Effect of different blanching treatments on variation in colour/texture of French fries frying by food handlers

Thesis

MSc Food Quality Management (PDQ-80436)

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Preface

After reading this thesis paper again and thinking back to the days when I was doing the research, I feel proud and happy that I managed a research like this. A lot of teachers and international friends in Wageningen helped me with my study and thesis.

First, I would like to thank my supervisors--Ms. Pieternel Luning and Mr. Geoffrey Hagelaar who gave me the opportunity to do the technological experiment in the lab, and their advices highly improved this thesis article. Their academic knowledge and experience about food quality management inspire my study in this area.

Second, I want to thank PhD student Ali Muhammad for his rigorous coaching during the two experiments implement. I will always remember the big snowing days when we busy dealing with the potatoes in Biotechnion.

Third, I definitely need to thank my parents here; they gave me the opportunity to study abroad, supporting me financially and spiritually during my MSc studies.

Finally, I will thank all my friends and classmates in Netherlands; you are always helpful and willing to give me a hand when I needed.

THANK YOU ALL!

Siyi Wang

Contents

Chapter 1: Introduction to the Research

1.1 Background

Potato has been long recognized as a healthy, economical and low-fat food product being the fourth most important crop in the world (Miranda&Aguilera, 2006). During the last century potatoes became one of the most cultivated crops worldwide (Reimerdes& Franke, 2006). Nearly one-third of the potato production is processed into par-fried frozen potatoes and fried chips (snacks) (Miranda&Aguilera, 2006). Beyond traditional ways of consumption, the food industry processes potatoes in a wide variety of alternative forms, potatoes are an important food raw material for a very broad range of industrially manufactured products like potato starch, cooked potatoes, dried potato products, croquettes, mashed potatoes, fried potato products and others (Reimerdes& Franke, 2006). French fries is one of the most popular fast foods in restaurants and supermarket (Kasahara, et al. 2002).

The processing of potatoes to French fries became of economical relevance in the USA at the end of the 1940s and approximately 25 years later in Europe, in 1990, half of the annual potato harvest in the USA was processed to these kinds of products (Lisinska& Leszczynski, 1989). French fries are also welcomed in other countries, such as India. Potato processing started in India on a commercial scale in 1911. It is mainly confirmed to the developed countries but it is in its infancy in most of the developing countries as well. French fries have a vast scope for fast growth in India due to increased preferences for easy-to-prepare and fast foods. Fried products such as French fries are likely to become more popular (Marwaha, 1997). Global production capacity of frozen potato products is estimated to be at least 9.6 million metric tons per year. Worldwide exports of frozen potato products in 2000 (over 90% of which are frozen French fries) were valued at $1.9 billion. This amount does not account for the billions of dollars of frozen potato products produced and sold domestically in different countries around the world (Plummer&Makki, 2002).

The fast food industry sells about 90% of the fries consumed in the U.S. Hot oil is the secret behind making a good fried product; it gives the crisp texture and taste that people find so enjoyable, and it provides a pleasurable sensation of satiety (Miranda&Aguilera, 2006).

Since French fries become so popular, it leads to the increased competition in the potato market, consumers now place special demands on all aspects of potato quality and methods of production (Barrera et al, 2007).

1.2 Demarcation

1.2.1 Food behaviour and human behaviour both contribute to final food quality

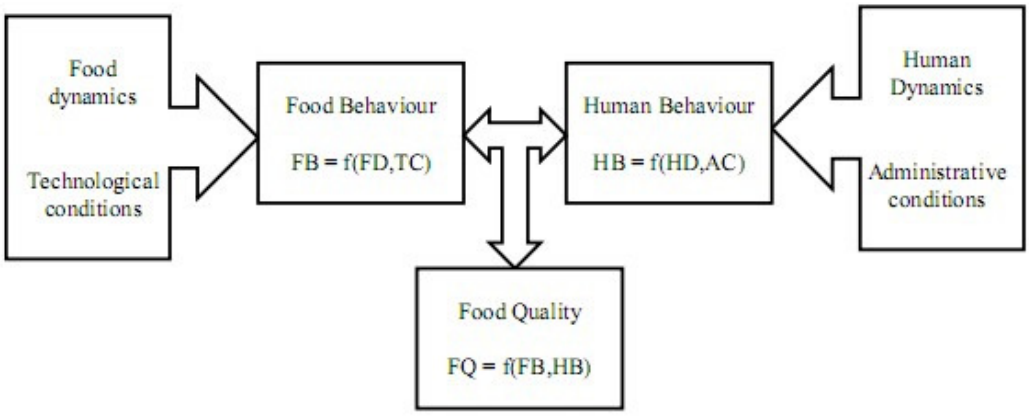

Figure 1: Food quality relationship (Luning&Marcelis, 2009)

According to Luning and Marcelis(2009), a food system is a complex system with a dynamic and variable habeviour. Figure 1 shows the relationship between food behaviour, human behaviour and food quality, both human and food systems contribute to understand and predict the food quality outcome.

Food behaviour is dependent on food dynamics and applied technological conditions,

as food products have complex structure, heterogenous distribution of constituents, they are dependent on different weather and harvest conditions, quality attributes differs because of large range of food processes. In this French fries case, the variation of product properties (texture & colour) and one of the French fries production processes will be analyzed.

Human behaviour is dependent on human dynamics and administrative conditions, because people have different perceptions, attitudes and interests which may influence decision making on food quality; procedures, rules and information system support also differs food quality. Therefore, decision making of the food handlers and its management system has to be learned as well.

1.2.2 Colour and texture variation influence the quality of French fries

The appealing colour as well as the relatively fast creation of unique texture make the deep-frying process of French fries one of the most popular food preparation methods, both industrially and at home (Pedreschi et al, 2007). Colour is considered as one of the most important food product characteristics because it is the first quality parameter evaluated by the consumer, even before the food enters the mouth (Pedreschi et al, 2005). Texture is determined by structure, shape, chemical composition and other physical properties of a product, and it is an important quality parameter in French fries.

Al these literature sources (Pedreschi et al, 2005, 2007) showed the importance of colour and texture to French fries, consumers take the two properties as quality indicators, only colour and texture will be analyzed in this thesis, although flavor, oil content and other properties are also important to consumers.

1.2.3 Food handlers' behaviour

French fries are widely prepared in Food Service Establishments (FSE), and their preparation is highly relying on the food handler. Especially in the (often) small and

medium enterprises (Sanny et al, 2010).

People do not always make decisions with logic and rationality, Simon(1960) introduced two concepts in his administrative model, one is bounded rationality, such as incomplete information, limited knowledge, another is satisfying behaviour, such as choosing first satisfactory alternative. According to this approach, people have their own way of dealing with problems, human behaviour is rather unpredictable.

Management typically takes decisions on technological and administrative conditions by selecting appropriate (technological and people) resources to create an adequate technological and managerial infrastructure for the production of desired products. In addition, management takes short-term decisions on food dynamics by putting requirements on product properties, to ensure adequate materials/products, and on the control of human dynamics by directing their actions through providing specific information, gaining commitment, and/or by giving detailed direct instructions. Additionally, food handlers typically take daily control decisions on out of tolerance situations of product properties and process conditions, and on subsequent corrective actions (Luning & Marcelis, 2007; Luning et al., 2009). Procedures on standardised control of frying practices are however available. They require food handlers to control the actual product features by visually inspecting the colour of French fries against the product specification provided (CIAA, 2006). Food handlers may take a corrective action that includes sorting out fines or brown pieces of French fries (Grob et al., 2003). The successful implementation of standardised control depends on the workforce quality and on the actual compliance to procedures by the food handlers in their daily practice (Sanny et al, 2010).

1.2.4 Summary of demarcation

According to the food quality relationship model (Figure 1), it was assumed that food quality was dependent on both dynamic properties of the food product as related to applied technological conditions and dynamic properties of food handler as related to

applied administrative conditions. Colour and texture are the two indicators of quality of French fries. Food handlers' behaviour can influence the quality of French fries. Both technological and managerial parts (food handlers' behaviour) which could influence the colour and texture of French fries will be discussed in this article.

1.3 Problem feeling

Parallel to the development of French fries business, 'potato science' has been established for a better understanding of interrelationships between potato properties, processing behaviour and its influence on the final product quality (Reimerdes& Franke, 2006). In addition to these basic research opportunities, technological investigations have also been performed on special processing steps like the frying processes (Agblor& Scanlon, 2000).

According to Luning and Marcelis (2009), quality attributes are the result of various product properties, which are noticeable by sensory observation or via communication, one of the quality attributes is called sensory, appropriate sensory characteristics of products are assumed to be important for food acceptance and repeated purchase in the long term (Meiselman& MacFie, 1996). Colour and texture belong to the sensory attribute. Colour can affect the initial quality perception of a food before and during consumption, it is a result of recipe design and production process condition. Reimerdes and Franke (2006) indicated that general quality parameters of fried potato products are colour, taste and texture, which are directly related to raw material composition and properties.

Miranda and Aguilera (2006) reported that consumers appreciate light-coloured to golden fried potato products. Fried potatoes should have a uniform 'Maillard'-brown colour and an expected texture with a crisp impression of the outer layers of French fries. Because of the media development and the marketing competition, the colour became a differential recognition of the commercial mark for the sensation of a good

product (example: oranges, apples, French fries, soft drinks) (Leta et al, 2002). In addition, texture is another sensory attribute of uppermost importance for potato preference (Thygesen et al, 2001), and it is a critical parameter for fried potato quality (Ross and Scalon 2004). Barrera et al (2007) reported that high quality French fries should have uniform light cream to golden colour and good flavour, free from rancidity, bitterness or off odours. Their external surface should be moderately crisp, showing no separation from the inner portion, which should remain tender, mealy and free from sogginess.

At present, French fries business is making a progress, colour and texture are considered to be two important quality properties of French fries, therefore, the main problem is to what extent technological conditions and food handlers' practices contribute to the value of colour and texture attributes of French fries.

Before the consumers evaluated the quality of French fries, there is a supply chain system exist, which involves organizations, people, technology, activities, information and resources. The supply chain activities transform natural resources, raw materials and components into a finished product that is delivered to the end customer. There are some critical control points in the chain which may highly influence the final quality of French fries, it means that the small variation in these critical control points may lead to big effects on the final quality of French fries, so it is not only important to test the value of colour and texture, but also necessary to test their variation and try to reduce the variation.

After searching literatures about French fries, I found that some studies (Bourne et al, 1993; Agblor& Scanlon, 2000; etc) carried out to test the effect of blanching treatments which can influence the colour/texture of French fries, the studies usually have been carried out with two or three very different blanching temperatures and times (70°C, 10 minutes and 97°C, 2 minutes), so significant effect can be observed. Hence, I would like to do a research (by doing experiment) to find effect of blanching

with smaller differences in temperature and time condition in order to find the value as well as variation on colour and texture of French fries. What is more, according to the food quality relationship model (Luning&Marcelis, 2009), human behaviour can also influence the final quality of French fries, but the previous studies commonly ignore the effect of food handlers. So this study will be focused on blanching treatment and food handlers these two aspects.

1.4 Problem definition

What is the effect of different blanching conditions (time and temperature) on the value and variation in colour and texture of French fries? How does food handlers' frying behaviour affect the variation of colour and texture of French fries?

1.5 Research objective

The objective of this research is to find out effect of process conditions (temperature and time settings during blanching) and production condition (thickness of French fries) on mean value and variation in colour/texture of French fries. In addition, to find the effect of food handlers' behaviour in final frying step on colour and texture variation is another goal of this thesis.

1.6 Hypothesis

Different time and temperature blanching conditions could lead to different value and variation on colour and texture of French fries after frying, different people's frying behaviour can lead to different variation on texture and colour of French fires due to human dynamics.

1.7 Research approach

- Which parameters could influence the effect of blanching treatment?
- What are the specific processes (guidelines) for doing the experiment?

