factors, we could connect the PCA model with the GLM model. PC 1 and PC 2 explain 21.56% of the variance totally; nevertheless it is acceptable in consumer science. And here, PCA is used as supplement to the GLM model.

Language versions are also separated by PC 2, LA (DK) and LA (UK) show an

inverse influence on the PCA model. Regarding information level (Info), there is no main effect for it on liking from the GLM model, nevertheless, from the PCA mode, it has the trend that participant taking the info (3) rated higher scores on liking than participants taking the info(1). Moreover, the *post-hoc* test shows that there is no difference between info (2) and info (3), so in order to further explore the relationship between information level in the study in Food festival, only two information levels was used.

From the PCA plot, we may get more information regarding individual difference. Age group (2) is close to BMI (2); in the contrast, age group (4) and (5) are close to BMI (3). That means most of the participants' ages between 20 and 30 have normal weights, and most of the participants' ages above 40 are overweight. In addition, age group (2) is close to LA (UK) and LA (DK) is close to age group (5). It infers that the most of the English speakers in the test are among age group (2), on the other hand, participants in age group (5) are Danish speakers. To some extent, it can explain the result from the GLM model: most of the participants in age group (5) are Danes, who like this kind of products than others. On the contrary, English speakers taking part in the test are youths who are the less liker.

### 3.3 The study of the collative motivation model in Food festival

398 consumers took part in the test, and 362 consumers finished the questionnaire. Table 6 shows the description of participants in the study.

Table 6. Description of participants in the study of the collative motivation model in Food Festival.

Information level		BMI groups				
Info(1)	Info(3)	1 ( $\leq 18.5$ )	2 (18.6-24.9)	3 (25-29.9)	4 ( $\geq 30$ )	
183	179	15	262	59	26	
Age groups					Gender	
1 ( $\leq 20$ )	2 (20-30)	3 (30-40)	4 (40-50)	5 ( $\geq 60$ )	G(0) Male	G(1) Female
23	220	43	22	50	126	236

The results of univariate data analysis are shown in Table 7. Moreover, Post Hoc Tests are performed to detect significance ( $p < 0.05$ ) for each fixed factors. Descriptive statistics was performed and the means and standard deviations of the six response variables: liking, familiarity, novelty, complexity, harmony and satisfaction to four products are presented in Table 8.

From Table 7, significant main effects of information level and the rating on hunger on six attributes were found. In addition, the rating on rye familiarity has main effects on five attributes except for novelty. *Post-hoc* tests show that hunger is positively

correlated with liking. But the difference on rye familiarity is not regular. No significant interaction effects are observed.

Table 7. p-values for the main effects and two-way interactions, for the six variables.

	Liking	Familiarity	Novelty	complexity	Harmony	Satisfaction
Model	0.000	0.000	0.000	0.000	0.000	0.000
products	0.049	0.735	0.175	0.128	0.080	0.396
Information level	0.000	0.013	0.000	0.019	0.000	0.000
Gender	0.283	0.375	0.010	0.922	0.676	0.167
Age groups	0.626	0.000	0.010	0.042	0.643	0.273
BMI	0.417	0.106	0.000	0.358	0.061	0.001
Hunger	0.022	0.017	0.002	0.000	0.037	0.044
Rye familiarity	0.000	0.000	0.283	0.001	0.030	0.001
Products * Information level	-	-	-	-	-	-
Products * Gender	-	-	-	-	-	-
Products * Age groups	-	-	-	-	-	-
Products * BMI	-	-	-	-	-	-
Products * Hunger	-	-	-	-	-	-
Products * Rye familiarity	-	-	-	-	-	-

The “-” denotes non-significant interactions removed from the model to produce a more stable model.

Regarding liking, the ratings on liking increase with the adjunction of different combination of additional ingredients (Table 8). Significant difference ( $p=0.049$ ) was found between products regarding liking (Table 6); but the multiple comparisons (post hoc tests) show the difference just exists between RP (N) and RP (ASV) ( $p = .005$ ). Except the liking, there are no significant difference can be found between products on other variables (Table 7).

Regarding complexity, the rating on RP (N) is higher than those of on RP (A) and RP (AS), as verifies that the relationship between perceived complexity and chemical complexity is not straightforward.

In order to explore relationships between hedonic response (i.e. liking, satisfaction,

harmony) and collative properties (i.e. familiarity, novel, complexity), and relationships between demographic factors and the six response variables, all variables are included in a PCA (Fig. 9). As can be seen from Fig.9, harmony and satisfaction are still positively related with liking. In terms of collative properties (i.e. familiarity, novelty and complexity), PC 2 separates familiarity from novelty and complexity.

