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Analysis of sensory and texture properties of three potato cultivars boiled to different thermal center temperatures

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Popular Science Summary

The study of the quality of different potato varieties cooked to different cooking temperatures and cooking methods.

The quality of cooked potatoes is affected by the maturity, fertilizers, seasonal climate and physical conditions of the soil, handling and storage conditions. During processing of potatoes, it is important to have the information cooking at what temperature and time combination could give a better quality potato. It is also important to remember that factors mentioned above and the cooking method could affect the final product. How the texture behaves when a potato is cooked is vital criteria for consumer's choice. It is common practice to divide potatoes in the supermarket either mealy or non-mealy potatoes. The texture of a potato varies during thermal processing due to the breakdown of the cementing cellular martial.

There is a lack of satisfying information at what temperature that a potato should be cooked to have satisfying cooking quality for the purpose of further processing, research and development or for day-to-day consumption. This study answers this problem based on the results found by studying Salome, Ditta and Asterix potato varieties that are cooked to varying temperatures and cooking methods.

Combining instrumental measurements and sensory quality investigation methods are the recommended way of assessing a certain quality aspects of a food product. In this study ash content, total dry matter content, instrumental texture profile analysis and sensory attributes of the cooked potatoes was measured.

Instrumental texture profile analysis is a method of measuring a texture of a product by application of a mechanical compression force. It is usually applied on a food product and it can be related to the sensory attributes detected by human beings. The sensory analysis attributes used are hardness, mealiness, wateriness, mouth feeling and total appearance. These sensory attributes are examined and associated with the Instrumental texture profile analysis results.

The breakdown of the results found from the instrumental and sensory investigation methods provides the information to a number of applicable questions. It provides the information at what temperature that a potato is recommended to be cooked to have good cooking quality, which potato variety have better cooking quality and how the ash content, as well as dry matter contents affect the quality of the potatoes. This work can be used also to have insight of the relation between the instrumental measurements and the sensory measurements.

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Abstract

Potatoes *Solanum tuberosum,* L are among the most consumed crop type by millions of people around the world. It has high amount of starch content and it is known to be a good source of potassium, vitamin B6, vitamin C and fiber. There are more than 4000 varieties of potatoes. Salome, Ditta and Asterix cultivars are among well-known potatoes in the Swedish market. In recent years the consumption of potatoes is shifting from fresh potatoes to processed potatoes. The texture of potatoes is one of the important quality parameter in consumer's choice. Sensory quality of a potato combined with Instrumental texture analysis is an effective method to determine the quality of the potato. In this study Salome, Ditta and Asterix cultivars were cooked to 95.0 °C and 96.0 °C temperatures by steam cooking and conventional cooking method where the potatoes are placed in a boiling water. Sensory, ash, dry matter and textural analysis was performed. The cultivar difference on Salome, Ditta and Asterix has caused on the quality of the cooked potatoes to be evaluated differently. The cooking method and temperature has affected the sensory quality of the potatoes. The dry matter and the ash content of all potatoes has no significant difference between Salome, Ditta and Asterix cultivars. It can be concluded that Salome potatoes cooked by steam cooking to 95.0 °C for 30.0 minutes has the impression of better quality in terms of hardness, mealiness and total appearance than Ditta and Asterix cultivars. The sensory evaluation of the potatoes gives a very distinguished result among the independent treatments while some of the instrumental texture analysis results are not. For further studies, it is recommended to have samples of the potatoes collected and treated uniformly starting from the harvesting time as well as with the different set up of the texture analyzer.

Preface

The project that I have done on my advanced course was about the effect of the packaging material and atmospheric conditions of cooked potatoes. In the advanced course one of the challenges was that we had no satisfying literature source to answer a question what a recommended temperatures and time is for optimum cooking quality of potatoes. Therefore, this project was initiated in hope that those questions will be answered and used for day to day practice by consumers, industries and for further studies.

From starting to the end of this work, some special persons gave, served and care for me very much. First of all, I would like to thank my God. I had really memorable life experience while doing this project. I would like to give my gratitude to my supervisors Klara Sjölin, Ingegerd Sjöholm, Jeanette Purhagen and my examiner Björn Bergenståhl for their constrictive comment, guidance, support and advice. I would like to acknowledge also the Swedish Institute for giving this opportunity and believing in me.

Generally, I would like to thank all family and friends that I did not mention their names that helped me to complete this project including the department teachers and laboratory technicians.

Contents

1. Introduction

Potatoes *Solanum tuberosum,* L. is among the major agricultural crops that are consumed by a large population of people from different countries and processed industrially to a number of ready to eat product types (Alessandrini et al., 2010). The consumption of potatoes has started at around four centuries ago. Now consumption of potato has become part of day-to-day diet for millions of people. It is the fourth most consumed crop next to maize, wheat and rice. In general, the consumption of potato is shifting from the consumption of fresh potatoes to processed potatoes. Producing processed potatoes having consistent quality is one of the challenges facing the food industry (FAO, 2008).

Fresh potatoes have around 80 % water and 20 % dry matter. From the dry matter content 60 to 80 percent is starch. Potatoes are one of the tubers that are known for good source of potassium (897 mg), vitamin B6 (0.62 mg) and fiber as well as vitamin C (42 mg) (FAO, 2008). Furthermore, it has little fat content. The table presented below (Table 1) shows the approximate composition of a potatoes.

Table1: approximate composition of potato (FAO, 2008).

Component of potato	**Mass fraction(approx.)**
Protein	0.02
Fat	0.00
Carbohydrate	0.20
Fiber	0.02
Ash	0.01
Water	0.75

There are different types of potato cultivar provided in Sweden supermarkets. poSalome, Ditta and Asterix cultivars shown in figure 1 are among the potatoes consumed commonly in Sweden.

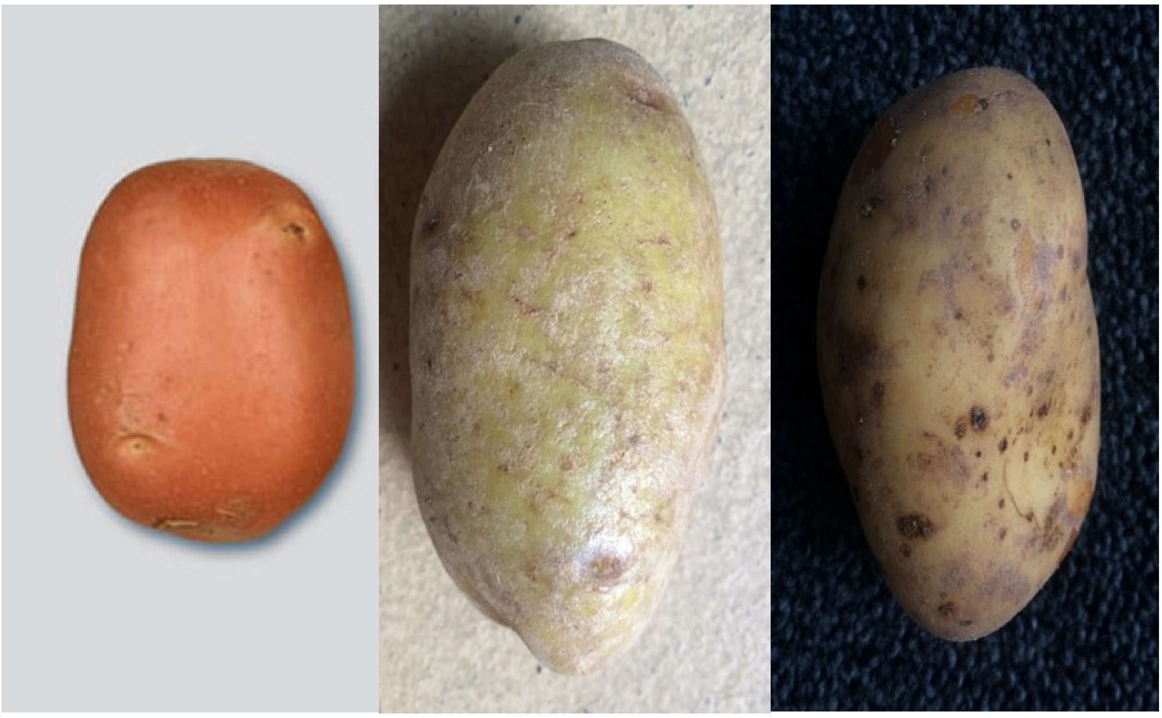


Figure 1. Asterix, Ditta and Salome potatoes respectively.