- What is the relationship between sugar content and colour?
- How to use the laboratory equipments for texting sugar content, colour and texture?
- Which factors have great impact on the food handlers' behaviour when they are making decisions?
- Which factors can influence the food handlers' behaviour? And how to control their behaviour in order to improve the French fries quality?

Chapter 2: Theory analysis

2.1 Introduction

Van Loon (2005) indicated that the world production of fried, frozen potato products exceeds 4.500 million kg, of which French fries represent about 86%. Netherlands is the largest potato processing country in the world with a production of more than 1.500 million kg potato products in 2001. Colour and texture are considered to be two important quality attributes of French fries, blanching is an important step in the French fries production process, food handlers' frying behaviour can also influence the colour and texture of French fries, so literatures towards blanching process and the human behaviour which may affect colour and texture quality of French fries need to be analyzed in this chapter.

2.2 The concept of quality control

Quality control is a basic activity of food quality management and the objective is to keep product properties, production processes, and human processes between certain acceptable tolerances. It is also the ongoing process of evaluating performance of both technological and human processes and taking corrective actions when necessary (Evans & Lindsay, 2005). Control activities are basically focused on gathering information and to reduce uncertainty. If the quality properties results are acceptable, then no further action is needed, unacceptable productions result in corrective action and it may cause troubles to the company (Luning &Marcelis, 2006). A way to reduce the unacceptable product is to reduce the variation of product properties.

So the major objective of quality control is to produce a product that complies with targets within set tolerance, a profound understanding of the sources of variation is required.

Montgomery (2008) defined quality as inversely proportional to variability; it implies

that if variability in the important characteristics of a product decreases the quality of the product increases. Reduction of variation leads to the reduced scrap and rework, greater efficiencies, happier consumers and repeated sales (Luning &Marcelis, 2009).

What is more, Bettman and Park (1980) reported that consumers often have prior experience with product, consumers with prior knowledge and experience may tend to use such standards earlier in the choice process. So we can see that consumers use the buying experience to judge the quality of food, the repeating buying behaviour is a result of consumer satisfaction, which means consumers have consistency on the buying behaviour, consumer expect food with less variation. So the reduction of colour and texture variation can help to improve the French fries quality.

However, variation is a natural phenomenon and some is inevitable, the maintained production line, raw material, food handlers, supervisors and quality control employees cannot be perfectly uniform, with no defects and no variation (Hubbard, 1996). No product can be produced without variation, but the variation can be reduced by quality control and assurance activities. According to Luning &Marcelis (2009), the sources of variation include people, material, machines, tools, methods and measurements.

2.2.1 Relevance, validity and reliability analysis

Quality control function and variation analysis is valid in appreciating the problem because the main purpose of this thesis is to reduce variation of colour and texture of French fries in order to control the quality well, quality control activities is helpful for reducing variation, and the variation analyzing emphasizes the importance of variation reduction and implies why this thesis want to find different variation effects.

This part is also relevant because some of the literatures and the experiment analyzed below belong to quality control activities, and their purpose is to reduce variation. All the literatures are extracted from published books or articles, most of them are from renowned authors in the field of food quality management, the book was published last year which is quite new, so this part is also reliable.

2.3 General scheme for the production process of French fries

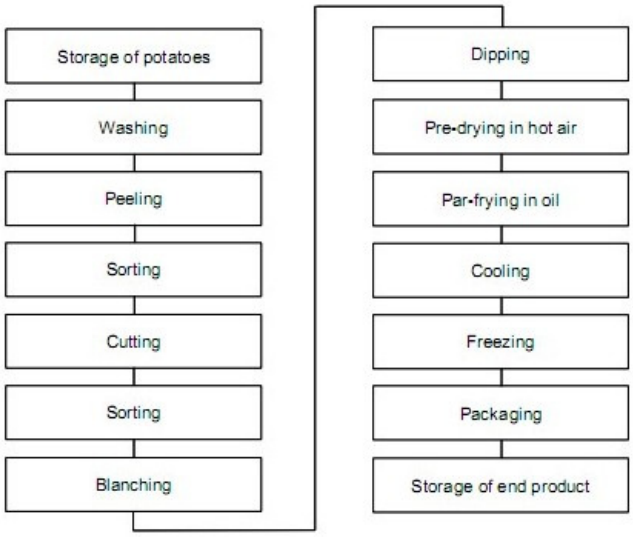

Figure 2: Scheme of French fries production process (Van Loon, 2005)

According to Luning and Marcelis(2009), in order to meet the requirements of consumers, generally the product need be produced by a process which is capable of operating with little variation around the standard of quality attributes, and every process is subject to variation. Therefore, a stable, repeatable and scientific French fries production process is needed, and one or two process can be analyzed here.

The common stages for processing of French fries are summarized in Figure 2.A general process for French fries production is blanching-drying-frying and each step is important for the final product quality (Lamberg et al, 1990).

The production process can be summarized here according to Van Loon (2005): Storage conditions after French fries harvesting are very important for further processing. Because high temperature storage induces sprouting, while cold storage increases the reducing sugar content. Therefore, potatoes are usually stored at 6–8 °C. Before peeling, potatoes are washed to remove soil, stones, and other foreign materials. Steam peeling is generally used because of low peel loss. A water gun is usually applied to cut potatoes into strips. Potatoes are pumped in water at high

velocity through a series of knife blades set to the required cutting size. Potatoes are oriented in such a way that they are cut longitudinally, obtaining maximum length and minimum waste. Potato strips are subsequently blanched in hot water. Enzyme inactivation occurs quickly at elevated temperature (80–100°C). Leaching of reducing sugars, on the other hand, takes time and a lower temperature (50–70 °C) is necessary to prevent overcooking. Therefore, blanching is often carried out in two steps. The minimum blanching temperature applied in practice is about 65 °C, otherwise spoilage due to bacterial growth may occur.

After blanching the strips are dipped in a solution of sodium pyrophosphate, sodium pyrophosphate chelates metal ions that would cause discolouration. Pre-drying in hot air prior to the frying step improves texture and reduces oil uptake. By removing surface water the beginning of a crust is made. Frying is traditionally carried out in two steps, par-frying and finish-frying, with a cooling step in between. Finish-frying has to be done close the place of consumption (cafeteria, fast-food restaurant or at home), as the product is consumed quickly thereafter.

Actually, one of the motives for food processing is to improve the sensory properties. The process also requires permanent adjustment according to the raw material characteristics and the interrelations among the process steps (Pravisani & Calvelo, 1986).

The French-fried potato processing, as we can see, after preparation steps, usually includes blanching in water at 60-80°C to inactivate enzymes and prevent browning (Chiang and Petersen 1985). It is also a unit operation used in the potato-processing industry to remove air from the tissue, to reduce potato reducing sugar concentration in order to control Maillard reactions, and to diminish acrylamide formation during subsequent frying (Moyano et al 2002;Gonzalez-Martınez et al 2004; Pedreschi et al, 2007). Therefore, the blanching step is considered to be critical in the production process.

2.3.1 Relevance, validity and reliability analysis

Figure 2 shows the general Scheme of French fries production process, it is quite relevant because it gives a good insight of whole production process, effects of different blanching and frying process treatment will be analyzed based on this, and the figure gives idea about the experiment operation process. What is more, in order to know the process which may affect colour and texture of French fries, it is better to know the whole production process first. The figure is valid as it is the guideline of the experiment and the literature indicated the functions of every step. Figure 2 is reliable as I found that most French fries production process is general the same, this one is pick from an article which written by people from Institute of Food Science and Nutrition and it was also published in core journals.

2.4 Effect of different frying conditions on colour and texture of French fries

Temperature and time of frying process have been shown to be the factors affecting the colour and texture in potato foods since characteristics of the product change considerably during frying, so it is always important to take into account these two key factors in the French fries frying process.

According to Romani et al (2008), the use of low temperature of frying (under 160°C) negatively affected the quality of the product like texture, color and then consequently the acceptability of the product by the consumer is deeply reduced. The situation is opposite in the high temperature situation (180°C). In Romani et al 's (2008) experiment, it also showed that the different time conditions (4, 7, 10, 13, 16 minutes) in frying step have big effects on the colour and texture of French fries. Another experiment (van Loon et al, 2006) also proved this fact. A higher value for crispness was found in French fries with increased frying time and higher temperature. All these literatures reported the fact that the different frying conditions can have effect on colour and texture of French fries.

2.4.1. Relevance, validity and reliability analysis

This part (2.4) is relevant to the French fries production processes, frying is the final step in the whole process, which high determined the final quality of French fries. It also give a clear idea that small variation in frying conditions could highly influence the colour and texture quality. The validity is unquestionable here since the main purpose of the thesis is check if blanching treatments could affect the variation. The reliability of the model cannot be doubted as it is all the articles were published in noted food science journals.

2.5 Effect of different blanching conditions on colour and texture of French fries

In the process line for French fry production, the blanching operation is indispensable to the development of an appealing fry of good quality in terms of texture and colour *(Loon, 2005)*. Blanching is a unit operation widely used in the potato processing industry for de-aeration of the tissue, and for the leaching of accumulated sugars in order to control the Maillard reaction during subsequent frying and to inactivate enzymes that are present in the plant tissue (González-Martínez et al, 2004). Because of the Maillard reaction, the chemical reaction between reducing sugar and amino acids in hot water could result in the yellow-brown colour of certain food, and according to Pedreschi et al (2009), the reducing sugar content in potatoes is strongly linked to non-enzymatic browning, the colour of potato is highly impacted by the amount of reducing sugars, and blanching helps to get ride of the reducing sugar from the potatoes.

The literatures above showed that one of the reasons for blanching is to reduce sugar content in order to obtain a bright, uniform colour after frying. Other functions of blanching are inactivation of enzymes, starch gelatinisation, they can reduces oil uptake during frying, and improve texture quality *(Loon, 2005)*. Andersson(1994) also indicated that blanching in hot water is used mainly to inactivate enzymes, to improve

texture of French fries, and to obtain a bright, uniform colour.

Main changes in colour of fries and chips occur by the Maillard reaction between aminoacids or free amino groups of proteins and peptides, and reducing sugars, mainly glucose and fructose. It is through blanching that enzymes are inactivated (Tajner-Czopek, 2003; Tijskens et al., 1997), sugars leached out, starch gelatinized, and cell separation achieved (Liu& Scanlon, 2007). The need to achieve all these objectives simultaneously constrains the choice of blanching temperature and time (Liu& Scanlon, 2007). Under long-time blanching conditions (60°C, 40 minutes), the extent of sugar leaching increases, less sugar content in potatoes makes Maillard reaction a little bit weak, so the colour will become lighter. Whereas at high blanching temperatures(90°C) the rate of sugar diffusion increases (Gekas et al, 1993), but browning becomes rapid at high temperatures (Miranda&Aguilera, 2006).

Referring to the texture attribute, enzyme preparations containing pectinase may cause changes in potato microstructure and, consequently, they may influence oil absorption and texture of French fries (Lisińska et al, 2007).Enzyme inactivation occurs quickly at elevated temperature (80–100 °C) *(Loon, 2005)*. Andersson et al (1994) also reported that blanching temperature increases textural quality decreases, a marked decrease of tissue firmness can be observed after treatment at temperatures over 70°C. Bourne's experiment (1966) approved this fact, fries processed by high temperature short time (97°C, 2 minutes) blanching conditions were significantly darker and lower in peak force than low temperature long time fries, and in low temperature long time blanching conditions (70°C, 10 minutes), it significantly improved both colour and textural quality. This is because that the time is limited for sugar to leach out which made Maillard reaction more active, the French fries in his experiment got a more brown colour. Therefore, as blanching time increases colour quality can be improved.