Table 8. Mean overall ratings ( $\pm$  standard deviation) for six response variables.

	Rye puff (N)	Rye puff (A)	Rye puff (AS)	Rye puff (ASV)
Liking	4.40 $\pm$ 1.934	4.62 $\pm$ 1.937	4.62 $\pm$ 1.836	4.79 $\pm$ 1.892
Familiarity	4.52 $\pm$ 2.112	4.48 $\pm$ 2.106	4.59 $\pm$ 2.150	4.43 $\pm$ 2.188
Novel	4.33 $\pm$ 1.931	4.36 $\pm$ 1.971	4.23 $\pm$ 1.957	4.54 $\pm$ 1.955
Complexity	4.41 $\pm$ 1.730	4.36 $\pm$ 1.802	4.37 $\pm$ 1.776	4.63 $\pm$ 1.770
Harmony	4.27 $\pm$ 1.921	4.47 $\pm$ 1.885	4.59 $\pm$ 1.870	4.30 $\pm$ 1.912
satisfaction	4.15 $\pm$ 1.910	4.28 $\pm$ 1.906	4.31 $\pm$ 1.826	4.38 $\pm$ 1.974

In terms of the demographic factors, the PCA model is used to supplement the GLM model. PC 1 and PC 2 explain 23.3% of the variance totally. Information levels have a significant effect on liking in this study. The PCA model shows that info (3) with more detailed potential benefits regarding fermented rye showed a positive relationship with liking (Fig. 9). More information can be obtained regarding individual difference, again BMI (2) is closed to age group (2), and BMI (4) is close to age group (4) and (5) in this study. That means most of the participants' ages between 20 and 30 have normal weights; and most of the obesity participants are aged above 40.

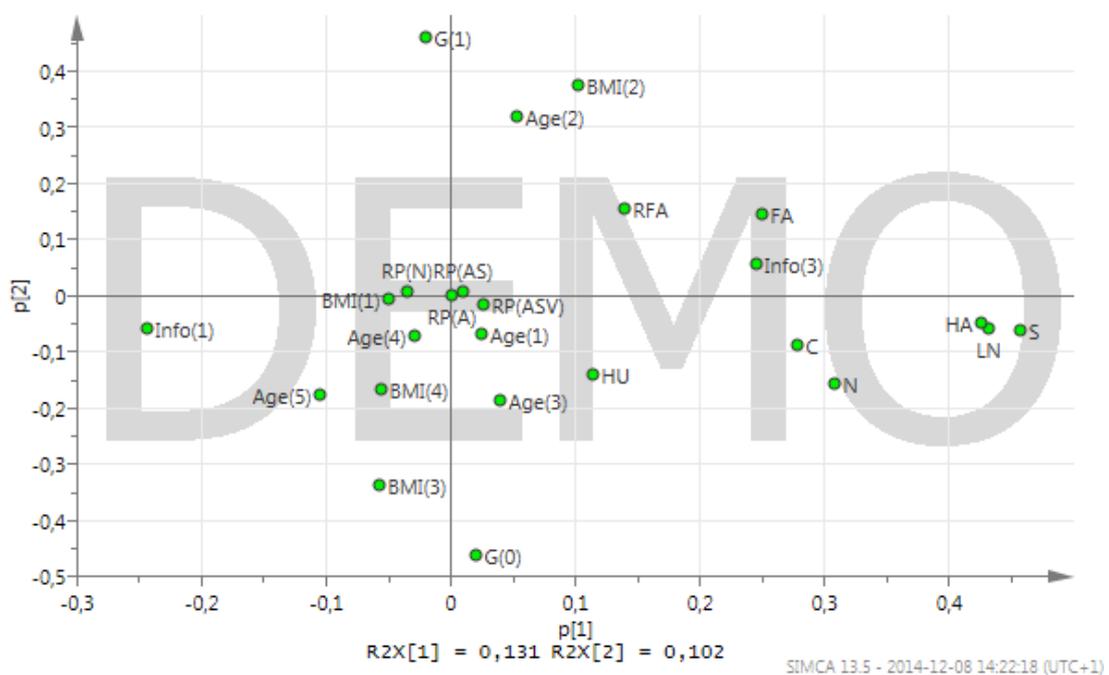


Fig.9. Principal Component Analysis (PCA) loading on all variables of the study on Food festival.

Regarding genders, they are separated by PC 2 (Fig. 9), and they have a main effect on novelty. It is partially in line with the result in ESOF that males and females perceive difference on novelty regarding products.