Salome potato is the type of potato having shallow eyes, yellow flesh color, yellow skin color and oval tubers. Salome has an extended dormancy period and high yield (Barbosa-Cánovas, 2003). Ditta potato cultivar is the type of cultivar having long oval size, shallow eyes, white to yellow skin color, light yellow flesh color, low to high yield. Furthermore, it has long dormancy period (Europotato.org, 2016) Asterix potatoes have oval shape, red skin color, light yellow flesh and red eye colors. In addition, Asterix gives high yields and have medium dormancy period (Europotato.org, 2016). The dormancy is affected with storage conditions (temperature, relative humidity etc.) environmental conditions during growth, exposure to dormancy, breaking compounds, tuber size and most importantly variety. Potatoes having average dormancy period where there is no sprout inhibition of potatoes will last for 90 to 120 days (Van Ittersum, 1992).

1.1 Physicochemical changes of potato during cooking

The majority of the dry matter of the potatoes is made up of starch. The amount of starch in potatoes varies from one cultivar to another cultivar thus resulting in different cooking properties. The gelatinization of starch in the potato during boiling affects how consumers perceive the taste and texture. Potato starch is made up of 21% amylose and 79% amylopectin polymers of glucose. Starch is found in the cells of the potatoes in the form of amorphous starch granules ranging in the size of 20 -100 µm. During boiling of potatoes with water at the temperature range of 52°C to 72°C, the bonds of the starch molecules starts to break down and engage in binding of more water molecules. This phenomenon leads to the swelling of starch granule and increase in size. Eventually, the incorporation of water molecules in the starch granules causes the soluble amylose molecules to leach out to the surrounding water and the cell to burst and disintegrate. (Bettelheim and Sterling, 1955). The pectin in the cell wall that helps to keep the whole structure of the cell is broken down by pectin methylesterase enzyme (Jarvis, 1984). These combined effects lead to the breaking down of the cementing intercellular bond and thereby creating separated cells. Which induces a soft texture upon eating (Sterling *et. al.,* 1995). In addition to this, boiling of potatoes will result in a loss of vitamins, minerals and free amino acids. The free amino acids have a tendency of forming complexes by reacting with sugars. Furthermore, reactions such as activation of enzymes, denaturation of proteins, starch swelling and gelatinization will take place. (Macholz, 1986).

1.2 The cooking quality of potatoes.

The cooking quality of potato is dependent on a number of factors such as maturity, fertilizers, growing conditions (seasonal climate and physical conditions of the soil), handling, storage conditions etc. In the study of the textural changes of cooked potatoes, the cooking quality of the potatoes and starch content, pectic materials present, specific gravity have shown a strong statistical correlation (Bettelheim and Sterling, 1955). In another study of the behavior of cooked potatoes, it was discovered that there was a correlation between the dry matter content, sensory perceived texture properties and the starch content (Van Dijk et al., 2002).

Studies have shown that orthologous pectin methylesterase (PME) gene may have effect of the texture of the different fruits. The more the amount of PME gene expression the more the in the change of the texture of the potato. Pectin is the main part of middle lamella and cell wall. It has effect in the texture of the potato (Ross et al., 2010).

Frequently, fresh potatoes are selected by the consumers based on the information given by the retailer that the potato is either mealy or non-mealy. Texture is one of the important quality attributes for consumers. A number of European countries divide the texture of cooked potatoes from A to D by the sensory analysis perceived attributes. Sensory analysis of a product is usually labor intensive, subjective and not suitable for industrial applications. Therefore, the industry is always in need of the technology that could replace the sensory analysis. A number of attempts have been made to replace and correlate the sensory analysis attributes with the instrumental analysis. It is found that shear tests could differentiate non-mealy potatoes from mealy potatoes (Mccomber etal, 1987). Softness, mealiness, and dryness sensory attributes were correlated with penetration tests (Böhler etal, 1987). The use of specific gravity to predict the texture of potato is also one method to predict the sensory attributes. The study conducted to check the correlation between dry matter and texture of potatoes shows that there is in fact a correlation. The mealy-ness of a potato is correlated with high dry matter content (Warren and Woodman, 1974).

A number of studies shows that dry matter content is highly associated with different quality aspects of a potato. It has a role in determining how the end product of a potato should be. For example, the frying industry prefers potatoes having higher dry matter content. Studies show that potato dry matter is positively correlated with its specific gravity and the yield. The dry matter of potatoes can range from 16.5% to 24%. This reading is correlated to the specific gravity of 1.055 to 1.095 (Services etal, 2016).

1.3 Sensory evaluation

The impression of a food consumed by different group of people may vary from a group to group of people. Often consumer's trend to choose a certain food product is taste, health, intriguing, convenience, inexpensive etc. Sensory evaluation is a method to measure, analyse, evoke and interpret the response given by the panelists. Establishing standard to the sample preparation, temperature, volume, space time and the meal consumed by the consumer prior to the sensory analysis will help to reduce the experimental errors. It is a mechanism to create a meaningful relationship between the data collected during sensory evaluation and the human sensory perception. Since the data collected from the sensory evaluation is usually variable, it is important to properly apply statistical tools during the analysis of the data from the panelists. The interpretation and conclusion of the results requires the consideration of the data, results and analysis. It involves the consideration of how the method is performed, the background of the panelists, limitation of the experiment and framework of the study. There are three types of commonly used sensory testing methods. Discrimination test tries to answer the question are products perceptibly different in any way, descriptive taste tries to answer the question how do products differ in specific sensory characteristics, and affective taste (hedonic) will answer the question how well are products liked or which products are preferred (Lawless and Heymann, 2010).

1.4 Thermal properties of food

The knowledge of thermal properties of food is important in designing heating and cooling systems, prediction of heat transfer operations during canning, processing and distribution of food. Thermal properties of food include, in broader perspective, any parameter related to the heat transfer operation of a food product. It is commonly divided as thermo-dynamical properties (specific heat, specific volume, entropy and enthalpy) and heat transport properties (thermal conductivity and thermal diffusivity. But, during analysis of heat transfer operations it is also important to consider other physical properties e.g. viscosity, porosity, density etc (Heldman and Lund, 1992).

Convection is a method of heat transfer by means of the movement of molecules due to the difference in density gradient or by stirring of fluids. The method of heat transfer can be steady state where there is no temperature change through time between the materials. During unsteady heat transfer the temperature is constantly changing through time. Determination of the heat transfer properties in these conditions is difficult but it can be made easier by considering different assumptions (Heldman and Lund, 1992). Potato heating process is unsteady state process. What happens when it is cooked conventionally is that, the continuous heating of the potatoes tissues will result in the separation of the potato cells resulting in the decrease of the tensile strength of the potatoes. As the cooking temperature reaches to 50 °C, the water molecules will pass from non-starchy part of the potato to starch granules as a result the starch granules begin to swell. When the cooking temperature is raised to 65 °C, there will be a noticeable change in size of the cellular structure of the potatoes where the starch granules starts to gelatinize and the intermolecular bonds of the starch molecules breaks down giving the access to the hydrogen bonding sites to engage in additional water molecules. The swollen starch granules will rapture the cell walls of the potatoes allowing the soluble amylose molecules to leach out. These changes will result the texture of the potato to become soft. As cooking of the potatoes is prolonged to a temperature of 100 °C and for more than 16 minutes, the mechanical disintegration of the potatoes tissues will be significantly high and it will reach to a point where the overall structure of the potatoes will collapse (Derbyshire and Owen, 1988).

1.2 Project Aims

- Determine optimum cooking temperature of the potatoes.
- Make priority among the three studied potato cultivars regarding temperature in thermal center when they are boiled.
- Correlate the changes in instrumental textural analysis with sensory evaluation of different potato cultivars.
- Analyze the effect of dry matter and ash content on the texture of cooked potatoes.