The peak force of French fries texture blanched by low temperature long time conditions (70°C, 10 minutes) was greater than that of standard blanching. In contrast, for high temperature short time blanching (97°C, 2 minutes), peak force and also peak deformation were generally lower compared to the standard (Agblor& Scanlon, 2000).Because biochemical changes during blanching cause both tissue softening and tissue firming (Bourne et al, 1993). Tissue softening, evident by a large peak deformation, is mainly due to pectin solubilization and hydration and swelling of starch granules (Loh et al, 1982). The extent of tissue softening is greater under low temperature long time blanching conditions (70°C, 10 minutes) than under high temperature short time (97°C, 2 minutes) conditions (Bourne et al, 1993). Tissue firming, on the other hand, can be ascribed to two phenomena: (i) starch gelatinization and retrogradation and (ii) formation of calciumpectate complexes. These phenomena lead to increased tissue strength and high peak forces (Bourne, 1966).

From the literatures above we can get an idea that blanching is used to optimizing the colour and texture of French fries after frying, but whether the different blanching conditions could influence the effect of frying treatments is unknown, it is possible that in certain blanching condition, the variation of colour and texture can be reduced after frying treatment compared with the no blanching condition.

2.5.1 Relevance, validity and reliability analysis

This analyzing part is relevant to Figure 2, it is one of the French fries production process, the importance of colour and texture properties was discussed in demarcation part already. The analyzing combined the both and gives the reason why blanching is picked in this thesis, the different conditions of blanching has different effects on the colour and texture quality of French fries. It also give a clear idea how and why blanching treatment influences the colour and texture, and it indicates that temperature and time is crucial in blanching treatment, so the validity is unquestionable here. The reliability of the model cannot be doubted as it is all the articles were published in noted food science journals, and many of were referenced

by other authors.

2.6 Chemical composition variation in potatoes

There are many people doing research on effect of blanching in colour and texture of French fries, but this is the first study to find effect of blanching on variation in colour/texture of French fries, seldom literature can be found in this area.

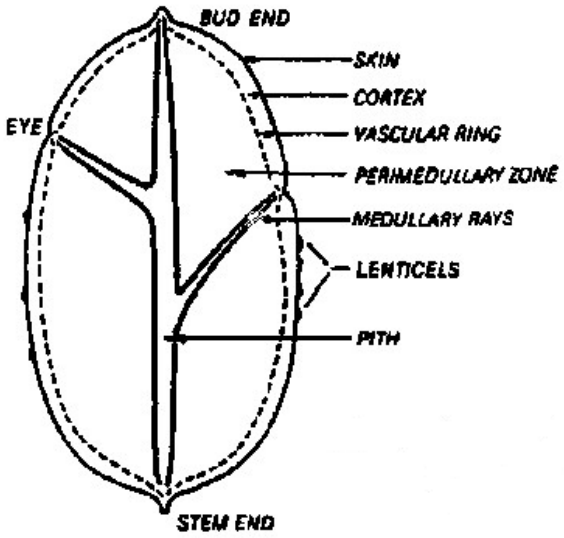

Figure 3: Diagram of a longitudinal section of a potato tuber (Andersson et al, 1994)

According to Andersson et al (1994), the chemical composition of potatoes can be very variable. Figure 3 shows the longitudinal section of a potato tuber, cortex which posited under the outer skin is a thin layer of parenchyma tissue, the cells normally contain large amount of starch grains, and vascular also is high in starch content. However, the cells in the pith are smaller and have low starch content. Because of this, after cutting potato into strips, there will be variation among the strips for texture and colour results since the chemical composition for potatoes are different.

2.6.1 Relevance, validity and reliability analysis

This analyzing part is relevant to the variation on quality of French fries (colour and texture) which is the outcome of the whole research. It shows that the compositional variation in potatoes, it is important to know that variation exists in raw material, so

the validity is unquestionable here. The reliability of the model cannot be doubted as it is all the articles were published in noted food science journals, and many of were referenced by other authors.

2.7 Behaviour of Food Handlers

2.7.1 Planned Behaviour theory

The theory of planned behaviour is a theory which proposed by Icek Ajzen in 1985, it is considered as one of the most predictive persuasion theories. This theory explains why people perform certain behaviour; their behaviour is determined by his/her intention. Intentions are influenced by the behavioral attitude, subjective norms and perceived behavioral control (Figure 4).

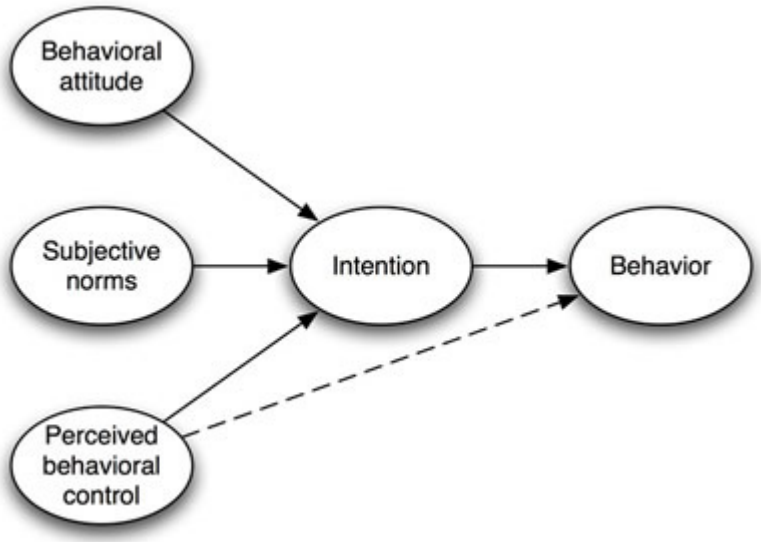

Figure 4: Model of planned behaviour theory

- **Behavioral attitude**

Behavioral attitude links the behavior to certain outcomes. The attitude towards the behavior is determined by the person's evaluation of the outcomes associated with the behavior. The more positively the person evaluates the outcomes and believes that the behavior will achieve these outcomes then the more likely it is that the person will perform the behavior. In this frying case, if food handlers believe small differences in French fries frying temperature and time lead no variation in colour and texture of

French fries (the outcome), then they may not stick to the exact frying temperature and time when frying.

- **Subjective norms**

Subjective norms is about an individual's perception of social normative pressures, or relevant others' beliefs. The important referents include the person's parents, spouse, partner, close friend, co-workers, supervisors etc. As Ajzen (1988) explains: "people who believe that most referents with whom they are motivated to comply think they should perform the behavior will perceive social pressure to do so." For example, if one person believes that most people are motivated to approve the behavior then he or she will perceive social pressure to perform the same behavior. Therefore, if the food handlers are asked to fry the French fries at exact temperature and time by the supervisor, and other colleagues also motivate them to do it, the chance for food handlers to restrict to the temperature and time is larger.

- **Perceived behavioral control**

Perceived behavioral control refers to the perceived ease or difficulty of performing the behavior. The greater a person's perceived behavioral control, the stronger should be their intention to perform the behavior. So, for example, if a person considered that he or she has enough resources (e.g. time, means of transport) to attend a meeting then he or she would be more likely to form an intention to perform the behavior. So if the resources for frying (timer, fryer, thermocouple etc) are provided well, the possibility of the right frying behaviour would increase.

2.7.2 Planned Behaviour theory and food handlers' non-compliance behaviour

In Park and Jung's report (2003), they indicated that statistics shows the operators' non-compliance behavior is one of the leading causes of accidents in industry, it strongly support that the possibility of human error will increase along with the increase of the non-compliance behavior. As to the food industry, in order to increase

food quality, it is important to know the reason why food handlers do not follow procedures as given by the supervisors.

Luning and Marcelis (2006, 2007) gave the idea that variation in food quality is due to variation in product properties and technological conditions as well as variation in behaviour of people involved in the food production system. Product properties and processing conditions are also affected by how people deal with them in daily practice, which means that the way people exercise control of the technological conditions can affect the product properties variation (Sanny et al, 2010). Daily control activities include assigning competent people to daily tasks, and giving them instructions about the exact final colour, frying time, and portion size, and correcting inadequate behaviour (Fiselier & Grob, 2005; Grob et al., 2003). Luning and Marcelis (2006) reported that peoples' behaviour in combination with the technological complexity can have unexpected consequences on food quality due to lack of knowledge of the origin, lack of information, personal characteristics and improper communication. All these factors which influences food handlers' behaviour can be explained by planned behaviour theory.

- **Behavioral attitude and food handlers' behaviour**

Teigland and Wasko (2009) said that food handlers actually control product and process parameters depends on how they are instructed and motivated, it helps to improve their knowledge and influence their awareness. Mathias et al (1995) did a research about the effect of food handlers' education on restaurant inspection, the result showed that food handlers who had completed education courses had better inspection scores than those without. Food handlers who have been trained had better scores especially for time and temperature aspects. These outcomes were all significant in a multiple regression mod. This research gives a clear idea that training course can help to improve the behaviour of food handlers' as instructed by the company, it also showed that food handlers are willing to follow the time and temperature guidelines.

In Park and Jung's view (2003), operators' experience level is another factor which may influence food handlers' behaviour. The working experience of food handlers may be directly related to creating useful knowledge or expertise which can influence non-compliance behaviour. Food handlers who have more knowledge or expertise would have different attitudes and/or strategies when frying French fries. It is expected that the way of using procedures for experienced food handlers may be different, since the belief of experienced operators may be different from that of less experienced operators.

According to planned behaviour theory, if food handlers' attitude towards frying is the same with the instructions, then the chance of having compliant behavior is higher, and the quality variation may become less, the attitude can be changed by training and accumulating experience.

- **Subjective norms and food handlers' behaviour**

Luning and Marcelis (2009) indicated that the support of managers will lead to a great improvement in food handlers' quality behaviour. Egan et al (2007) also said that the effectiveness of training is very dependent on management attitude, according to planned behaviour theory, people can perceive pressure from co-workers and managers which could change their dairy behaviour. Hence, the way of leadership in the company plays a big role in determining food handlers' behaviour.

- **Perceived behavioral control and food handlers' behaviour**

Figure 5: Conditions for quality behaviour (Gerats, 1990)

As discussed in behavioral attitude part, training program may have an impact on behaviour changing, so it is quite important for the industry. Eduarda et al (2010) reported that the success of training relies on certain resources, such as the choice of the program, considering the relevance of the course to work activities, and providing food training at a level that allows the food handler to understand the content. In Egan et al (2007)'s view, the effectiveness of training is dependent on their willingness to provide the resources and systems for food handlers to implement good practices. Similar theory can be summarized from figure 5.

Luning and Marcelis(2009) indicated that human behaviour is dependent on human dynamics and administrative conditions, people restrict themselves to decisions and actions on quality, and this is called quality behaviour. Figure 4 shows two main conditions for quality behaviour: disposition refers to people's behaviour intentions, it is the outcome of processes within people's mind; while ability refers the physical conditions and personal skills which enable people to really meet requirements. According to this theory, beside the knowledge, skills food handlers have and the management attitude, resources and systems (facilities and means) is also important to

improve food handlers' quality behaviour.

Lack of resources is a barrier preventing food handlers from implementing food practice, providing more budget or new equipments could be helpful. Take French fries colour inspection as an example, in visual measurements human capabilities are a critical factor, although the eye is sensitive to small differences, the colour judgment by eyes will lead to various interpretations, thus, a standard colour chart or model for comparison need to be provided

Park and Jung (2003) mentioned that inaccurate, incomplete or complex working instructions are factors which may lead to non-compliance food handlers' behaviour. Even though food handlers try to follow procedures as given (i.e. in a step-by-step manner), if procedures cannot provide the food handlers with accurate and/or complete instructions in order to cope with frying situations in an effective and understandable manner, then the operators are susceptible to deviating from procedures. In addition, the non-compliance behavior could arise from a lack of understanding. The possibility of non-compliance behavior could increase if the procedures are so complicated that the operators cannot clearly understand the context of required tasks or actions specified in procedures. Thus, the clear and understandable instructions are required in the frying step.