### 3.4 The descriptive analysis

During the training sessions, the trained panel determined the sensory attributes that were to be scaled in the two main sessions. All the assessors made consensus with the definitions of attributes. The sensory attributes used in the two tests are presented in table 9.

Table 9. Sensory attributes used in the two descriptive analysis tests.

	Attributes in test without milk	Attributes in test with milk
Aroma	Vanilla A	Vanilla A
	Oellebroed	Oellebroed
	Fermented rye A	Fermented rye A
	Fruit porridge	Fruit porridge
	Caramel	/
Basic taste	Sweetness	Sweetness
Flavor	Vanilla F	Vanilla F
	Fermented rye F	Fermented rye F
	Rye bread crust	Rye bread crust

The data analysis of the two evaluations (products served with milk, and products served without milk) was carried out by PanelCheck. The PCA in Fig. 10, shows that PC 1 and PC 2 explained 96% and 3% of the variance, respectively. In Fig. 11, PC 1 and PC 2 explained 87.8% and 7.4% of the variance, respectively. A three-way ANOVA showed that both fermented rye F and rye bread crust are not significant in the two tests, and fermented rye A is not significant in the test with milk.

In order to be easier to understand by readers, the products are explained again:

- RP (N): no additions;
- RP (A) : amino acid mix without reducing sugar;
- RP (AS): amino acid mix + mix of reducing sugar;
- RP (ASV): amino acid mix + mix of reducing sugar + vanillin;
- RP (V): vanillin mix without precursor aroma.

To compare the two results from the two bi-plots, RP (AS) is closed to RP (N) in the test without milk, and closed to RP (A) in the test with milk. So serving with milk in the test does have an effect on the taste of the products and should be included in the consideration.

For sensory attributes, fermented rye A, oellebroed, fermented rye F and rye bread

crust are closed together that means they have similar tough related to fermentation in rye or bread. Sweetness, fruit porridge and caramel are closed that means they have similar tough related to sweet. So the three main categorical tough in products are vanilla, sweet, and fermented rye, although fermented rye is not significant.

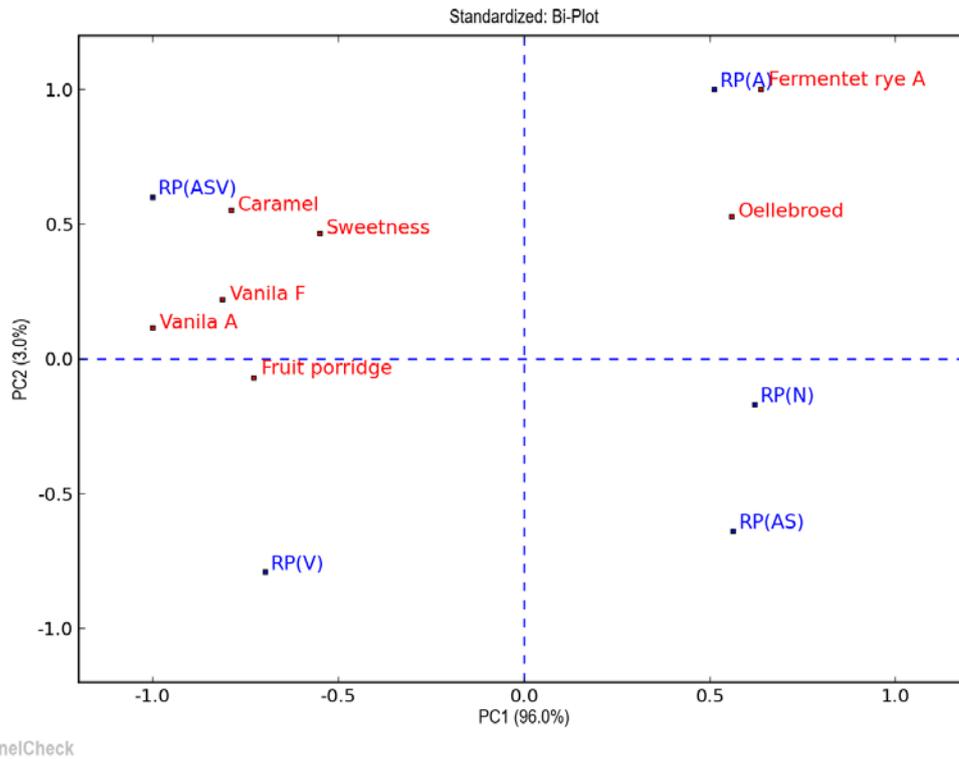
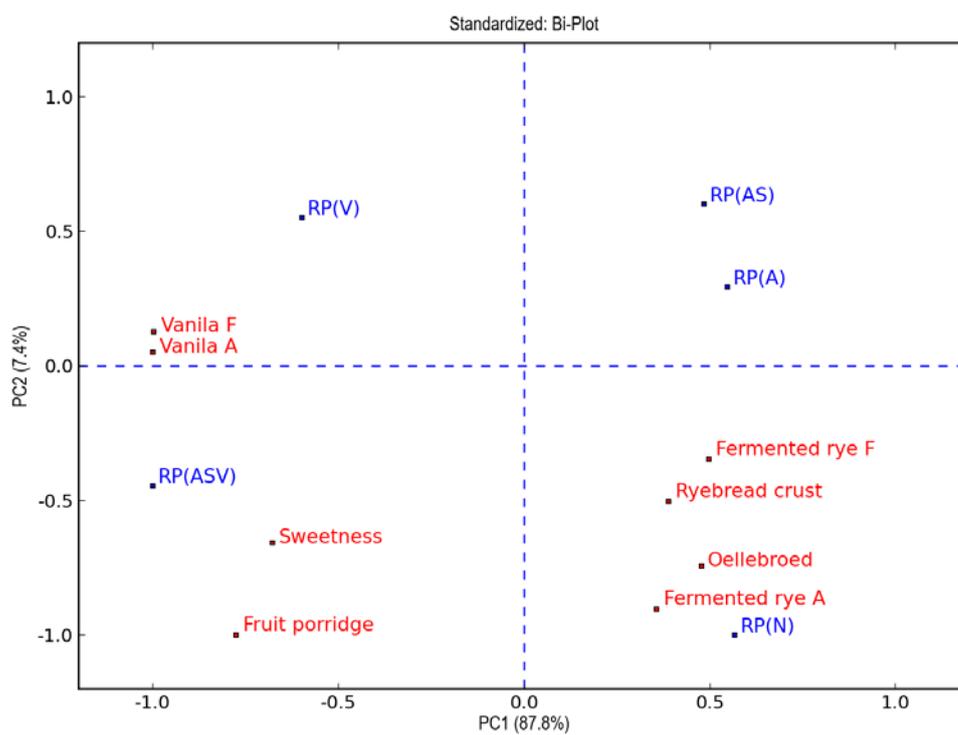