2. Material and methods

2.1 Cooking methods

Three potato cultivars Salome, Asterix and Ditta (figure1) with ten tubers of each cultivar having 3.9 to 4.1 cm diameter and uniform size was bought from the local market and hand peeled. Thirty-six potatoes were selected from each potato cultivar type and used for the experiment. The peeled potatoes were divided into two batches. The first batch of potatoes were cooked until the center temperature of the potatoes reached 95.0 °C ± 0.6°C by both steam and conventional cooking method. While the second batch of potatoes were boiled until the center temperature of the potatoes reached 96.0 °C ± 0.4°C by both conventional cooking and steam cooking method. The time required to reach the desired temperature was noted.

2.1.1 Steam cooking: A combi-steamer (SCC WE 61, RATIONAL AG, Germany) was preheated to 100 °C with 100 % steam. All peeled potato cultivars were placed into the combi-steamer to be cooked by the preheated steam. The temperature was determined by a thermocouple type K placed into the center of the potato.

2.1.2 Conventional cooking: The hand peeled potatoes were placed in a stainless steel pot containing boiling unsalted tap water. By using a thermocouple placed into the center of the potatoes, the temperature required to reach at the center of the potatoes was determined and the time taken was noted.

2.2 Sensory evaluation

The sensory evaluation was conducted in the department Food Technology, Engineering and Nutrition Lund University sensory evaluation room. A hedonic sensory evaluation was performed after a short explanation of how the scoring should be. Half of the cooked potatoes from all cultivar types and cooking methods were served to a group of panelists having 9 Swedes with the age ranging from 22-67 years old. The parameters for the sensory evaluation were hardness, mealy-ness, wateriness, mouth feeling and total appearance with scorning values of 1 to 10, where 1 is extremely low and 10 is extremely high.

The sensory evaluation room was booked for the purpose of conducting the sensory evaluation only and to make sure that there will not be noise and cooking smells coming from other people working in the room. The sensory evaluation room was cleaned including the tables and the chairs that the panelists will sit and be served. The samples were placed by coding 3 - digit random number along with the cup of water, empty cup, pen, fork, knife and sensory evaluation worksheet. Each potato served was given a specific code based on the type of the cultivar and the cooking method used as shown in appendix 1.1. The evaluators were informed how to use the tools provided and how the evaluation should be done. In order to make sure that the panelists are not destructed with noise and cooking smells the doors were closed and the evaluators were left alone to evaluate the potato samples served.

2.3 Dry Matter content

Three to four grams of potato sample was placed in a clean, empty and dry moisture can. The moisture-can containing the sample was placed in the drying oven (200IG/EL, HORO, Germany) that was set at 105 ^{0}C. The sample was dried until a constant weight was reached (overnight).

The moisture content (%) was determined by the formula given as:

$Mw=(Ww/Ms)*100$ …………………………………………………………. equation 1.

Where Ww is mass of the water and Ms total weight of the material and Mw is the moisture content in percent in wet basis.

2.4 Ash content

The weight of clean and dry crucible was determined and 1.5 - 2.5 gram of sample was placed in the oven. The crucible containing the sample was placed in a muffle furnace (KM 170, Heraeus, Germany) at 550 ^{0}C ± 10°C overnight. When the ashing is complete the weight of the sample was measured again. The ash content was determined by the following formula:

Ash content percentage = $(W2/W1) *100$……………………………………………equation 2.

Where W2 is weight of the remaining sample and W1 weight of the original sample

2.5 Texture Analysis

The cooked potatoes were cut into half parts and half of the potato was served to the panelist and the remaining half part was placed inverted on the texture analyzer (300XP, Perten Instruments AB, Sweden) where a cylinder probe (P-CY02S) having 2 mm diameter penetrates the potato at the speed of 1mm/s to the depth of 16 mm. The instrument records the force offered by the potatoes to the cylinder probe during penetration.

2.6 Statistical Analysis

All the results from the instrumental and sensory analysis was collected and ANOVA was performed using statistical tools (Microsoft excel 2016, version 2016.0.6001.1078 and R, version 3.2.5(2016-04-16)). The difference of the mean of the results was considered significantly different when $p<0.05$.

3. Result and discussion

3.1 Sensory evaluation

Sensory analysis of a food product may be a subjective expression of certain sensory parameter. Centering and normalization of the sensory data collected will help to correct the difference in the use of the scale by the panelists. Centering and normalization of the sensory data collected from this study was conducted as shewn in Appendix 1.2, 1.3 and 1.4. Furthermore, ANOVA was performed and how much different each independent variable was determined.

The panelists were able to give to some sensory parameters significantly different scores and leave comments on the presented different potato cultivars that are cooked in different cooking method and temperature. The following are among the comments that stand out. It was commented by one of the panelist that Ditta potatoes cooked by steam boiling to 95.0 °C as perfect taste while two panelists commented as the best among other cooking methods and temperatures used. Ditta potatoes cooked by conventional to 96.0 °C were evaluated as harder than potatoes cooked by steam cooking method to the same temperature.

The comparison of different cultivar types by the cooking to the same temperature and the same cooking methods shows that there is different scoring in some specific parameters as shown in the figure 2 to figure 6. Furthermore, there was a difference in the sensory evaluation attributes between potatoes cooked to 95.0 °C and 96.0 °C by steam cooking method.

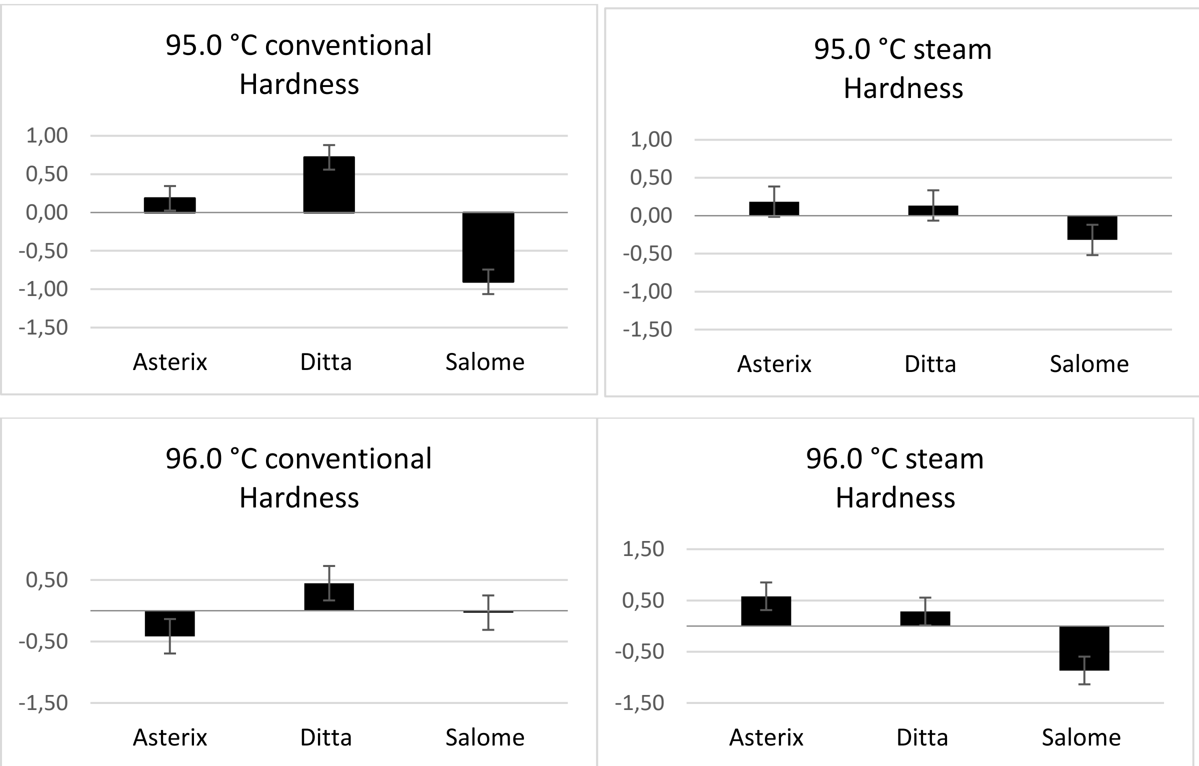


Figure2. Sensory evaluation for hardness of potatoes cooked to 95.0 °C and 96 0 °C by conventional cooking method and steam cooking method.