In planned behaviour theory, perceived behavioral control refers to the perceived ease or difficulty when performing the behavior. All kinds of resources need to be provided to the food handlers, otherwise the behaviour will be difficult to perform. In short, all necessary resources, such as well organized equipments, accurate, complete and understandable instructions are needed to improve food handlers' behaviour.

2.7.3 Relevance, validity and reliability analysis

From the demarcation part it is easy to see that food handlers can influence the quality of French fries, and this part is relevant to the demarcation as it implies what are the

factors that can influence food handlers' behaviour, the factors are explained by planned behaviour theory. This part is valid since the treatments to food handlers are based on the three factors. The reliability of the three factors is undoubted as most of the literatures are an extraction from a well-known and widely used book(Food quality Management; a techno-managerial approach) for Food Quality Management students, whose authors are lecturers in that field. Other articles are also reliable as they were published in food field.

Chapter 3: Research Model

3.1 Introduction

The conceptual research model in figure 6 is developed based on the problem situation which is described in chapter 1 and the literature analysis from chapter 2. The model is constructed by combining the two important production processes (blanching and frying) at the French fries processing industry with the colour/texture measurement and the aspects of relevance. Both food and human behaviour (Luning and Marcelis, 2009) can influence the final quality of food, raw material and blanching treatments refers to food behaviour and the food handlers' frying behaviour which refers to human behaviour both are constructed in the research model.

3.2 Research Model

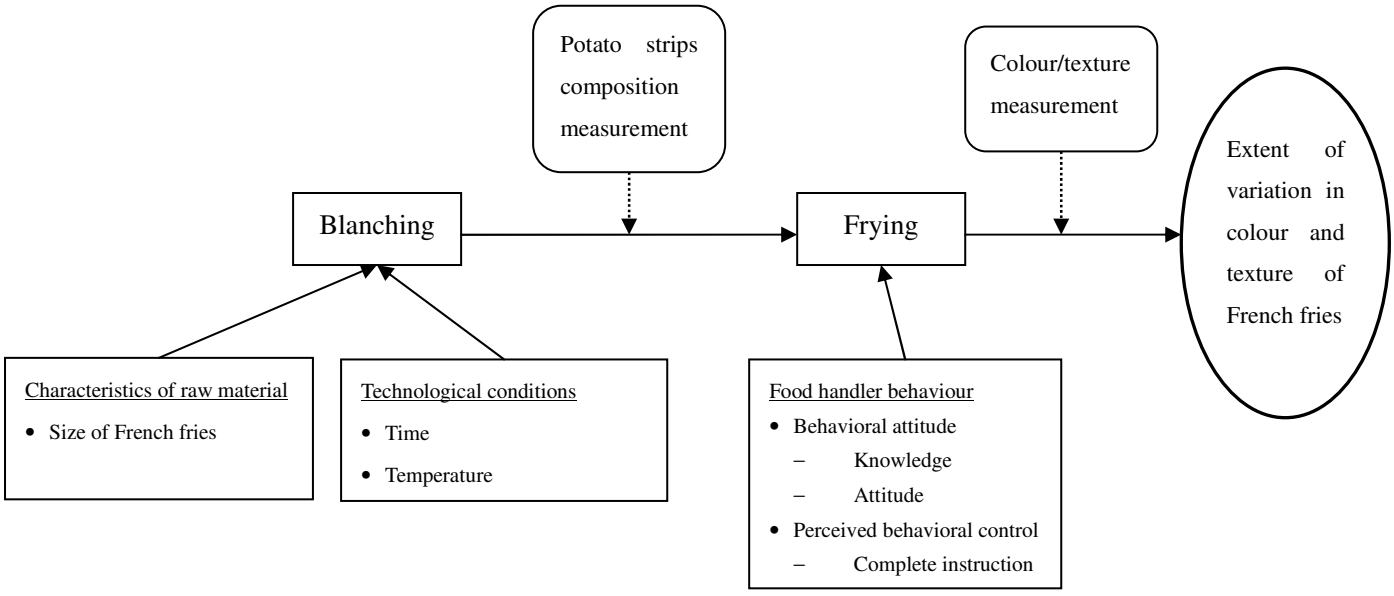

Figure 6: Research model

Blanching and frying process

The research model shows the two important processes (blanching and frying) when making French fries and the measurement steps in the research, it also includes the technological factors in blanching step and managerial factors in frying step which contribute to the value of texture and colour of French fries. According to Van Loon (2005), the whole production process is designed followed by his French fries production process, blanching operation is considered as an indispensible step to the quality of French fries in terms of colour and texture. Romani et al (2008) indicated that the final frying conditions can also influence the colour and texture of French fries, and because people's intention towards behaviour can be different (Icek Ajzen, 1985), the value and variation of colour and texture results can be affect by people in the final frying step. Hence, both blanching and frying steps were constructed in the research model.

Characteristics of raw material (Size of the French fries)

As mentioned in the demarcation part, Luning and Marcelis (2009) reported that the food behaviour and human behaviour both contribute to final food quality. Concerning to the food dynamics, it is taken into account the size of French fries. Krokida et al (2001) reported that the size of potato strips affects significantly the lightness of the samples during frying. The lightness of potato strips is lower for smaller thickness values and for the same frying time. According to Tajner-Czopek et al (2008), their experiment indicated that different French fries sizes can have big effects on the texture attributes, the cutting force was higher for French fries of 10 mm x 10 mm than those of 8 mm x 8 mm. So the size of the potato strips is a factor which can influence its colour and texture of French fries.

Technological conditions (Blanching temperature & time conditions)

Regarding the applied technological conditions, some literature sources indicated that the temperature and time settings during blanching treatment could influence the colour and texture attributes of French fries. According to Andersson et al 's research,

blanching of potatoes greatly affects their texture, the blanching at 50-85 °C has for a long time been a common practice to improve the texture of French fries, it makes the texture after blanching firmer and mealier than without blanching and then affect the texture after frying. In Ludwig's experiment, he found that blanching temperature under 70°C had minor effect on the texture attributes, blanching at 55-70°C, followed by par-frying, increased the firmness of French fries, and the firmness appeared to increase with the immersion time in the blanching bath. According to Agblor & Scanlon (2000)'s experiment, the low temperature long time (70°C, 10 minutes) blanching conditions significantly improved colour quality, their results showed longer blanching time or high temperature could result in lighter colour of French fries. In Aguilar et al (1997)'s opinion, the low temperature of blanching treatment is from 55 to 70°C, and long time is between 15 to 60 minutes. According to Van Loon (2005) and Brown, Morales (1970), they indicated that the potatoes softened too rapidly at 95 °C. So the temperatures between 55°C and 95°C were chosen, both long and short blanching time conditions were considered in my experiment. So the different temperature and time conditions used in blanching step can affect the colour and texture of French fries.

Food handler frying behaviour

With respect to human dynamics, the research model includes the compliance with frying instruction. According to the planned behaviour theory which has been discussed in theory analysis part, there are three main factors which can influence food handlers' behaviour: behavioral attitude, subjective norms and perceived behavioral control. People with different food knowledge or people have different attitude towards instructions might lead to different variation of colour and texture after French fries frying. So the behavioral attitude is considered as a factor which can affect the final quality of French fries. What is more, the presence of instruction about frying might change their way of frying, but the inaccurate or incomplete instructions could lead to non-compliance food handling behaviour. So perceived behavioral control is another factor can influence the final quality of French fries. However,

because all participants are from Wageningen University not the real company, so they may feel no pressure from managers and co-works, the subject norms here may leads to non-compliance behaviour.

Potato strips composition measurement

After different blanching treatments the sugar content in potato strips can be very different and finally influence the colour of French fries (Pedreschi et al, 2009). And according to Tajner-Czopek et al (2008), a positive correlation was found between dry matter content and the firmness of French fries. Therefore, dry matter content and sugar content as the important composition in potato strips were measured after blanching, the results can help to explain the colour and texture results after frying and they were considered as indicators of the colour and texture of French fries.

Colour and texture measurement

The main objective of this thesis to find effect of blanching and food handlers' behaviour on colour and texture of French fries, so the mean value and variation of colour and texture need to measured. Colour and be measured by visual inspection, and the indicator of texture is the firmness of the French fries which can be measured by texture analyzer. After analyzing all colour and texture data under different blanching treatments and food handlers' frying, the mean value and the variation of colour and texture in different situations can be found.

Outcome of the research

The outcome of the research model is to find out the extension of variation in colour and texture of French fries under different blanching treatments and food handlers' frying behaviour.

3.3 Indicators

The technological factors (‘size of the French fries’, ‘blanching time’, and ‘blanching temperature’) and the managerial factors (behaviour attitude and perceived behavioural control) are used in the research model. According to the theory analysis, these factors which could influence the final outcome were used and measured in the experiment.

In order to find out the effect caused by these different factors, the factors should be transferred to measurable indicators as can be seen below.

- Dry matter content and reducing sugar content

The dry matter content and reducing sugar content of potato strips various under different blanching conditions, and this is the main reason why the colour and texture of French fries are different after frying process. Lisinska and Golubowska (2005) said that the texture of French fries changes during blanching and frying is due to water loss, and dry matter content can show the water loss after blanching, the firmness of French fries is higher if the dry matter content of potato strips is larger (Tajner-Czopek, 2008), so dry matter content was measured after blanching as an indicator to the texture of French fries. The colour of French fries after frying become darker because of the Maillard reaction, the less reducing sugar content in potato strips, the weaker Maillard reaction will be. Therefore, reducing sugar content is an indicator to the colour of French fries after frying.

In the mean while, colour and texture of French fries were tested directly by visual inspection and texture analyzer respectively after frying in order to get a more reliable and intuitive results.

- Level of food handles’ knowledge and quality attitude

According to planned behaviour theory (Ajzen, 1985), one factor influence the human behaviour is the perceived behaviour control. Park and Jung (2003) said that the

inaccurate, incomplete or complex working instructions can lead to non-compliance food handlers' behaviour. It indicated that food handlers' behaviour can be improved after getting accurate and complete instructions. However, behavioral attitude is another factor which can change the human behaviour, if their personal evaluation of the outcome is positive, they are more willing to perform the behaviour. As the indicators of behavioral attitude, people's knowledge and attitude which can influence their evaluation of the outcome were tested by using a questionnaire (Appendix 1).

3.4 Hypothesis

1. *Characteristics of raw material (Size of the French fries)*

According to the experiments which have been done by Krokida et al (2001) and Tajner-Czopek et al (2008), thin French fries will lead to more variation than the thick ones in the same blanching and frying conditions.

2. *Technological conditions (Blanching temperature & time conditions)*

a) Regarding Van Loon (2005)'s experiment, the low temperature (under 70°C) blanching condition can lead to firmer texture of French fries, and the firmness will increase if the blanching time is longer (more than 20 minutes).

b) Agblor&Scanlon (2000) indicates that the colour of French fries will be darker when blanching temperature is higher (more than 70°C) and blanching time is longer (more than 20 minutes).

3. *Food handler frying behaviour*

a) According to Park and Jung (2003), incomplete and inaccurate instructions may lead to non-compliance food handler behaviour, so the hypothesis is that the variation will be reduced after participates getting more detailed instructions.

b) According to the planned behaviour theory, food handlers who have different

knowledge or attitude could lead to different behaviour, so another hypothesis is that participates who have higher knowledge or higher quality attitude can lead to less variation after getting detail instructions.

Chapter 4: Material and methods of blanching experiment

4.1 Introduction

Food quality is considered to be influenced by both dynamic properties of the food product and dynamic properties of people (Luning and Marcelis, 2009), colour and texture are the two main important properties of French fries, both food behaviour and human behaviour can have an impact on the quality of colour and texture during production. This chapter will be focused to the food behaviour (food dynamics and technological conditions) and test how it affect the quality attributes of a food product, which refers to the effect of different blanching treatments on the value and variation of colour and texture of French fries. The experiment design can be found in this chapter and the results of the experiment were discussed in chapter 5.