Fig. 10. Bi-plot from PCA of the descriptive analysis test without milk.



PanelCheck

Fig. 11. Bi-plot from PCA of the descriptive analysis test with milk.

To correlate attributes with products, in both bi-plots, RF (N), RF (A) and RF (AS) are separated from RF (V) and RF (ASV) by PC1, and they can be explained by attributes related to fermented rye. On the other hand, RF (V) and RF (ASV) are explained by attributes related to vanilla and sweet.

The test with milk was chosen to explore the relationship with the study of the collative motivation model, because both the products were served with milk. From the three-way ANOVA on the descriptive analysis data, there is no significant difference on fermented rye A, fermented rye F and rye bread crust between products. Nevertheless, these three attributes are still included in the bi-plot to analyze because fermented rye is the most important characteristic for fermented rye products. Fig. 8 is the Bi-plot that shows the placement of the products in relation to attributes. Regarding the products, PC 1 separates RF (N) and RF (ASV) from RF (V), RF (A) and RF (AS). PC 2 separates RF (N) from RF (ASV), and separates RF (V) from RF (A) and RF (AS). The bi-plot illustrates that RF (A) and RF (AS) have similar characteristics.

To explain the attributes between products, RP (V) shows significant characteristics of vanilla aroma and vanilla taste. Flavors in terms of fermented rye (e.g. fermented rye A, fermented rye F, ryebread crust and oellebroed) are mostly presented on RF (N), but the difference with other products is not significant. RP (ASV) and RP (V) show all flavors and tastes related to vanilla and sweet.

## 4 General discussion

### 4.1 The study of prospective portion size

The study of prospective portion size shows that expected satiety is negatively related to prospective portion size regarding rye products. Thus  $H_1$  is supported. In terms of three metrics of rye products, the respective prospective portion sizes are significant different with each other, hence  $H_2$  is supported.

Across the three rye products, rye puff is expected to deliver more satiety (calorie for calorie) than rye grain, and then rye flake. In the contrast, rye puff is chosen the smallest portion, and rye flake is chosen the largest portion. The study was carried out via visual stimuli that may indicated that the memories of the types of food, volumes and satisfaction with the foods are cues for people's food choice.

The participants chose their answers by understanding the three foods were made from rye; in other words, the three foods are three different food metrics regarding one certain food (i.e. rye products in our case). This is important, it would be taken into account in the product development process under the situation that weigh-control is a factor that influence the consumption of food. When the study comes to the application in companies, understanding the prospective portion sizes of different food metrics could be useful, such as in differentiate products and markets in the product development process.