From Figure2 it can be shown that, there is a difference in the hardness of steam cooked and conventionally cooked Salome potatoes to 95.0 °C. Moreover, in both cooking methods Salome potatoes were evaluated as softer potatoes as compared to Asterix and Ditta potatoes. During conventional boiling to96.0 °C as shown from figure2, Ditta potatoes were perceived as harder than Astrix potatoes, but in steam cooking to 96.0 °C there was no difference.

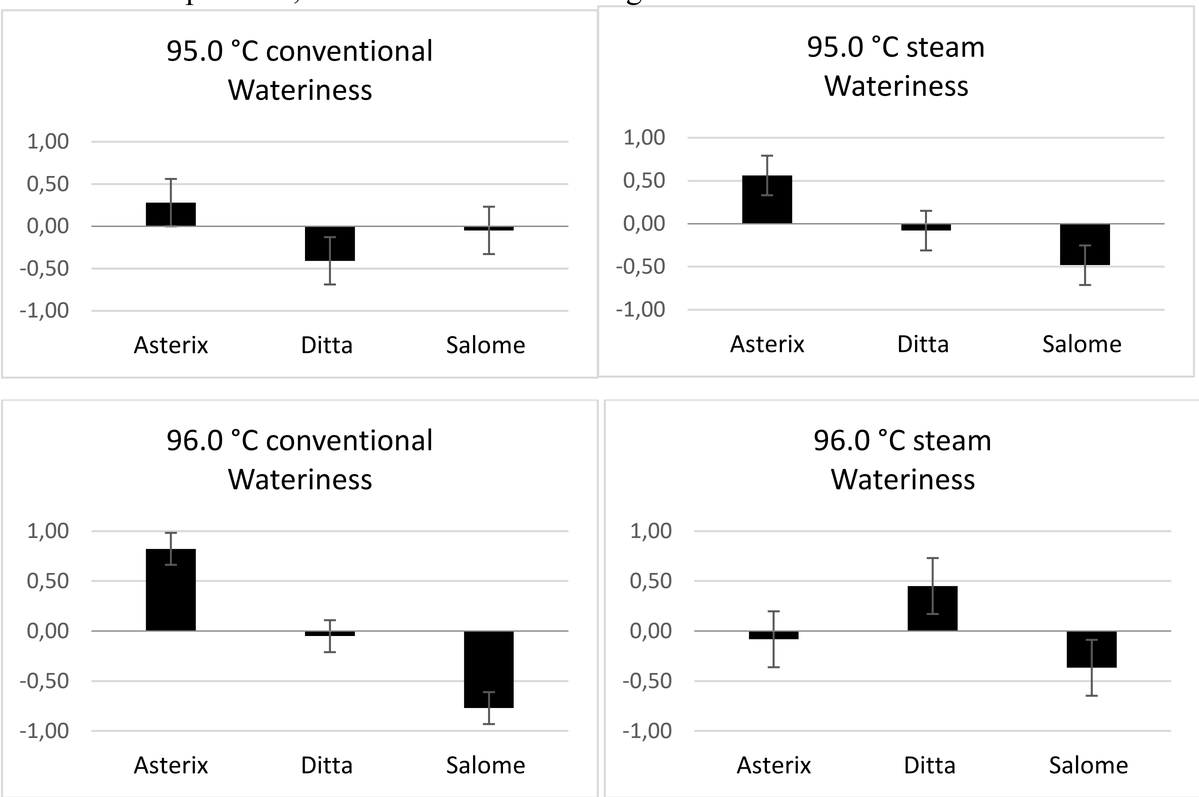


Figure3. Sensory evaluation for wateriness of potatoes cooked to 96.0 °C and 95.0 °C by conventional cooking method and steam cooking method.

Steam cooking method of Ditta potatoes to 96.0 °C resulted in waterier potatoes than conventionally cooked potatoes as shown on figure 3. Furthermore, there was a difference in the wateriness attribute of the three potato cultivars cooked conventionally. It can be shown from figure 3 that, Aterix potatoes are evaluated to be less watery than Ditta potatoes in both cooking methods used to 95.0 °C.

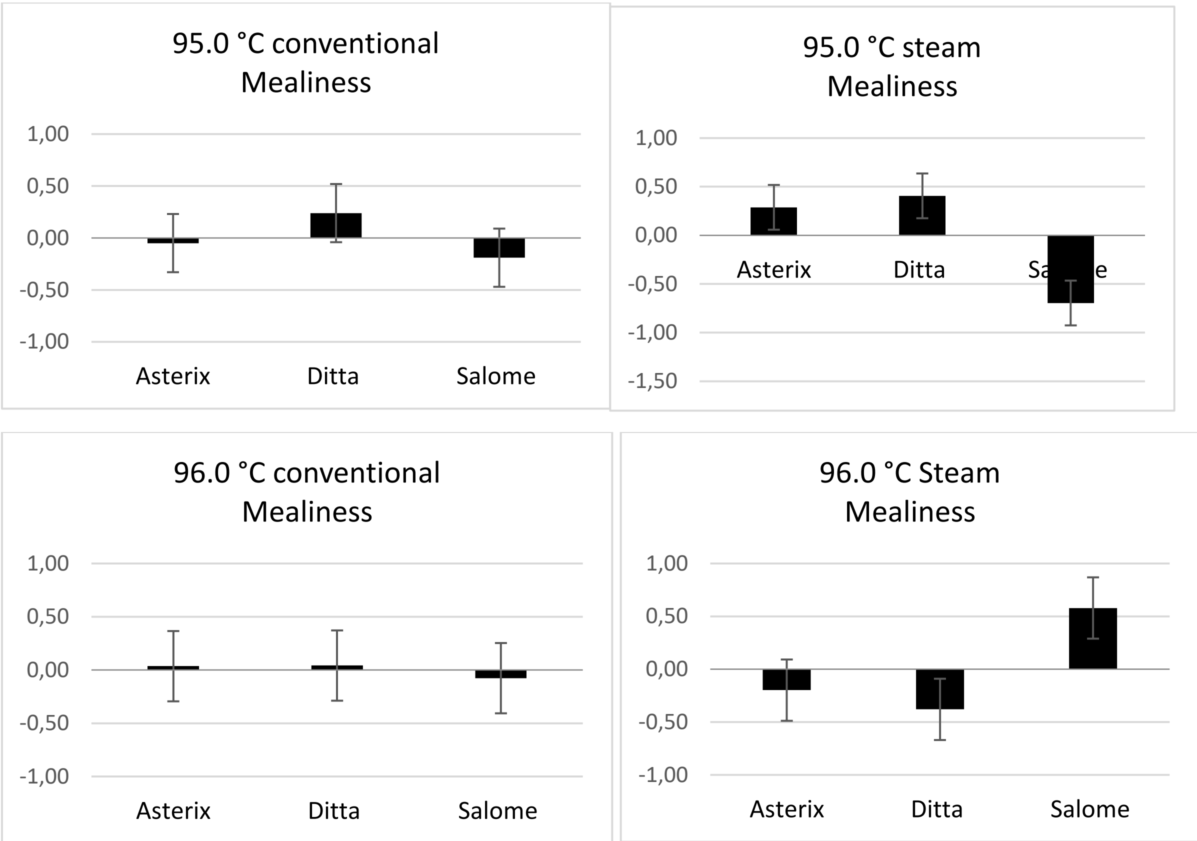
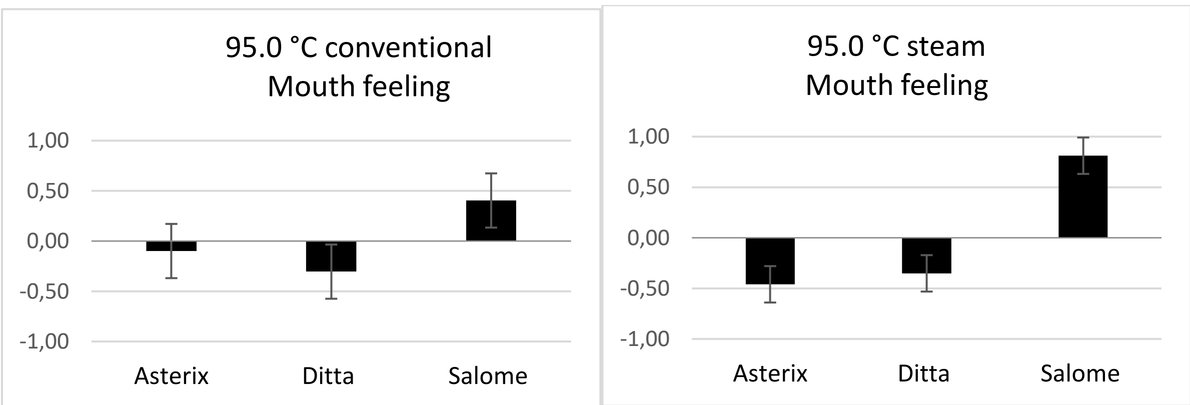


Figure4. Sensory evaluation for mealiness of potatoes cooked to 96.0 °C and 95.0 °C by conventional cooking method and steam cooking method.