Since dry matter content is an indicator to the texture attribute, it gives the reason why the firmness of French fries changes under different blanching treatments. In addition, sugar content is the indicator of colour results because of Maillard reaction. Therefore, besides the colour and texture results of French fries, dry matter content and sugar content of the potato strips were also measured during the experiments. Two types of French fries (thick and thin) were used in the experiment in order to get a deeper idea of the influence of blanching treatment**.**

4.2 Research objective

The target of the research is to test how time and temperature condition of blanching treatments affects the value and variation of colour and texture of French fries.

4.3 Hypothesis

1. Thin French fries will lead to more variation than the thick ones under the same blanching and frying conditions.

2. Low temperature (60°C and 70°C) blanching condition can lead to firmer texture of French fries, and the firmness will increase if the blanching time is longer (30 minutes).

3. The colour of French fries will be darker when blanching temperature is higher (80°C) and time is longer (30 minutes).

4.4 Methodology

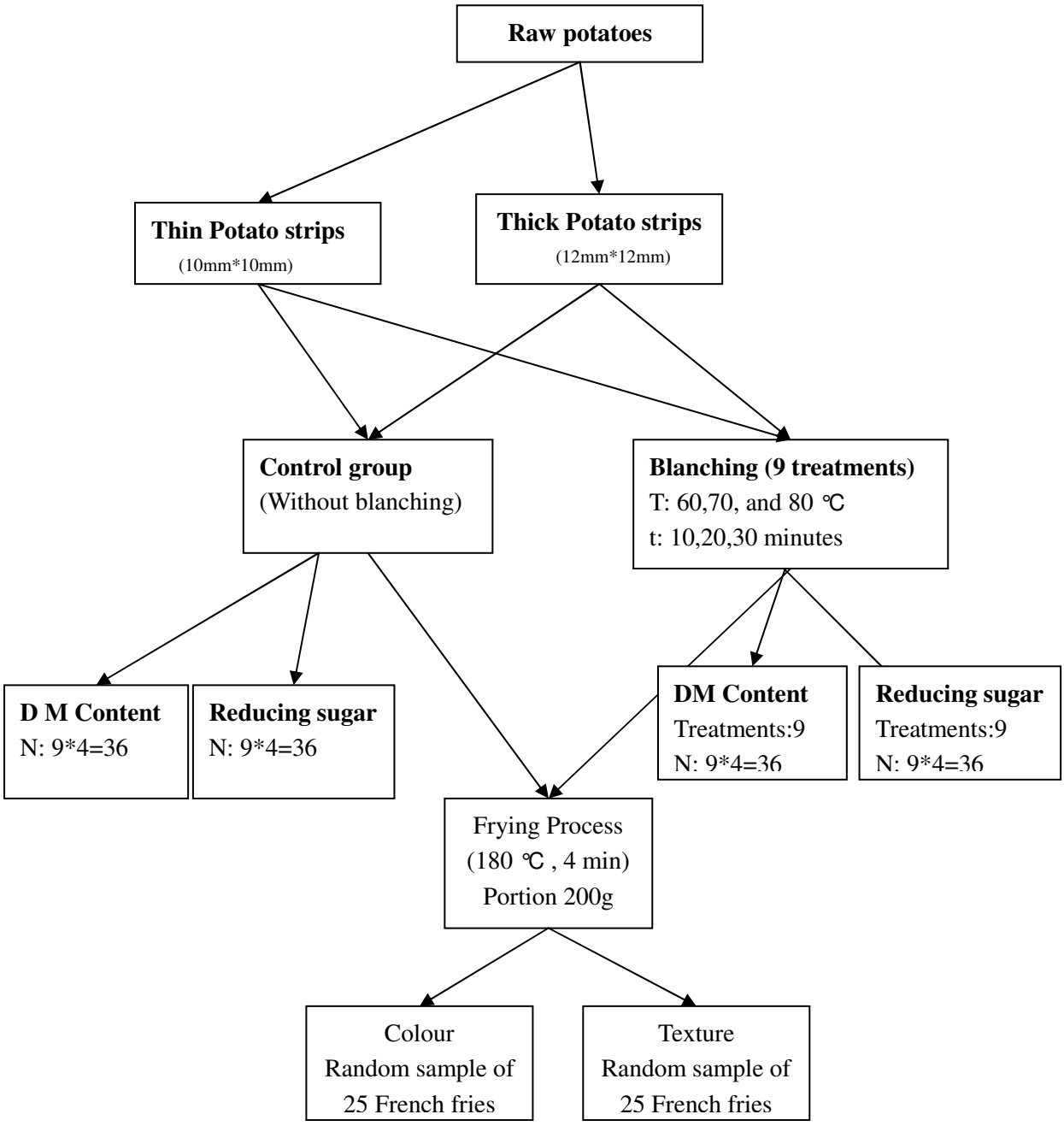

Figure 7: Schematic diagram of experimental process

4.4.1 Sample preparation

Potatoes ("Nicola" variety) and plant oil (Diamant, the Netherlands) were the raw material which purchased from the local supermarket. Potatoes tubes were washed in normal water to remove the foreign materials, and then they were peeled using a manual peeler to remove the skin. After washing, the potatoes were cut into strips of

two different sizes (thin potato strips: 10 mm * 10 mm * 60mm; thick potato strips: 12 mm * 12mm * 60mm) by using a manual cutter (Brabantia, the Netherlands). Then the potato strips were socked in water for 10-20 minutes to get rid of the excess starch and sugar content.

During blanching treatment, potato strips were subjected to blanching in water (potato/water ratio 0.1[w/v]) at 60, 70 and 80°C for 10, 20 and 30minutes (9 treatments) in 4 replications (Table 1). During blanching temperature was regularly monitored by thermocouple (PeakTech 3150, Germany). Control potato strips will not be subjected to blanching.

After getting potato strips out of the water bath, blanched strips were pre-dried at 70°C for 10 minutes in the oven (Model E104, Heraeus, Germany). Dried strips were subjected to pre frying at 175°C for 1.5 minutes. Temperature of the oil was also monitored by thermocouple (PeakTech 3150, Germany). Following par-frying, paper towels were used to get ride of excess oil of the strips. Then the fries were placed in the freezer (-20°C) on a metal tray for 30 minutes. The frozen fries were packed in pre-labeled packages and they were stored in the freezer at -20°C for at least 24 hours.

Table 1: Nine conditions for the blanching treatments

	Time condition	Temperature condition
Treatment 1 (control group)	_	_
Treatment 2	10min	60°C
Treatment 3		70°C
Treatment 4		80°C
Treatment 5	20min	60°C
Treatment 6		70°C
Treatment 7		80°C
Treatment 8	30min	60°C
Treatment 9		70°C
Treatment 10		80°C

4.4.2 Frying

The contents of each package (200gm) were subjected to frying at 180°C for 4 minutes in a French fries fryer (Princess, Classic family castel 3L, the Netherlands). Temperature data were recorded every 1 minute during the experiment using thermocouple (PeakTech 3150, Germany). The thermocouple was positioned in the centre of the oil bath, hung at about half of the oil level.

4.4.3 Design of experiment and statistical analysis

The schematic diagram of experimental process (Figure 7) shows the general experimental and analysis steps for the experiment. 72 portions (2 thickness x 3 blanching times x 3 temperatures x 4 replications) of potato strips were subjected to blanching, and then all 72 portions of par-fried frozen fries were fried randomly, by creating random fry ID, at 180°C for 4 minutes. 25 French fries from each fried portion were randomly selected for texture and colour analysis as given in analysis section below. 4 samples from each treatment (2 thickness * 3 times * 3 temperatures=18 treatments) were taken, before and after blanching, for the determination of sugar content and dry matter content as mentioned in the analysis section below.

a) Reducing sugar content:

Reducing sugar content of frozen fries from the three groups was analysed by he method used by Matsuura-Endo et al, (2004 and 2006). The frozen potato fries were homogenised in 80 % (v/v) ethanol and the sugars in the homogenate were extracted at 60°C for 1 hour. After centrifugation, the supernatant was dried under a vacuum, dissolved in distilled water and passed through a membrane filter (0.45µm Omnipore, Millipore Tokyo). The concentrations of sugars in the filtrate were determined by HPLC (specifications with columns). Quantification of sugars in the samples was performed by standardization with external standards of fructose and glucose.

b) Dry matter content:

Potato dry matter will be measured by putting strips into an oven at a temperature of 80°C till it a constant final dry weight is obtained (Moyano & Pedreschi, 2001). Dry matter content is determined from the difference in the weight of potato samples before and after oven drying. The calculating formula is: Dry matter content = weight of potato strips after drying / weight of potato strips before drying

c) Texture analysis:

Peak force was used as a measure (index) of texture quality of French fries (Agblor and Scanlon, 2000). A texture analyzer model TA XT2i- HR (Stable Micro Systems, Surrey, UK) was used for instrumental analysis of texture. A sample size of 25 French fries were used to determine the peak force. Each French fry was fractured longitudinally with a wedge-shaped probe (30° cutting angle, 15 mm width), using a cell load of 5 kg and probe distance at 12 mm at a speed of 10 mm/s. A force–distance diagram was constructed from the resistance that the probe encountered during fracture. Cutting tests were carried out by measuring the shear force F (in Newton) expressed by the first peak necessary to cut the French fries sticks. The first peak identification was done by the same person that can reduce the error due to different judgemental standards. Because sometimes it is not possible to find out peak force on the curve, only clear and reliable peak force results were shown.

Mean values and standard derivation for each treatment (100 samples) were calculated by SPSS, tables and histograms were made for comparison (chapter 5)

d) Index colour analysis:

Colour of French fries was evaluated by USDA colour cards (Munsell Corp. USA) using scale 000 (lightest) to 4 (darkest). The chart has seven different classes of fry colour, from C000 (lightest) to C4 (darkest). Sample size used for colour evaluation was 25 strips, and the colour was classified by the same person in order to significant errors since people all have different judgemental standards.

During data analysing, the number of potato sticks per class was multiplied by a

specific number per class (C000 = 1, C00 = 2, C0 = 3, C1 = 4, C2 = 5, C3 = 6, and C4 = 7), so there were 100 values of colour results for each blanching treatment. The mean values for each treatment were calculated, and histograms were made by using SPSS in order to compare the variation and mean values between all nine treatments. What is more, Tukey table was used to find out significant differences of variation between the treatments.

Statistical Analysis:

The data obtained from the analysis and experiments were statistically analyzed by using software SPSS 17 and Microsoft Office software.

Because the numbers of samples are not big enough, all the texture and colour data were log transferred in order to make the data normally distributed. All the results used in the figures are log transferred data.

Statistical analyses (ANOVA and Tukey) were carried out using SPSS, Homogeneous groups were determined with the multiplicative comparison test of Tukey (at significance level a = 0.05). The measure of variability used for the study of variance was the standard deviation. Variance (s2) of a set of N measurements $x_1, x_2\ldots, x_N$ ($s^2 = \Sigma (x - x^-)^2 / N – 1$). Standard deviation (s) of a set of N measurements $x_1, x_2\ldots, x_N$ is the square root of the variance s^2. Standard deviations were estimated by means of Microsoft Excel. All the figures and tables below are summarized from ANOVA, Tukey and other data.

Chapter 5: Effect of blanching treatments on value and variation of colour and texture of French fries

5.1 Introduction

This chapter is an exploration of the food dynamics and how the characteristics of raw material and technological conditions affect the colour and texture of French fries. The experiment design was shown in chapter 4, both thin and thick French fries were tested in the research, nine blanching treatments with different temperature and time conditions were used to get insight of the effect of blanching treatments on the value and variation of colour/texture of French fries.

5.2 Effect of blanching treatments on dry matter content

Dry matter content of potato strips is an indictor towards the texture of French fries, Lisinska and Gołubowska (2005) indicated that texture of potatoes changes during the technological process (such as blanching, par-frying), one of the reasons is due to water losses. Dry matter content can show the moisture loss of all the potato samples after blanching. This chapter gives a general idea of the dry matter content situation under different blanching treatments, it is an indicator and gives reason to the texture results in chapter 5.4.