### 4.2 The study of the collative motivation model

The separating of familiarity and novelty/complexity by PC 1 in the two studies are in line with the previous study that flavor preference/acceptance are driven by two needs: one need is the concurrent need for consistency (preference for familiar stimuli) and the other need for stimulation (preference for novel/complex stimuli) (Giacalone et al., 2014).

For complexity, the fermented rye bran is indicated to be one of the elements to be perceived complexity in products. In the study in ESOF, hedonic response appears to be linear monotonic function of complexity, as partially support  $H_3$ . On the other hand, in the study in Food festival, increasing complexity may improve the hedonic response (Rye puff (N) vs. Rye puff (ASV)), but not in an inverse U shaped relationship, as it cannot support  $H_3$ . To sum up, the results from the two studies in this work cannot support  $H_3$ . Nevertheless, the results of the two studies on complexity confirmed the theoretical assumption that complexity depends on the detectability of individual elements (i.e. the flavor of the fermented rye), as well as on the degree of harmony of the individual elements (i.e. the result in the study in Food festival).

From the descriptive analysis, Rye puff (A) and Rye puff (AS) have the closed characteristics. It may be because the addition of amino acid and reducing sugar suppressing the taste of the fermented rye bran. Nevertheless, the addition of vanillin in Rye puff (ASV) complicates the overall taste of the products, because the taste of vanillin is completely different from that of the fermented rye bran, so that it is not the effect of simple suppression. Owing to this similarity between Rye puff (A) and Rye puff (AS), it is not easy to be perceived difference regarding complexity for consumers.

For familiarity, the study of collative motivation model in ESOF shows that familiarity is more positively correlated to liking than novelty and complexity on the tested products. It may be explained that to everyday products (i.e. breakfast products), familiarity is linearly related to the hedonic response; the Berlyne's theory is better observable when abstract products are evaluated (Giacalone et al., 2014). Nevertheless, in the study in Food festival, it cannot be observed, which may be because of the similarity between some products.

For novelty, the products evaluated in the studies are in the same series of products (the products produced in the study in Food festival are just trying to cover the unpleasant flavor and taste of the fermented rye bran, instead to create different kinds of flavors and tastes), so it is hard to distinguish between them.

In general, finding a curvilinear (inverse U shape) relationship between hedonic response and collative properties depends on the range of the perceived inter-product difference, in other words, more samples or different product categories might reveal such curvilinear relationship.

At last, among demographic and background factors, information levels is significantly positively correlated with liking in the studies, although in ESOF, it also shows this trend, but not significant. That means for a new product, if more detailed information regarding health is given, consumers are easier to pay attention to it and hence accept it. In addition, language version also correlates with liking in the study in ESOF that means people coming from different countries and areas would perceive difference to fermented rye products.

Regarding age groups, in the study in ESOF, consumers who age above 50 have higher scores on the fermented rye flake than others, which means consumer above 50 years old may easier to accept this fermented rye products. Consumers with normal weight also show higher scores on liking. Nevertheless, there are no main effects on liking regarding age groups and BMI groups in the study in Food festival. It may be because numbers of participants in age group (4) and (5) in Food festival are much less than those of in ESOF, hence the influence cannot be shown. But we could connect this result with another finding from both two studies, that is most of the

participants' ages between 20 and 30 have normal weights, and most of the overweight obesity participants are aged above 40. As a result, two potential consumer groups are showed: consumers' age between 20 and 30, who have normal weights and are seeking healthy food to maintain weights, and consumers' age above 40, who have overweight or even obesity and are seeking healthy food to lose weights. It could be helpful if Lantmännen seeking for product differentiation and market differentiation.

When it comes back to the tested products, the flavor and the taste of the fermented rye bran is a critical factor. For the study in ESOF, rye flake 2 (20% fermented rye bran) is the most promising product. For the study in Food festival, although H3 is not supported by the results, but if the Berlyne's(1967) and the Walker's (1980) theories are applied here to improve the rye puff products, the four rye puff products are still in the left part of the inverse U shape, they haven't reach the individuals' arousal optimum, a product with higher ratings on collative properties (e.g. complexity) and hedonic response is possible. In order to do that, complicating the product in other directs (e.g. the addition of some "familiar" flavors, such as vanillin in rye puff (ASV)) may be a way to make it not only more complex, but also more balanced.

Regarding the use of the collative motivation model, it could be more useful if it is used with products having significant difference in a variety of attributes (e.g. in the early stage of the product development process, such as screening different product prototypes).