There was no difference in mealy-ness attributes of Asterix, Ditta and Salome potatoes cooked conventionally to 96.0 °C, while for steam cooking of Salome potatoes to 96.0 °C was perceived as less mealy than Asterix and Ditta as shown on figure 4.

There was no difference in mealy-ness quality parameter of the different potato cultivars by conventional cooking method to 95.0 °C as shown on figure4, which is the same in case of cooking to 95.0 °C. In addition, Salome was evaluated as less mealy than Asterix and Ditta when cooked by steam cooking method as shown on figure4.



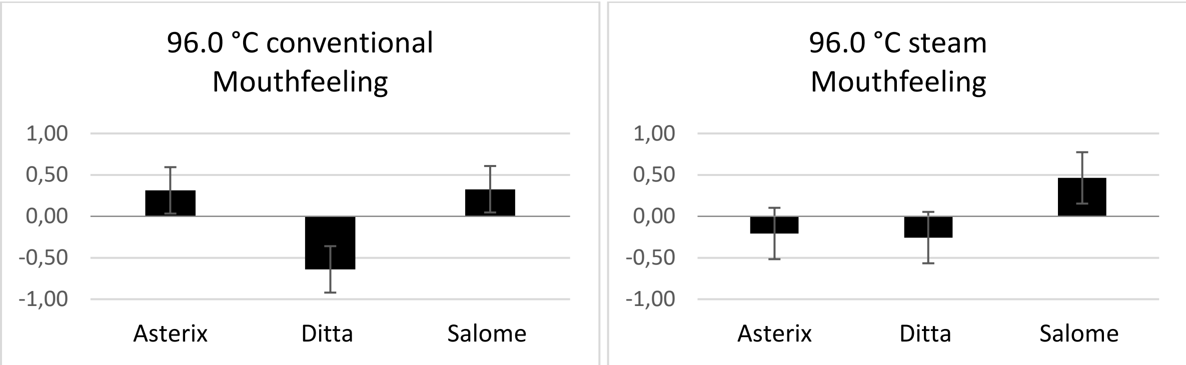


Figure5. Sensory evaluation for mouth feeling of potatoes cooked to 96.0 °C and 95.0 °C by conventional cooking method and steam cooking method.

From figure5, Mouth feeling of Ditta potatoes was evaluated as rawer than Asterix and Salome potatoes when cooked conventionally to 96.0 °C, while by steam cooking method Asterix and Ditta was rawer than Salome. Despite the temperature difference, the mouth feeling evaluation was the same for potatoes cultivars cooked to 96.0 °C and 95.0 °C with steam cooking method as shown on figure 5.

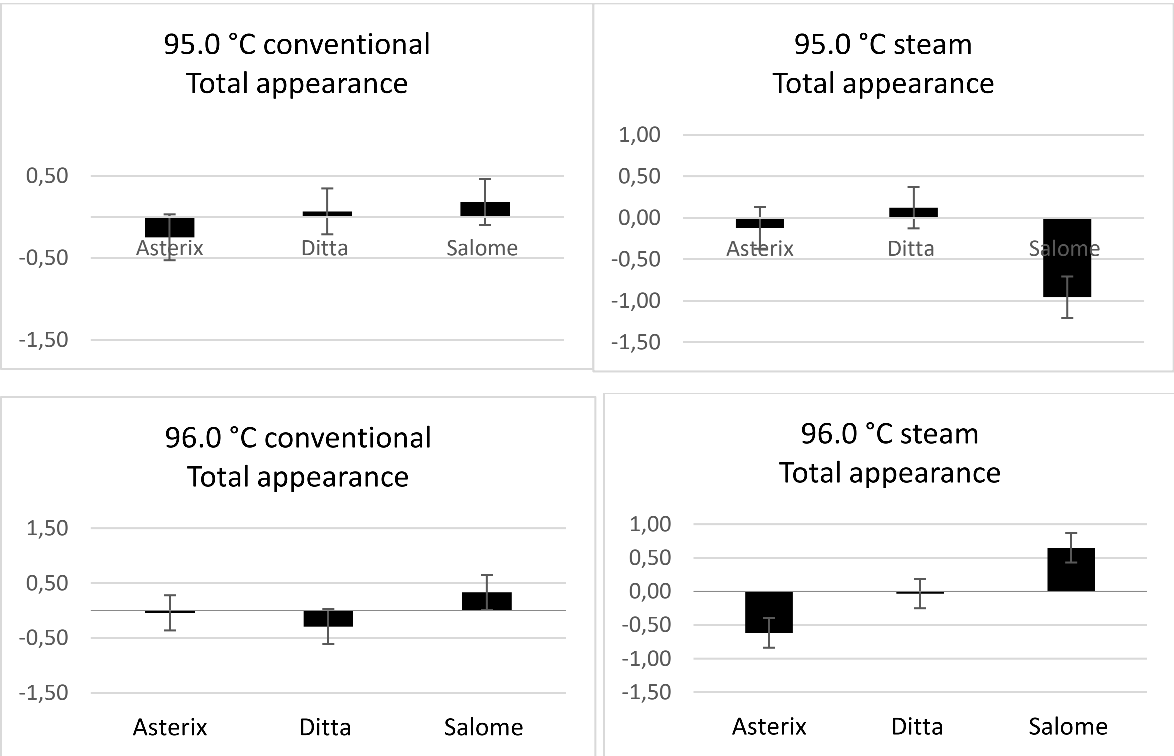


Figure6. Sensory evaluation for total appearance of potatoes cooked to 96.0 °C and 95.0 °C by conventional cooking method and steam cooking method.

As shown from figure 6, total appearance of Salome potatoes was perceived as more appetizing than Asterix and Ditta potatoes during boiling to 96.0 °C by both cooking methods. There is no difference in total appearance of the three potato cultivars cooked by conventional cooking method to 95.0 °C as shown on figure 6. Asterix and Ditta cultivars were evaluated as more appetizing than Salome potatoes during steam cooking to 95.0 °C.

As presented on the above sensory evaluation graphs, the quality attributes of different potato cultivars cooked to 95.0 °C and 96.0 °C by steam or conventional method shows that some of sensory quality parameters were evaluated differently ($p < 0.05$) when the cultivar type, temperature of cooking and cooking method differs. The result of the sensory evaluation of different cooking method and different cooking temperature combinations has shown that the quality attributes may vary from cultivar to cultivar depending to the method of cooking and temperature used.

3.2 Ash and dry matter analysis

The table 3 shows the ash content of Asterix, Salome and Ditta varieties before boiling with triplicate analysis results.

Table 3. Ash content (%) of different potato cultivars.

	Asterix	Ditta	Salome
Average	1.15	1.00	1.05
SD	0.13	0.13	0.05

To check if the ash content had an effect on the perceived potato texture, the ash content of each cultivar was compared with each other. The ANOVA analysis of the ash contents of the cultivars showed that there was no significant difference ($p > 0.05$) in the amount of ash content between the cultivars. Hence no correlation between the perceived textural differences of the different potato cultivars and their ash content could be found.

The dry matter is calculated by subtracting the amount of water content (%) in wet basis in a potato from 100 %. Table 4 displays the result of the dry matter content of Asterix, Salome and Ditta varieties

Table 4. Dry matter content (%) of Asterix, Salome and Ditta verities.