Table 2: Dry matter content of thin and thick French fries after blanching at different temperature–time combinations condition

Thin French fries			
Temperature	Time		
	10 Minutes	20 Minutes	30 Minutes
60°C	0.23±0.01b	0.25±0.01bc	0.26±0.01c
70°C	0.19±0.01	0.19±0.01	0.20±0.01
80°C	0.19±0.01	0.19±0.01	0.19±0.02

Thick French fries			
60°C	0.20±0.01	0.23±0.03	0.22±0.01
70°C	0.23±0.01	0.22±0.01	0.20±0.01
80°C	0.20±0.03	0.20±0.02	0.21±0.02

**Values=Mean dry matter value ± standard deviation*

The value without letter is considered as **a.*

**Values share the same letter are not significantly different (P>0.05).*

Table 2 shows the mean value and variation of dry matter content for both thin and thick potato strips after different blanching conditions. For thin potato strips, the mean value of dry matter content was significant higher ($p<0.05$) when blanched at 60°C compared with 70°C (0.19) and 80°C (0.19) after 10minutes. Similar results can be found after blanching for 20 and 30 minutes, the dry matter content was significantly higher ($p<0.05$) when blanching at low temperature (60°C), this is because moisture goes slower inside the potato strips at low temperature .

Referring to thick French fries, dry matter content for all the treatments are non significant ($p>0.05$) to each other, because the moisture transfer slower in the thick French fries. In addition, less variation can be expected in thick potato strips, because more strips can be cut from one potato, and the chemical composition can be different in different part of the potatoes (Figure 3).

5.3 Effect of blanching treatments on sugar content

As discussed in theory analysing part in chapter 2.5, colour of French fries is determined by chemical composition of potato tubers, such as the reducing sugar content. The more reducing sugar content in potato strips, the more active the Maillard reaction is, which leads to darker colour of French fries. Sugar content result in this chapter is an indictor to the colour of French fries after frying in chapter 5.6.

Table3: Reducing sugar content of thin and thick French fries after blanching at different temperature–time combinations condition

Thin French fries			
Temperature	Time		
	10 Minutes	20 Minutes	30 Minutes
60℃	0.26 ± 0.19	0.42 ± 0.09 ac	0.37 ± 0.14 ac
70℃	0.21 ± 0.09	0.21 ± 0.08	0.20 ± 0.23
80℃	0.25 ± 0.22	0.08 ± 0.01 b	0.06 ± 0.03 b
Thick French fries			
60℃	0.47 ± 0.06	0.29 ± 0.06	0.30 ± 0.04
70℃	0.29 ± 0.01	0.23 ± 0.08 b	0.23 ± 0.12 b
80℃	0.45 ± 0.45	0.23 ± 0.23 b	0.17 ± 0.17 b

**Values=Mean dry matter value ± standard deviation*
The value without letter is considered as **a.*
**Values share the same letter are not significantly different (P>0.05).*

Table 3 shows the value of reducing sugar content for both thin and thick potato strips after different blanching conditions. In case of thin potato strips, the reducing sugar content significantly decreased after high temperature (80°C) and long time (20 and 30 minutes) blanching treatment compared with low temperature (60°C and 70°C) short time condition (10minutes), the value dropped from o.26, 0.21 to 0.08 and 0.06. In case of thick potato strips, similar results can be observed, the potato strips with high temperature and long time blanching treatment (80°C, 20min and 30min) had significantly less sugar content (0.23, 0.27) than the ones with low temperature (60°C) short time (10min) blanching treatment (0.47), So long time and high temperature blanching could highly reduce the sugar content of potato strips.

This is in line with Pedreschi et al's (2009) article, the extent of sugar leaching increases under long-time blanching conditions. Regarding temperature condition, the rate of sugar diffusion increases at high temperature (Gekas et al, 1993), but browning

becomes rapid at high temperatures (Miranda&Aguilera, 2006), no significant differences can be found between different blanching temperatures when in same blanching time for reducing sugar. So time plays a larger role in colour determination than temperature.

However, the variation of sugar content for each treatment was large, especially in high temperature short time condition (80°C, 10min) for both thin and thick French fries (0.22 and 0.45 respectively). Large variation can be observed between four duplicates in same blanching condition, because the potato pieces were collected from different positions of the potatoes, and the sugar goes to external part of the strips when blanching.

5.4 Texture of the French fries without blanching

Potato strips were blanched under nine different conditions, but there are also four portions of potato strips which were without blanching, they are considered as a control group. The texture of French fries was tested after frying for both thin and thick French fries, the results will be compared with the blanched ones in chapter 5.5.

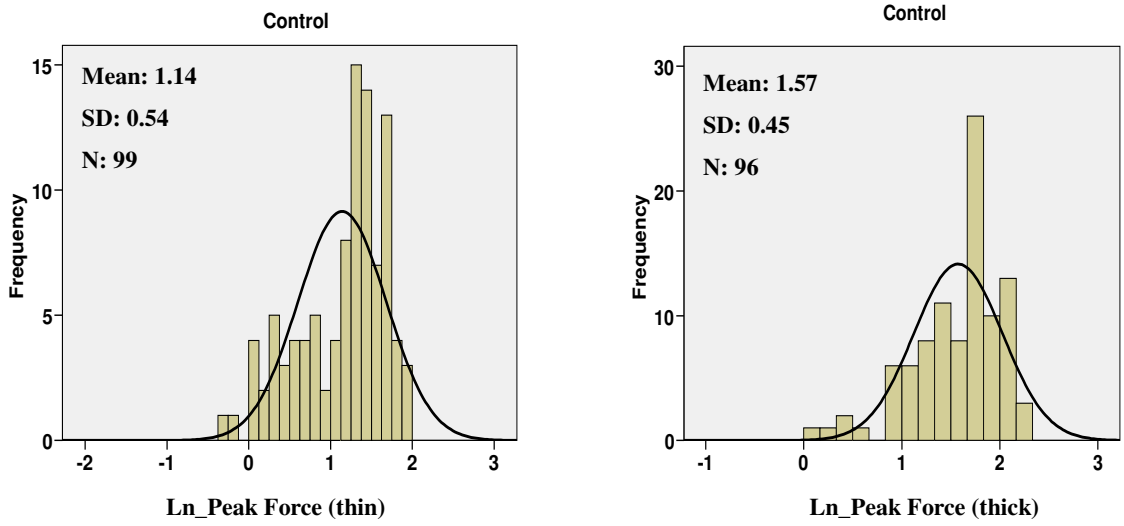

Figure 8: ***Peak force*** *data of thin and thick French fries without blanching (control). Y-axis indicates the frequency numbers of French fries. X-axis indicates the log peak force results*

after frying. Mean is the mean value of log peak force results, SD is standard deviation. N is the number of French fries used for texture analyzing.

Figure 8 shows histogram illustrating the peak force data set for thin and thick French fries without blanching (control). The mean peak force value for thick French fries (1.57) was significant larger ($p<0.05$) as compared to thin French fries (1.14). However, mean variation (calculated variation) of peak force was significant larger in the case of thin French fries (1.14) as compared to the thick ones (1.57).

5.5 Effect of blanching treatments on texture of French fries

The mean values as well as the variation of texture result after frying under nine different blanching treatments are analyzed in this chapter. The main objective of the chapter is to find effect of temperature and time conditions of blanching on texture of French fries. Not only thin French fries but also thick ones were tested, the two tests had very similar results, so only the figure of thin French fries was shown here.

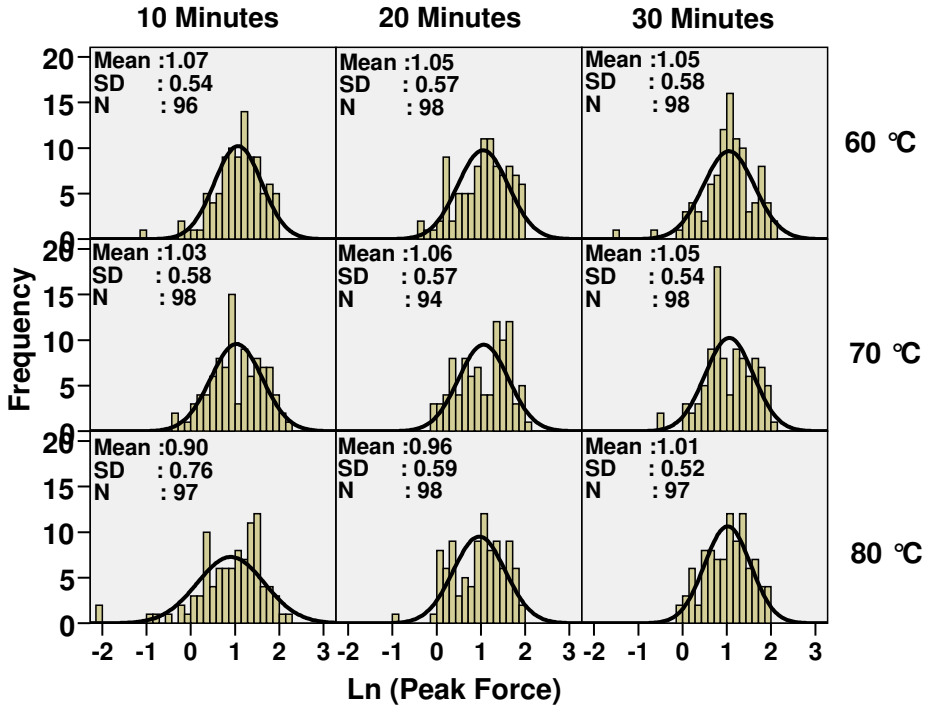

*Figure 9: **Peak force** data of French fries after frying under different temperature–time condition for **thin** French fires. 10, 20, 30 Minutes are the time conditions for blanching,, 60°C, 70°C, 80°C are the temperature conditions for blanching. X-axis indicates the log peak*

force results after frying for different blanching conditions. Y-axis indicates the frequency numbers of French fries. Mean is the mean value of log peak force results, SD is standard deviation. N is the number of French fries used for texture analyzing.

Figure 9 shows the mean value and variation on texture of French fries under different temperature and time settings applied during blanching for thin French fries. The mean peak force values were significant larger ($p<0.05$) after blanching at 60°C for 10 minutes (1.07) as compared to 80°C after 10 minutes of blanching (0.90). The mean value also decreased significantly after 20 minutes blanching at 80°C (0.96) compared with 60°C (1.05). Moreover, mean peak force was significant larger after 30 minutes (1.01) than 10 minutes (0.90) of blanching at 80°C. Blanching time had little effect on the texture of blanching strips at low temperature (60°C).

Very similar results can be found for thick French fries, the peak force value was significant larger for those blanched at 60°C (1.53 and 1.66) compared with 80°C (1.49 and 1.37) after 10 and 30 minutes blanching. Peak force(1.66) for long time blanching (30minutes) is larger when blanching at low temperature (60°C). Blanching time only had effect on the texture at high temperature (80°C), from 1.49 (10 minutes) to 1.37 (30 minutes).

According to Lisinska and Gołubowska (2004), after blanching, the starch swelling occurred in the outer layers of potato strips, along with an enormous increase in their volume, because of the partial pasting of starch, the hardness of strips could reduce. In Mate et al (1998) and Alvarez & Canet (1999)'s report, they found that the first 2 minutes of blanching significantly affect the texture of French fries since structure of potato tissue is loosened, compared to those observed during further minutes of blanching. Liu and Scanlon (2007) also found that blanching time had little effect on the texture of blanching strips, especially at low temperature. So in this case, the peak force for French fries without blanching (Figure 8) has higher value (1.14) compared with other treatments (0.9 to 1.07) (Figure 9).