## **5. Conclusions**

This work aimed to investigate consumers' perceived satisfaction with the fermented rye products by two studies: the study of prospective portion size and the study of the collative motivation model.

The study of prospective portion size:

- It confirmed H<sub>1</sub> that the prospective portion size of rye products was identified to be negatively correlated with expected satiety. Rye puff was indicated to have the largest expected satiety and was chosen to have the smallest portion size; on the contrary, rye flake was indicated to have the smallest expected satiety and was chosen to have the largest portion size.
- It confirmed H<sub>2</sub> that the prospective portion sizes of the three rye products were significant different.
- Regarding individual difference, the feelings of hunger and satiety were correlated with expected satiety that could have an effect on making decisions about portion size.

The study of collative motivation model:

- It didn't confirm H<sub>3</sub> that the relationship between liking and collative properties was an inverse U shape. The reasons may be the range of the perceived inter-product difference is not large enough in the study in Food festival.
- Nevertheless, the collative property familiarity and collative properties novelty and complexity were identified to be two interacted factors to influence consumers' liking regarding rye products. It could be a direction to improve the acceptance of the fermented rye products.
- Among demographic factors, information levels, language versions were found to have main effects on the acceptance of the fermented rye products.
- Two potential consumer groups were showed: consumers' age between 20 and 30, who had normal weights and were seeking healthy food to maintain weights, and consumers' age above 40, who had overweight or even obesity and were seeking healthy food to lose weights.
- At last, demographic factors, information levels and language versions were identified to have effects on the acceptance of the products.
- 

## **6. Perspective**

For the study of the collative motivation model, the current study did not support the inverse U shape relationship between liking and the collative properties. In literatures, products used were usually different in different dimensions of taste and flavor. Hence, for a series of products (e.g. products are different in a few dimensions in a product development process, such as products in this study), more attributes related to complexity could be generated and defined in a preliminary study before the consumer test. It might be helpful for consumers to understand the concept "complexity" and perceived difference between products.

## **7. Acknowledge**

I would like to thank Line Holler Mielby, my external supervisor coming from AU. She gave me this opportunity to be involved in this exciting project and she taught me all the things regarding sensory and consumer techniques. Thanks to Nina Eggers and Birgitte Foged coming from AU, for their helps in all of the tests. Thanks to my supervisor Maud Lantgon, for the tutoring of the whole construction of the thesis and gave me useful suggestions. Special thank for her working during the Christmas and New Year holiday.

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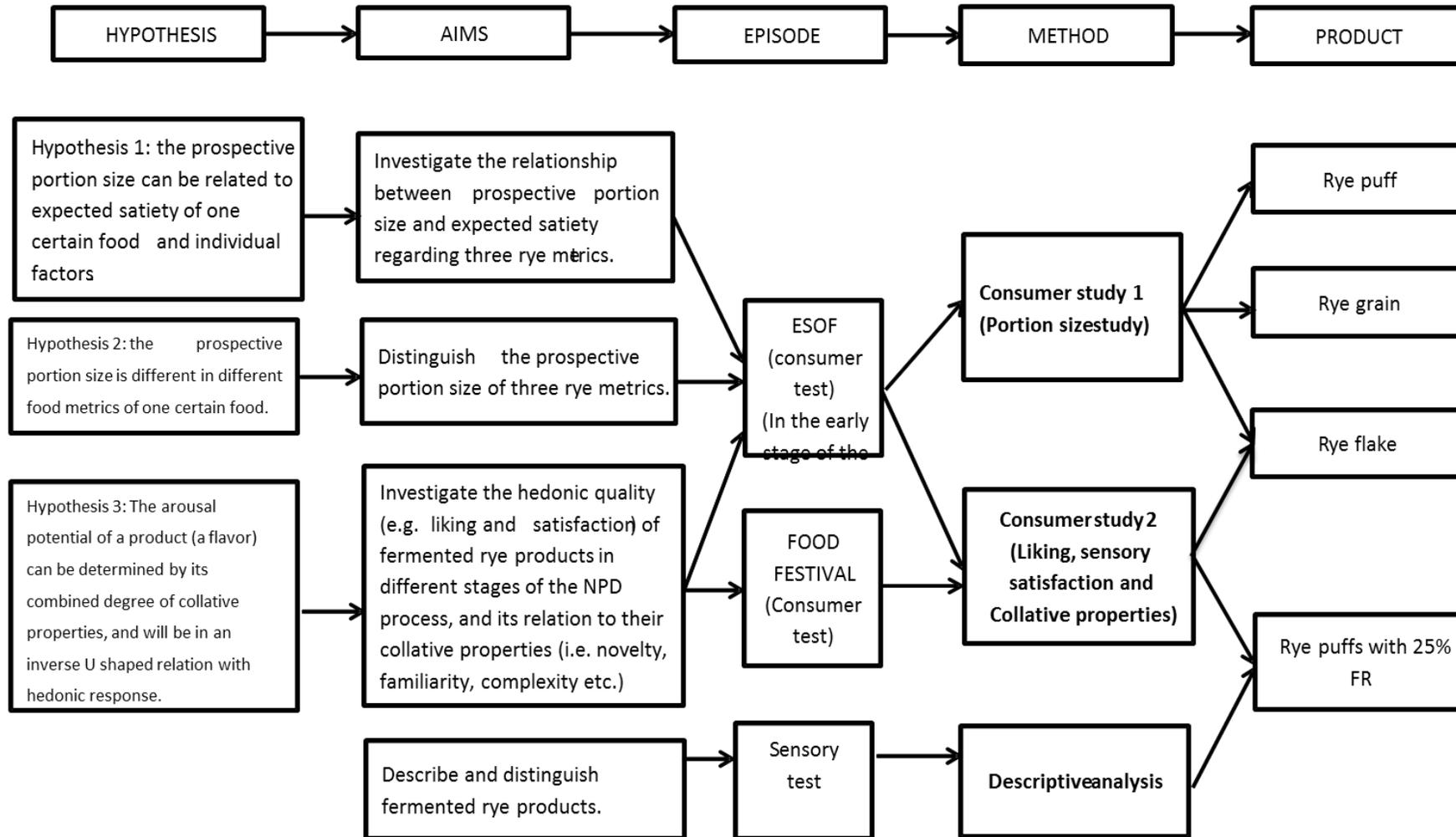
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## Appendix 1. Overview of the study.