	Asterix	Ditta	Salome
Average	19.76	19.18	18.33
SD	0.92	0.73	0.67

There is no significant difference ($p > 0.05$) between the different cultivars (Asterix, Salome and Ditta) in the amount of dry matter content. Therefore, the perceived texture difference of the potatoes cannot be correlated to the dry matter content of the potatoes.

3.3 Texture analysis

The graph (figure 7) shown below corresponds to the textural analysis of Salome potatoes that were cooked to the thermal center temperature of 96.0 °C by conventional cooking method and steam cooking method.

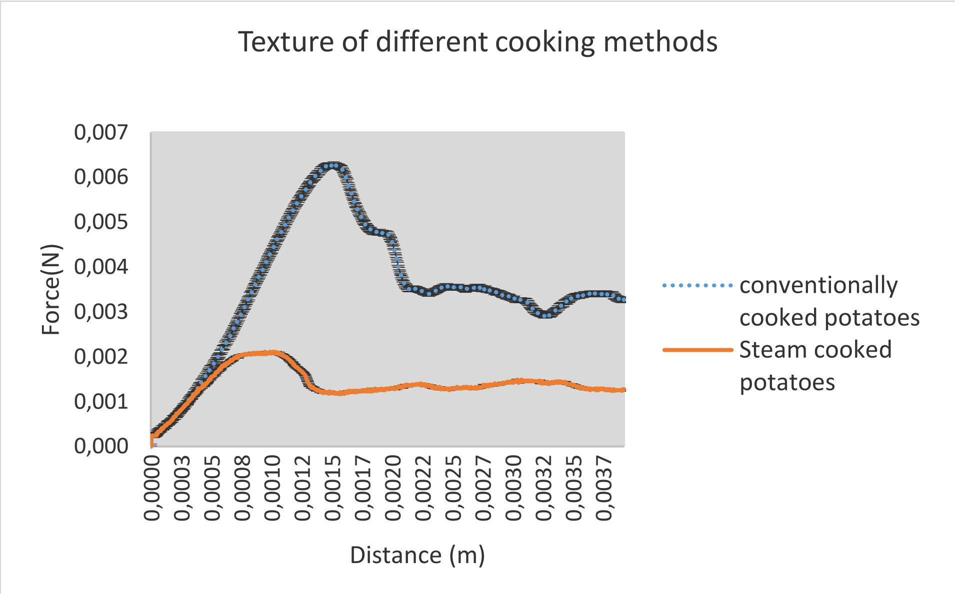


Figure7. The textural analysis of steam cooked vs conventional cooked Salome potatoes to 96.0 °C

From the results of the texture analysis instrument (TPA), the area under the curve from 0 to 4 seconds of the penetration of the potatoes was calculated representing the core toughness of the potatoes. There was a significant difference ($p < 0.05$) for the toughness of Salome potatoes that were cooked by conventional (SD ± 0.14) and steam cooking to 96.0 °C (SD ± 0.04).

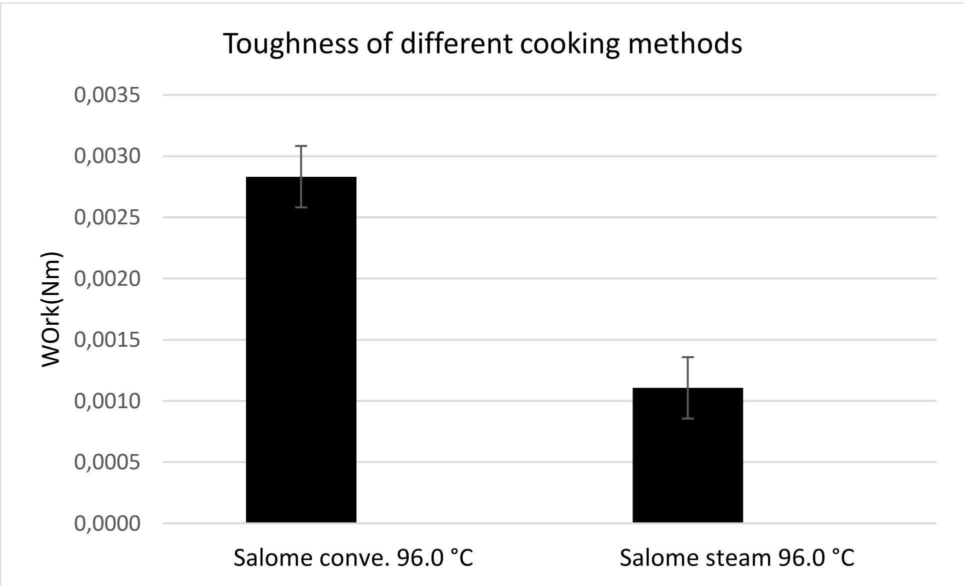


Figure 8. The above graph corresponds to the core texture analysis of Salome potatoes cooked to 96.0 °C by steam and conventional cooking method.

As shown on figure 7 and figure 8, it can be seen that there is a difference in toughness of the center of Salome potatoes that are cooked conventionally, where there is more resistance to the applied force by the probe than potatoes cooked by steam method.

The graphs presented below corresponds to the correlation of the sensory evaluation and the texture analysis of different cooking method and temperature.

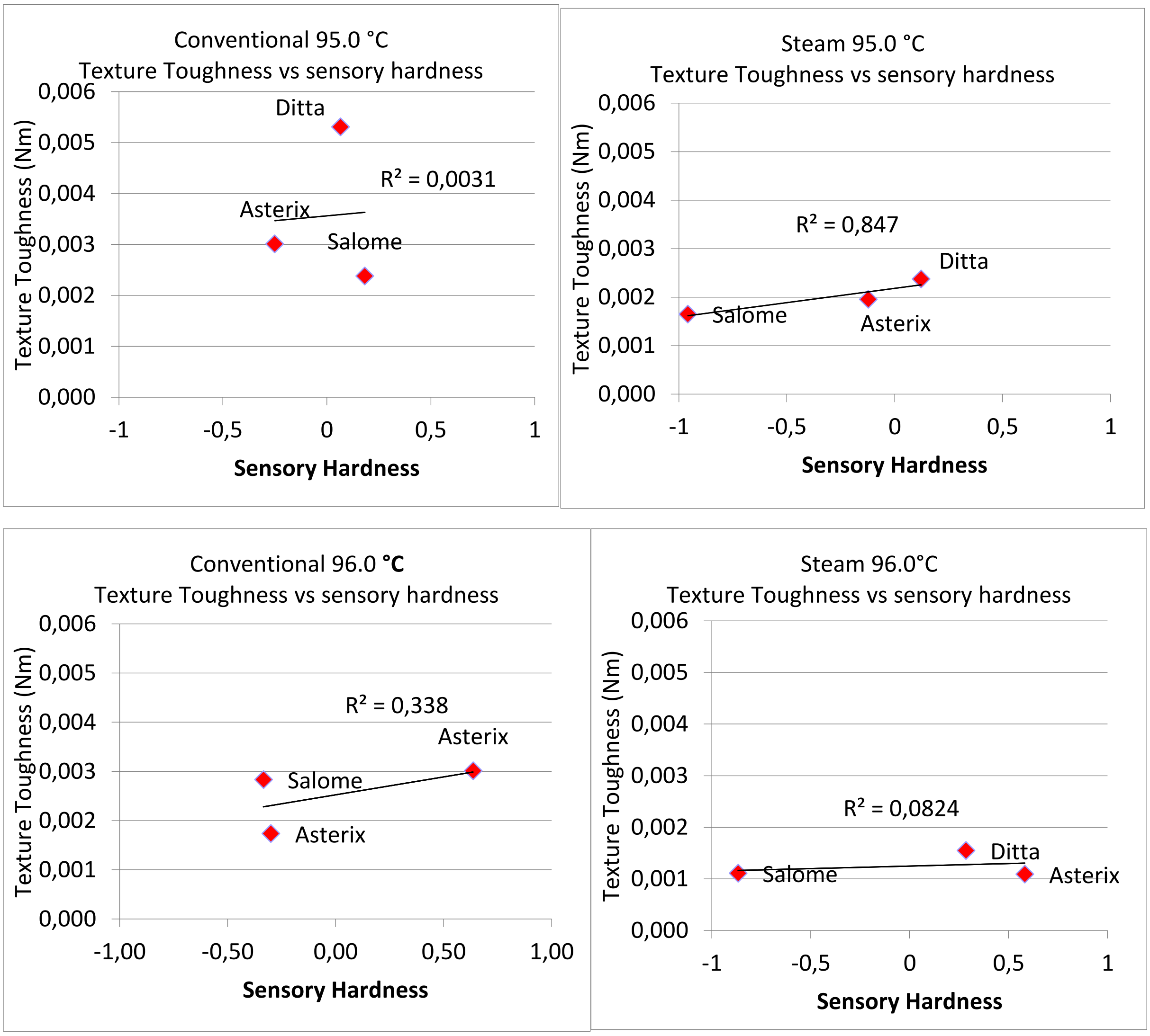


Figure9. Correlation of the sensory evaluation and textural analysis during cooking to 95.0 °C and 95.0 °C by steam and conventional cooking method.