The peak force difference between unblanched French fries and the ones blanching for 10 minutes is big, but there only small differences can be seen after further minutes of blanching (Figure 9). The small difference can still be observed, at these low temperatures (60°C, 70°C), longer blanching did not soften the texture of strips, the activity of pectin methyl esterase at low temperature (55–75°C) accounts for this, because of the ‘‘calcium bridging’’ between sidechains of the polyuronic acids (Liu and Scanlon, 2007)

Pedreschi et al (2009) indicated that for high temperature (80°C) blanching condition, it can lead to structural damage and loss of firmness in the vegetable tissue. When blanching in the range of 55–75°C, it can improve the firmness of vegetables and to reduce physical breakdown and sloughing during further processing. Abu-Ghannam and Crowley’s experiment (2006) also showed that firmness was higher for potatoes blanched at 65°C than those cooked at high temperature (95°C), because high temperature blanching disrupts cell integrity and cell adhesion, which result in decrease in tissue rigidity (Truong et al, 1998). The literatures are in accordance with texture results for this experiment, French fries which blanched with low temperature (60°C) have higher firmness (1.07, 1.05 and 1.05) than the ones with high temperature (80°C) (0.9, 0.96, 1.01) (Figure 9).

*Table 4: **Variation** of **peak force** data for thin and thick French fries after blanching at different temperature–time combinations condition*

Thin French fries			
Temperature	Time		
	10 Minutes	20 Minutes	30 Minutes
60°C	0.54 a	0.58	0.58
70°C	0.59	0.57	0.55 a
80°C	0.76 b	0.60	0.53 a
Thick French fries			
60°C	0.36	0.50	0.44
70°C	0.54	0.49	0.52
80°C	0.40	0.56	0.48

**Values= standard deviation of peak force data*
The values without letter are considered as **ab which are non-significantly different*
**Values share the same letter are not significantly different (P>0.05).*

Table 4 indicated the effect of different temperature and time setting applied during blanching on the mean variation of peak force for both thin and thick French fries. With respect to thin French fries, the variation is significant higher at 80°C than 60°C when blanching for 10 minutes. The mean variation for potato strips with long time blanching (30minutes) was significant smaller than the ones blanching for 10 minutes at 80°C. Regarding the thick French fries, no significant difference is observed among all treatments, because the chemical composition variation in thick potato strips is less.

5.6 Colour of the French fries without blanching

Besides the potato strips which were blanched under different conditions, there are also four portions of potato strips which were without blanching, they are considered as a control group. The colour of French fries was tested after frying for both thin and thick French fries, the results will be compared with the blanched ones in chapter 5.7.

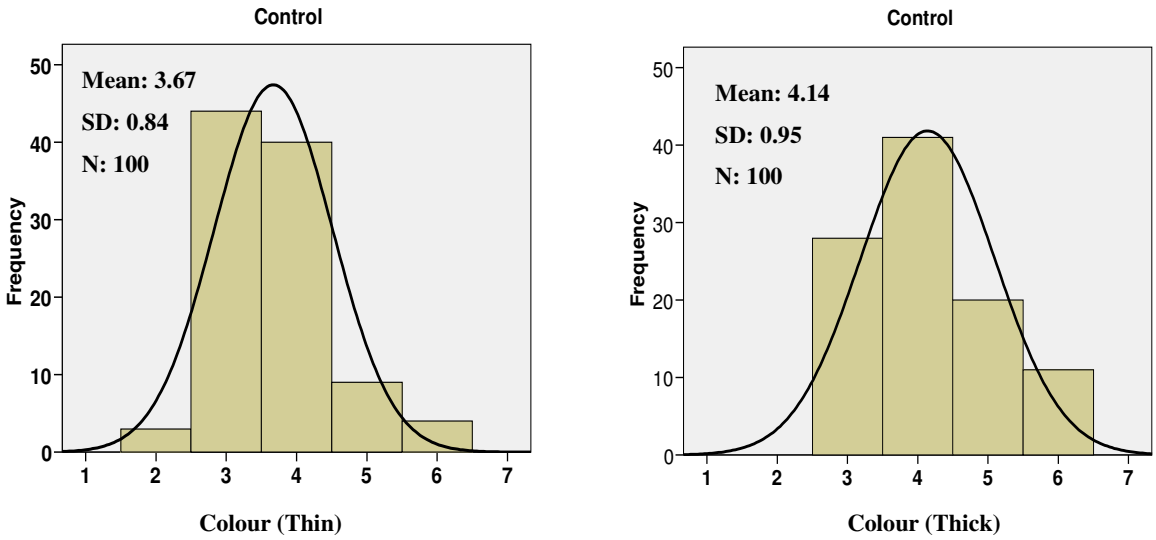

Figure 10: Colour data of thin and thick French fries without blanching (control). y-axis shows the frequency numbers of French fries. X-axis shows the colour results after frying. Mean is the mean value of colour results, SD is standard deviation. N is the number of French fries used for colour analyzing.

Figure 10 shows histogram which illustrating the colour data set for thin and thick French fries without blanching. On average, thick French fries without blanching has significant ($p<0.05$) darker colour (4.14) than thin ones (3.67), because more reducing sugar can be observed in thick French fries (0.65) compared with the thin ones (0.60).

5.7 Effect of blanching treatments on colour of French fries

The mean values and the variation of colour result after frying under nine different blanching treatments are shown in this chapter. The main objective of the chapter is to show the effect of temperature and time conditions of blanching on colour of French fries. Not only thin French fries but also thick ones were tested, the two tests had very similar results, so only the figure of thin French fries was shown here.

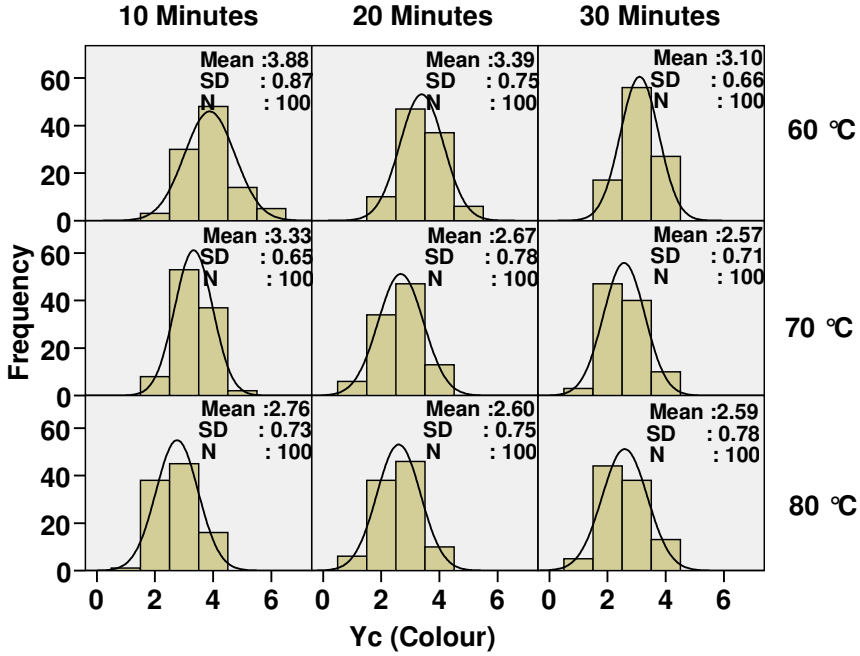

Figure11: ***Colour*** *data of French fries after frying under different temperature–time condition for* ***thin*** *French fires. 10, 20, 30 Minutes meanss the time condition for blanching,, 60°C, 70°C, 80°C means the temperature condition for blanching. X-axis indicates the colour results after frying for different blanching conditions. Y-axis indicates the frequency numbers of French fries. Mean is the mean value of colour results, SD is standard deviation. N is the number of French fries used for colour analyzing.*

Figure 11 shows the effect of different temperature and time settings applied during blanching on colour data for thin French fries. The colour became lighter when blanching time or/and temperature increased. For example, the colour is significant lighter when blanching at 80°C (2.76, 2.60, 2.59) as compared to 60°C (3.88, 3.39, 3.10) in three time conditions. The colour was also significant lighter when blanching time was 30 minutes (3.1, 2.59) compared to 10 minutes (3.88, 2.76) at 60°C and 80°C. Regarding thick French fries, it had almost the same colour changing tendency with the thin ones. French fries become lighter when temperature or time increases.

The extent of sugar leaching increases under long-time blanching conditions, because less sugar content in potatoes makes Maillard reaction weaker, the colour turns out to be lighter. Reducing sugar content results (Table 3) proved this theory, long time

blanching (20min, 30min) significantly decreased sugar content in most cases. From figure 11 it is also easy to see that the colour becomes lighter when the time increases in both thin and thick cases. Regarding temperature condition, the rate of sugar diffusion increases at high temperature (Gekas et al, 1993), but browning becomes rapid at high temperatures (Miranda&Aguilera, 2006), no significant differences can be found between different blanching temperatures when in same blanching time for reducing sugar. So time plays a larger role in colour determination than temperature. Generally speaking, the colour becomes lighter when blanching temperature increases, but there are some exceptions.

*Table 5: Effect of blanching treatments on **variation** in the **colour** attribute of French fries*

Thin French fries			
Temperature	Time		
	10 Minutes	20 Minutes	30 Minutes
60°C	0.86 b	0.76	0.67 a
70°C	0.64 a	0.79	0.72
80°C	0.72	0.76	0.78
Thick French fries			
60°C	0.84 c	0.78	0.67
70°C	0.70	0.69	0.63
80°C	0.70	0.74	0.69

**Values= standard deviation of colour results*
The values without letter are considered as **ab which are non-significant to other values*
**Values share the same letter are not significantly different (P>0.05).*

Table 5 demonstrated the effect of different temperature and time setting applied during blanching on the mean variation of colour for both thin and thick French fries. Concerning to thin French fries, the mean variation of colour in 60°C, 10minutes

(0.86) blanching condition was significant larger than the variation at 70°C for 10minutes (0.64), the colour was also significant lighter when blanching time went up to 30 minutes at 60°C (0.67) compared to 60°C for 10 minutes (0.86). Similar observation can be found for thick French fries, only significant differences can be found at 60°C, the variation is larger when blanching at 60°C for 10minutes (0.84). To summarize, there is no significant difference in colour variation when blanching temperature goes above 70°C.

5.8 Conclusion of the effect of blanching treatments on colour and texture of French fries

The value of dry matter content influences the texture of French fries, the firmness of French fries increases if dry matter content is higher. Blanching time has little effect on the texture of blanching strips, especially at low temperature, but the texture was higher for potatoes blanched at low temperature (60°C). Colour of the French fries becomes lighter when blanching time increases, and thick French fries have lighter colour than the thin ones.

For the potato processing industry, it has practical value to predict the effect of blanching temperature and time settings on the final quality of French fries. For example, the low temperature (60°C) and high temperature (80°C) could lead to significant difference on texture. Long time of blanching (30 minutes) can results in lighter colour of French fries. Hypothesis 2 in chapter 4.3 is rejected here, low temperature (lower than 70°C) blanching condition can lead to firmer texture of French fries only for thin French fries, and there is no clear relationship between firmness and the blanching time. Hypothesis 3 is also rejected here, although the colour of French fries are darker when blanching time is longer, but the relationship between colour and blanching temperature is not significant.

Size of the French fries is a factor which can affect the colour and texture of French

fries. The first hypothesis in chapter 4.3 in accepted, thin French fries lead to more variation on colour and texture than the thick ones in the same blanching and frying conditions. However, for both thin and thick French fries, low temperature blanching leads to higher texture results, colour becomes lighter when temperature or time increased.

Concerning the results of the experiment in chapter 5, the mean value of texture and colour can be influenced by blanching treatments, but no significant variation difference can be found between blanching groups in the range of 10°C for temperature or in the range of 10minutes for time, because 10°C and 10minutes' range is large in industry, the variation can be controlled well under normal condition by using industrial equipment.