**Appendix 2. The questionnaire of the study of prospective portion size in ESOF.**

**DISCOVER FOOD!!<sub>1</sub>**  
**CONSUMER FOOD STUDY**  
**2014**



**Thank you for taking part in this consumer study.**  
**Please do not hesitate to ask if you have any questions**





Now please take the folder marked **Rye flakes**

As you open the folder you will see a picture of a rye bun with cheese and butter on the left and a picture of a plate of **rye flake** cereals on the right. As you flip through the pictures in the folder the portion sizes increase.

Please indicate here when you think the plate with the **rye flake** cereal will make you just as full for just as long time as the rye bun with butter and cheese.

I think, that the portion on **picture number:**

\_\_\_\_\_

will make me equally as full for just as long time as the rye bun with cheese and butter in the front of the folder.

Now, imagine that it is 8.00 o'clock and you are about to eat breakfast. Please indicate which of the portion sizes would be ideal for you to eat for breakfast when you will not be having anything else to eat before lunch at 12.00 o'clock.

The ideal portion size for me would be **picture number:** \_\_\_\_\_

Now please take the folder marked **Rye grains**

As you open the folder you will see a picture of a rye bun with cheese and butter on the left and a picture of a plate of **rye grain** cereals on the right. As you flip through the pictures in the folder the portion sizes increase.

Please indicate here when you think the plate with the **rye grain** cereals will make you just as full for just as long time as the rye bun with butter and cheese.

I think, that the portion on **picture number:**

\_\_\_\_\_

will make me equally as full for just as long time as the rye bun with cheese and butter in the front of the folder.

Now, imagine that it is 8.00 o'clock and you are about to eat breakfast.

Please indicate which of the portion sizes would be ideal for you to eat for breakfast when you will not be having anything else to eat before lunch at 12.00 o'clock.

The ideal portion size for me would be **picture**

**number:**\_\_\_\_\_

Now please take the folder marked **Rye puffs**

As you open the folder you will see a picture of a rye bun with cheese and butter on the left and a picture of a plate of **rye puff** cereals on the right. As you flip through the pictures in the folder the portion sizes increase.

Please indicate here when you think the plate with the **rye puff** cereals will make you just as full for just as long time as the rye bun with butter and cheese.

I think, that the portion on **picture number:**

\_\_\_\_\_

will make me equally as full for just as long time as the rye bun with cheese and butter in the front of the folder.

Now, imagine that it is 8.00 o'clock and you are about to eat breakfast. Please indicate which of the portion sizes would be ideal for you to eat for breakfast when you will not be having anything else to eat before lunch at 12.00 o'clock.