The analysis of the correlation coefficient of the sensory evaluation of hardness and the instrumental analysis of Salome potatoes shows that there is a correlation on steam cooking to 95.0 °C as shown on figure 9. Specifically, the hardness sensory evaluation for Asterix, Ditta and Salome potatoes was correlated to the toughness instrumental analysis with R^2 value of 0.8. The rest of the sensory evaluation and texture analysis graphs shows that there is no correlation.

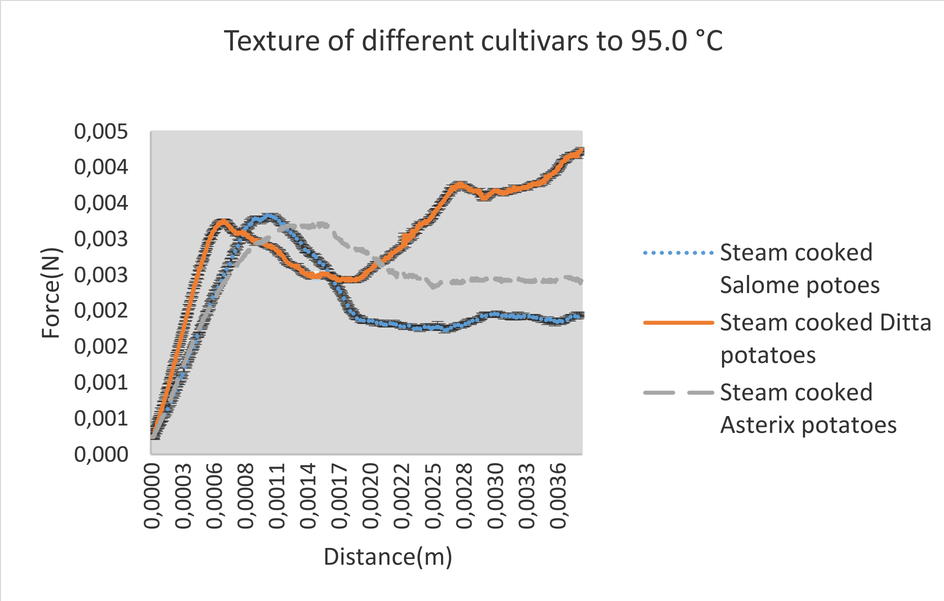


Figure 10. Texture of different potato cultivars cooked to 95.0 °C with steam cooking method.

As shown in figure10, all the other graphs from the other experiments (conventional cooking to cooking to 96.0°C, steam cooking to 96.0°C, steam cooking to 95.0°C and conventional cooking to95.0°C) show a certain difference visually in terms of how the texture profile curve behaves. Even though there is noticeable difference in the different treatments on the graphs and different statistical tools were applied, the statistical analysis of the result from conventional cooking to 96.0°C, steam cooking to 96.0°C, steam cooking to 95.0°C and conventional cooking to95.0°C shows that the difference was not significant where $p>0.05$. The Anova table is attached on the appendix 2, 3, appendix 4 and appendix 5 respectively. Moreover, the F-value from Anova is presented below for the instrumental analysis of toughness and sensory evaluation of hardness attribute in table5.

	conventional cooking 95.0°C F-value	conventional cooking 96.0°C F-value	Steam cooking 95.0°C F-value	Steam cooking 96.0°C F-value
Texture analysis toughness	1.17	0,47	0.66	1.6
Sensory evaluation hardness	25.95	3.92	11.8	2.9

Table5. F-vale of hardness sensorial evaluation and textural analysis of different cooking method and temperature.

It can be shown from table 5 presented above, the F-value of all the instrumental analysis is less than 5 indicating that there is too large error for the texture analyzer, which is more than the difference documented from the varying factors applied on the potatoes. Consequently, the large error for the texture analyzer resulted in the difference with the instrumental texture analysis of differently treated potatoes to be non-significant, as well as most of the correlation of sensory analysis result with the instrumental analysis to be poor. This large error could be caused by the type of probe used or the sampling of the potatoes that there is a difference in the texture of the potatoes even in the same cultivar type. In the other hand, table 5 shows that half of the F-value of the sensory evaluation for hardness is above 5, indicating that the panelists evaluated the potatoes reasonably during the sensory evaluation of differently treated potatoes as presented in the sensory evaluation result section 3.1.

3.3 Cooking time determination

To determine the cooking time first thermal properties must be known. The thermal conductivity of solid and liquid food (K) is given by the formula: (choi and Okos, 1986).

$$(K) = 0.25xc + 0.155xp + 0.16xf\ 0.135xa + 0.58xw \text{ ....equation 3.}$$

Where X is the mass fraction, c, carbohydrate; p, protein; f, fat; a, ash and w, moisture

Thermal conductivity of the potato:

K = 0.25 Xc + 0.155 Xp + 0.16 Xf + 0.135 Xa + 0.58 Xw

K = 0.25*0.2+ 0.155*0.02+ 0.16*0+ 0.135*0.01 + 0.58*0.75

K = 0.49W/mK,

The density of the potato, (choi and Okos, 1986).

$$\rho = \frac{1}{\sum Xi\rho i} \text{ ... equation 4}$$

Protein 1400 kg/m³, carbohydrates 1500 to 1600 kg/m³, fat 900-950 kg/m³, salt 2160 kg/m³, water 1000 kg/m³

ρ = (0.02*1400+0.20*1550+0*925+0.01*2160+0.75*1000)

ρ = 1109.6 kg/m³

Specific Heat (choi and Okos, 1986). - Assuming that there is no phase change through the heating process:

$$cp = 1.424Xc + 1.549\,Xp + 1.675\,Xf + 0.837\,Xa + 4.187\,Xw \text{ ....equation 5}$$

cp = 1.424*0.2 + 1.549 *0.02 + 1.675 *0.0 + 0.837 *0.01 + 4.187 *0.75

cp = 3.46 kJ kg^{-1} K^{-1}

Heat transfer coefficient of boiling water (h) = 1500 W/m^2K

Thickness of the potato (X) = 0.04m
Half thickness = 0.02m

$$Biot\ number\ Bi \frac{hx}{k} \text{ ... equation 6.}$$

= (1500 W/m^2K *0.02m) / 0.49 W/mK

Bi = 61.22

Since the biot number is greater than 0.1, there is resistance to heat transfer both internally and at the surface of the potato then, the cooking time can be calculated by reading from the Heisler's Chart and determining Fourier number.

$$The\ dimension\ less\ temperatur\ = \frac{T_a - T_t}{T_a - T_{t=0}}\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots.\ldots \text{equation 7.}$$

= (99.5 -95.0)/ (99.5-21.3)
= 0.06

Where Ta is the temperature of the boiling water, Tt is the center temperature of the potato throughout the cooking process and $T_{(t=0)}$ is the initial temperature.