The ideal portion size for me would be **picture number:** \_\_\_\_\_

Now please go to the next page to answer the last questions

**What is your height?** (Please make an estimate if you do not know exactly) \_\_\_\_\_ **cm**

**What is your weight?** (Please make an estimate if you do not know exactly) \_\_\_\_\_ **kg**

**Thank you for your participation**

**Appendix 3. The questionnaire of the study of collative motivation model in ESOF.**

**DISCOVER FOOD!!<sub>3-2</sub>**  
**CONSUMER LIKING STUDY**  
**2014**



**Thank you for taking part in this consumer study.**

**Please do not hesitate to ask if  
you have any questions 😊**



## Product sample 267

Please put the whole content of cereal in one of the cups of yoghurt and mix thoroughly. Now, please taste the cereal/yoghurt sample. Please make sure to eat at least one-half of the product so that you can form an opinion.

Do you LIKE the product?

<input type="checkbox"/>								
No, not at all				Neither yes nor no				Yes, extremely

Do you think the product is FAMILIAR?

<input type="checkbox"/>								
No, not at all				Neither yes nor no				Yes, extremely

Do you think the product is NOVEL?

<input type="checkbox"/>								
No, not at all				Neither yes nor no				Yes, extremely

Do you think the product is COMPLEX?

<input type="checkbox"/>								
No, not at all				Neither yes nor no				Yes, extremely

Do you think the taste of the product is HARMONIOUS/BALANCED?

<input type="checkbox"/>								
No, not at all				Neither yes nor no				Yes, extremely

If you consider the appearance, aroma, taste and texture of the product, how satisfied do you feel?

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
No, not at all satisfied				Neither yes nor no				Yes, extremely satisfied

## Product sample 672

Please put the whole content of cereal in one of the cups of yoghurt and mix thoroughly. Now, please taste the cereal/yoghurt sample. Please make sure to eat at least one-half of the product so that you can form an opinion.

Do you LIKE the product?

<input type="checkbox"/>								
No, not at all				Neither yes nor no				Yes, extremely

Do you think the product is FAMILIAR?

<input type="checkbox"/>								
No, not at all				Neither yes nor no				Yes, extremely

Do you think the product is NOVEL?

<input type="checkbox"/>								
No, not at all				Neither yes nor no				Yes, extremely

Do you think the product is COMPLEX?

<input type="checkbox"/>								
No, not at all				Neither yes nor no				Yes, extremely

Do you think the taste of the product is HARMONIOUS/BALANCED?

<input type="checkbox"/>								
No, not at all				Neither yes nor no				Yes, extremely

If you consider the appearance, aroma, taste and texture of the product, how satisfied do you feel?

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
No, not at all satisfied				Neither yes nor no				Yes, extremely satisfied

## Product sample 375

Please put the whole content of cereal in one of the cups of yoghurt and mix thoroughly. Now, please taste the cereal/yoghurt sample. Please make sure to eat at least one-half of the product so that you can form an opinion.

Do you LIKE the product?

<input type="checkbox"/>								
No, not at all				Neither yes nor no				Yes, extremely

Do you think the product is FAMILIAR?

<input type="checkbox"/>								
No, not at all				Neither yes nor no				Yes, extremely

Do you think the product is NOVEL?

<input type="checkbox"/>								
No, not at all				Neither yes nor no				Yes, extremely

Do you think the product is COMPLEX?

<input type="checkbox"/>								
No, not at all				Neither yes nor no				Yes, extremely

Do you think the taste of the product is HARMONIOUS/BALANCED?

<input type="checkbox"/>								
No, not at all				Neither yes nor no				Yes, extremely

If you consider the appearance, aroma, taste and texture of the product, how satisfied do you feel?

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
No, not at all satisfied				Neither yes nor no				Yes, extremely satisfied

## Product sample 998

Please put the whole content of cereal in one of the cups of yoghurt and mix thoroughly. Now, please taste the cereal/yoghurt sample. Please make sure to eat at least one-half of the product so that you can form an opinion.

Do you LIKE the product?

<input type="checkbox"/>								
No, not at all				Neither yes nor no				Yes, extremely

Do you think the product is FAMILIAR?

<input type="checkbox"/>								
No, not at all				Neither yes nor no				Yes, extremely

Do you think the product is NOVEL?

<input type="checkbox"/>								
No, not at all				Neither yes nor no				Yes, extremely

Do you think the product is COMPLEX?

<input type="checkbox"/>								
No, not at all				Neither yes nor no				Yes, extremely

Do you think the taste of the product is HARMONIOUS/BALANCED?

<input type="checkbox"/>								
No, not at all				Neither yes nor no				Yes, extremely

If you consider the appearance, aroma, taste and texture of the product, how satisfied do you feel?

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
No, not at all satisfied				Neither yes nor no				Yes, extremely satisfied