1/Bi = 1/61.22 = 0.02

Reading from the sphere Heisler chart

Fo = 0.5

$$Fo\ =\ \alpha \frac{t}{x^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{equation 8.}$$

t = Fo x^2/a

where α is Thermal diffusivity given by the formula;

$$\alpha = \frac{k}{\rho Cp} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{equation 9.}$$

Where:

ρ = 1109.6 kg/m³

K = 0.49 W/mK

cp = 3.46 kJ kg^{-1} $K^{-}1$ = 3460 J kg^{-1} $K^{-}1$

0.49/(1092.6*3460)

α = 0.49 W/mK /(987.6 kg/m³*3520J/kg.K)

α = $1.28*10^{-7}$ m^2/s

Fo = at/x^2

Then $t\ =\ Fo\frac{x^2}{a}$

Where:

Thickness of the potato (X) = 0.04m
Half thickness = 0.02m
Fo = 0.5
α = $1.28*10^{-7}$ m^2/s

$$t\ =\ \frac{0.5 * 0.02^2}{1.28 * 10^{-7}}$$

t = 1663 Sec. ≈ 26.0 min.

During the experimental run the time taken to cook the potatoes was noted and it was 1510 seconds which is approximately 25.0 minutes. There is 1minute difference than the calculated value this may be due to the assumption taken when calculating the thermal properties of the potatoes and the use of the approximate composition data of the potatoes from the literature.

With same manner, the time taken to reach to the required core temperature was calculated for potatoes cooked by conventional cooking method to 96.0 °C, steam cooking method to 95.0 °C and 96.0 °C. It was determined to be 27. 0 minutes, 30.0 minutes and 37.0 minutes respectively which is pretty similar to the time that is noted in the laboratory.

In both temperatures (95.0 °C and 96.0 °C), the steam cooking method took more time to reach the desired core temperature as compared to conventional cooking method resulting a longer exposure of the heat on the surface of the potatoes. This longer exposure of heat is one of the reason why potatoes cooked by steam cooking method are less hard than conventionally cooked potatoes as shown on figure 8.

4. Conclusion

Steam cooking of Salome potatoes to 95.0 °C could give an acceptable cooking quality of potatoes in terms of the quality parameters hardness, mealy-ness and total appearance, but the sensory evaluation worksheet used was not the most complete worksheet in order to determine the most preferred cultivar type and cooking temperature as it lacks preference questions. Therefore, the sensory evaluation result should be confirmed in order to trust the results found. During cooking of Salome potatoes to 96.0 °C, conventionally cooked Salome potatoes were evaluated as harder potatoes than steam cooked Salome potatoes by sensory evaluation and texture analyzer. The hardness texture difference is due to the cooking method difference resulting a longer cooking time to attain the desired temperature. In addition, there was a correlation between the sensorial evaluation and the texture analyzer for steam cooked potatoes. The ash content and the dry matter content of these potatoes varieties has no significant effect on the texture difference documented between the cultivars. It can be concluded that the cooking quality of a potato is dependent on type of potatoes used, temperature, time and method of heat transfer during cooking (cooking method).

The potatoes used in this experiment are bought from the local supermarket, therefore the prior history of the potatoes before the samples are collected is unknown. The season of the harvesting, storage time, storage temperature, storage relative humidity, method of cultivation of the potato samples are unknown. These factors may affect the potato quality even the cultivar type is the same. It is possible that there may be variation of the potato texture within the same variety. This could lead to the texture analyzer to detect these differences and giving a very spread data. Therefore, for future work it is recommended to use potatoes that are treated uniformly starting from farming. The other solution to have the expected significant difference in the texture of differently treated potatoes maybe, the application of different type of probe other than cylinder probe used.

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Appendix

Appendix 1.1 Sensory evaluation form.

Identity:____________________________

Sample number: 324

Hardness	*Very soft*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*Very hard*
Wateriness	*Very watery*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*Very dry*
Mealiness	*Very mealy*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*Non mealy*
Mouth felling	*Very raw*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*Over cooked*
Total appearance	*Unappetizing*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*Appetizing*

Comment:

Appendix 1.2 Raw data collection table

Raw data
Sample code:
Cultivar type:

			Panelists							
Parameters	P1	P2	P3	P4	P5	P6	P7	P8	P9	MEAN
Hardness	7	7	6	4	9	7	6	8	7	6.78
Wateriness	5	6	7	7	9	7	4	8	7	6.67
Mealiness	3	2	7	2	4	4	7	7	6	4.67
Mouth felling	6	3	5	5	8	3	3	3	3	4.33
Total appearance	4	3	4	3	2	5	3	3	4	3.44

Appendix 1.3 Raw data centering

Sample code:
Cultivar type:
Xn,i = (xi /x) −1

			Panelists								
Parameters	P1	P2	P3	P4	P5	P6	P7	P8	P9	MEAN	SD(SDxn,i)
Hardness	0.03	0.03	-0.11	-0.41	0.33	0.03	-0.11	0.18	0.03	0.00	-1.00
Wateriness	-0.26	-0.11	0.03	0.03	0.33	0.03	-0.41	0.18	0.03	-0.02	-1.00
Mealiness	-0.56	-0.70	0.03	-0.70	-0.41	-0.41	0.03	0.03	-0.11	-0.31	-1.00
Mouth felling	-0.11	-0.56	-0.26	-0.26	0.18	-0.56	-0.56	-0.56	-0.56	-0.36	-1.00
Total appearance	-0.41	-0.56	-0.41	-0.56	-0.70	-0.26	-0.56	-0.56	-0.41	-0.49	-1.00

Appendix 1.4 Data Normalization

Sample code:
Cultivar type:
Xsd,i = Xn,i/SDxn,i = ((xi /x) −1)SDxn,i

			Panelists								
Parameters	P1	P2	P3	P4	P5	P6	P7	P8	P9	MEAN	SD
Hardness	-0.03	-0.03	0.11	0.41	-0.33	-0.03	0.11	-0.18	-0.03	0.00	1.00
Wateriness	0.26	0.11	-0.03	-0.03	-0.33	-0.03	0.41	-0.18	-0.03	0.02	1.00
Mealiness	0.56	0.70	-0.03	0.70	0.41	0.41	-0.03	-0.03	0.11	0.31	1.00
Mouth felling	0.11	0.56	0.26	0.26	-0.18	0.56	0.56	0.56	0.56	0.36	1.00
Total appearance	0.41	0.56	0.41	0.56	0.70	0.26	0.56	0.56	0.41	0.49	1.00

Appendix 2. Anova of the texture analysis for conventional cooking method to 96.0 °C.

Conventional cooking method to 96.0 °C

Groups	*Count*	*Sum*	*Average*	*Variance*
Ditta conve. 96	3,00	919,96	306,65	85070,08
Salome conve. 96	3,00	866,52	288,84	624,17
Asterix conve. 96	3,00	530,38	176,79	9382,82

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	29735,70	2,00	14867,85	0,47	0,65	5,14
Within Groups	190154,13	6,00	31692,35			
Total	219889,83	8,00				

Appendix 3. Anova of the texture analysis for steam cooking method to 96.0 °C.

Steam cooking method to 96.0 °C

Groups	*Count*	*Sum*	*Average*	*Variance*
Ditta steam 96	3,00	473,58	157,86	351,20
Salome steam 96	3,00	338,67	112,89	3304,25
Asterix steam 96	3,00	332,75	110,92	1792,07

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4229,89	2,00	2114,95	1,16	0,37	5,14
Within Groups	10895,02	6,00	1815,84			
Total	15124,91	8,00				

Appendix 4. Anova of the texture analysis for steam cooking method to 95.0 °C.

Steam cooking method to 95.0 °C

Groups	*Count*	*Sum*	*Average*	*Variance*
Ditta steam 95	3,00	725,96	241,99	6311,40
Salome steam 95	3,00	505,03	168,35	8423,68
Asterix steam 95	3,00	597,16	199,05	4007,73

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8208,98	2,00	4104,49	0,66	0,55	5,14
Within Groups	37485,61	6,00	6247,60			
Total	45694,59	8,00				

Appendix 5. Anova of the texture analysis for conventional cooking method to 95.0 °C.

Conventional cooking method to 95.0 °C

Groups	*Count*	*Sum*	*Average*	*Variance*
Ditta Conv.95	3	1622,49	540,83	145442,47
Salome Conv.95	3	727,05	242,35	2595,59
Asterix Conv.95	2	654,89	327,45	3483,62

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	139808,67	2,00	69904,33	1,17	0,38	5,79
Within Groups	299559,73	5,00	59911,95			
Total	439368,40	7,00				