Chapter 6: Material and methods of food handlers' frying experiment

6.1 Introduction

Food quality can be influenced by both food and human behaviour, the effect of blanching treatments (production process) which refers to food behaviour has been discussed in chapter 4 and chapter 5. The aim of this research is to find out how the human factor influences the variation of colour and texture of French fries, food handlers' frying behaviour is considered here. As mention in planned behaviour theory, behaviour attitude and the perceived behavioral control can influence human behaviour, people's knowledge and the quality attitude are the indictors of behaviour attitude, the incomplete and inaccurate instructions is the reason of perceived behavioral control. This chapter gives the experiment design for food handlers' frying experiment, the outcome of the research can be found in chapter 7.

6.2 Research objective

The target of the research is to exam how food handlers with different knowledge and attitude level affect the variation of colour and texture of French fries before and after getting complete and accurate instructions.

6.3 Hypothesis

The variation of colour and texture will be reduced after participates getting more detailed instructions. Participates who have higher knowledge or higher quality attitude can lead to less variation after getting detail instructions.

6.4 Methodology

Figure 12: Schematic diagram of experimental process

6.4.1 Sample preparation

Potatoes ("Nicola" variety) and plant oil (Diamant, the Netherlands) were the raw material which purchased from the local supermarket. Potatoes tubes were washed in normal water, and then they were peeled using a manual peeler. Only thin French fries were analyzed here, potatoes were cut into strips (10 mm * 10 mm) by using a manual

cutter (Brabantia, the Netherlands). After socked in water for 10-20 minutes, put strips into blancher, two different time-temperature blanching treatments were used. According to the results of blanching experiment, blanching condition 1 (80°C, 10 minutes) turned out to have the least variation of colour and texture, and blanching condition 2 (70°C, 30 minutes) had the largest variation, these two extreme treatments were used in food handler experiment. The fries were put into freezer after dying and par-frying (175°C, 1.5min).

6.4.2 Experiment design and statistics analysis

Referring the results of experiment in chapter 5, two blanching treatments with the least and the most colour/texture variation were selected, and thin French fries were used in the food handler experiment since more variation was observed there. According to Van Loon (2005), the minimum blanching temperature applied in practice is about 65 °C, otherwise spoilage due to bacterial growth may occur. So the blanching temperature at 60°C was not considered as the frying condition for food handlers' experiment. Because there is no significant difference in colour variation, texture variation results were being considered. Blanching condition at 80°C for 10minutes which has the largest variation was chosen, and one of the conditions with significant smaller variation was pick out (70°C for 30minutes).

In order to find the effect of food handlers' frying behaviour on variation of colour and texture of French fries, participates were asked to frying both portions with largest and smallest variation under two blanching conditions (80°C for 10minutes and 70°C for 30minutes), and the participates will be separated into groups (people with higher and lower knowledge, people have high quality attitude and low quality attitude) according to the results of a questionnaire.

The participants were an international group of twenty people, all students (BSc, MSc and PhD) belonging to different disciplines, backgrounds and nationalities. In order to eliminate the potential that people from the same country could have the same

perception about French fries, the participants were a mix of 7 different nationalities from all over the world (China, Germany, Netherlands, Belgium, Ukraine, Mexican, Pakistan). Regarding to the gender of participants, the number of female ones was almost equal to the number of participants who were male. So, both genders were equally represented.

At first , the participates were simply instructed about some general frying knowledge, such as the safety points that they need to be aware of and the portion size before and during frying the French fries. They were asked to fry both French fries with blanching treatment A(80°C, 10minutes) and treatment B(70°C, 30minutes), frying time was recorded using a stopwatch with an accuracy of 0.1s. Food handlers were monitored to fry when the temperature in thermocouple drops to 180°C. The simple instruction is shown below:

· Never move the deep fryer during use. The oil becomes very hot and may cause severe burns.

• Place one package of the fries into the basket.

• Frying temperature is 180°C, put French fries into oil when the temperature in thermocouple drops to 180°C.

• Slowly lower the basket completely into the oil to prevent excessive bubbling.

• Lift the basket out again when you think the fries are ready.

• Hang it on the hook in the pan to allow the oil to drain out for 5 seconds.

After frying both two different portions, a questionnaire (see Appendix 1) was given to every participate, it covers the background of all participates, four questions (questions 9 to 12) are asked to test their knowledge towards food, and the last 4 questions are about attitude towards instructions in the product packages when handling with food.

Then the same participants were provided with the appropriate instructions (oral and

written instructions) about the parameters that they should take into account during frying and which factors and how affect the quality attributes of French fries. Frying time (4 minutes) was told, temperature (180°C) as well as portion size (200gm) were given. Thus, after filling questionnaire and giving this complete instruction, the participants obtained an improved level of awareness towards the quality attributes of French fries.

The structure of the experimental design gave us the opportunity to investigate the effect of knowledge and attitude of food handlers on variation of colour and texture of French fries (See chapter 6.4 for the schematic diagram of the experimental process).

Statistical analysis

The colour and texture of French fries after frying were analyzed by using colour chart and texture analyzer, the methodology can be found in blanching experiment part. All the data were processed statistically using the SPSS version 17 and Microsoft Office software.

Chapter 7: Effect of food handlers' frying behaviour on variation in colour and texture of French fries

7.1 Instruction

This chapter is an exploration of the human dynamics and how the behavioral attitude (knowledge and quality attitude) and perceived behavioral control (complete instructions) affect the colour and texture of French fries. The blanching condition lead to large variation (blanching 80°C, 10min) on colour and texture and the one with small variation (blanching 70°C, 30min) were selected in this experiment. The effect of food handlers' frying behaviour on colour and texture has been explored in this chapter by doing the experiment in chapter 6.

7.2 Effect of complete instruction on frying time

The average frying time which participates used before the complete instructions for blanching condition A (80°C, 10min) was 2.67minutes, and the average frying time for blanching condition B (70°C, 30min) was 3.51minutes which was quite similar to the required frying 4minutes in the complete instructions. To summarize, the time participates used for frying was shorter before instructions, and the frying time after instructions was 4 minutes. The complete instruction affects people's using of frying time.

7.3 Effect of complete instructions on the texture of French fries

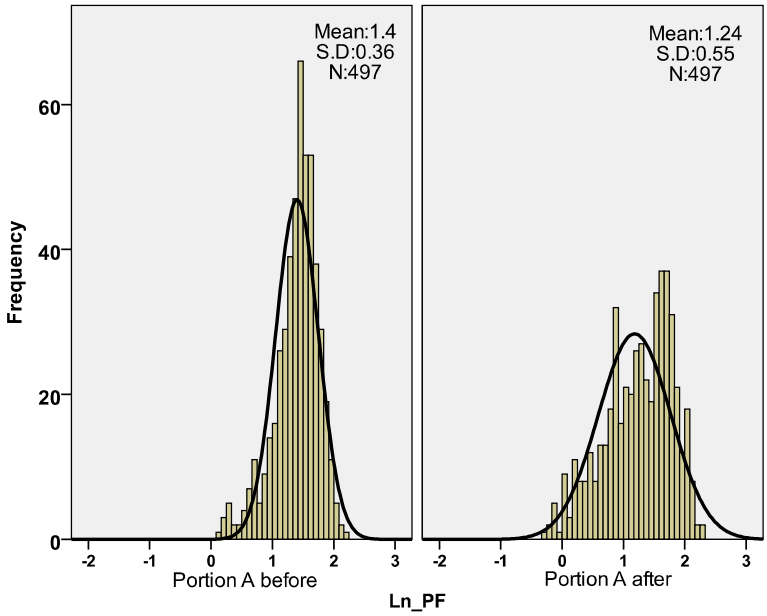

Figure13. ***Texture*** *measurement under* ***blanching condition A (80°C, 10min)*** *before and after getting complete instructions. Y-axis indicates the frequency numbers of French fries. X-axis indicates the log peak force results before and after complete instructions. Mean is the mean value of log peak force results, SD is standard deviation. N is the number of French fries used for texture analyzing.*

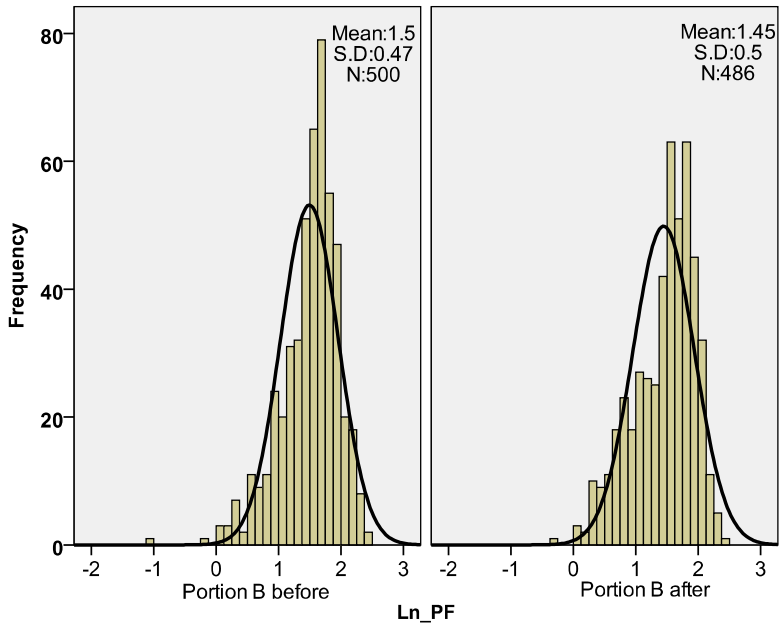

Figure14. ***Texture*** *measurement under* ***blanching condition B(70°C, 30min)*** *before and after getting complete instructions. Y-axis indicates the frequency numbers of French fries. X-axis*

indicates the log peak force results before and after complete instructions. Mean is the mean value of log peak force results, SD is standard deviation. N is the number of French fries used for texture analyzing.

The mean value of the texture of French fries was significantly lower ($p<0.05$) after instructions for blanching condition A (from 1.4 to 1.24). Concerning French fries under blanching condition B, no significant ($p>0.05$) difference can be found. The peak force before complete instruction was higher is due to the frying time, after getting complete instructions, people use 4 minutes as frying time. The result is in line with Figure 15 (Romani et al, 2008), the peak force of French fries decreases with longer frying time (less than 4 minutes).

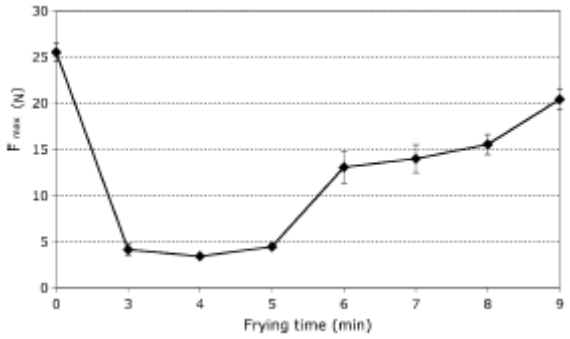

Figure 15: Changes of texture of potato sticks during frying (Romani et al, 2008)

With respect to the different blanching conditions, it was found that the standard deviation (0.55) for blanching condition A was higher than the standard deviation (0.5) for blanching condition B after complete instructions which is in line with the previous blanching experiment in chapter 5.

Regarding the texture for French fries, effect of complete instructions on the standard deviation of texture can not be observed. After instructions, the standard deviation of texture was even significantly higher ($p<0.05$) for blanching condition A (0.55), and the variation before and after getting complete instruction for blanching condition B was similar ($p>0.05$) to each other (0.47, 0.5). The variation even increased after getting complete instructions for blanching condition A, because frying time used for blanching condition A after complete instructions (4min) was significantly higher

than the frying time using simple instructions (2.61min). If more frying time is used, according to the thermocouple which has been watched during the whole frying process, the oil temperature changes all the time during frying, and frying time highly influences the peak force of French fries (Figure 15), so longer frying time could lead to more variation even after instructions.

7.4 Effect of complete instructions on the colour of French fries

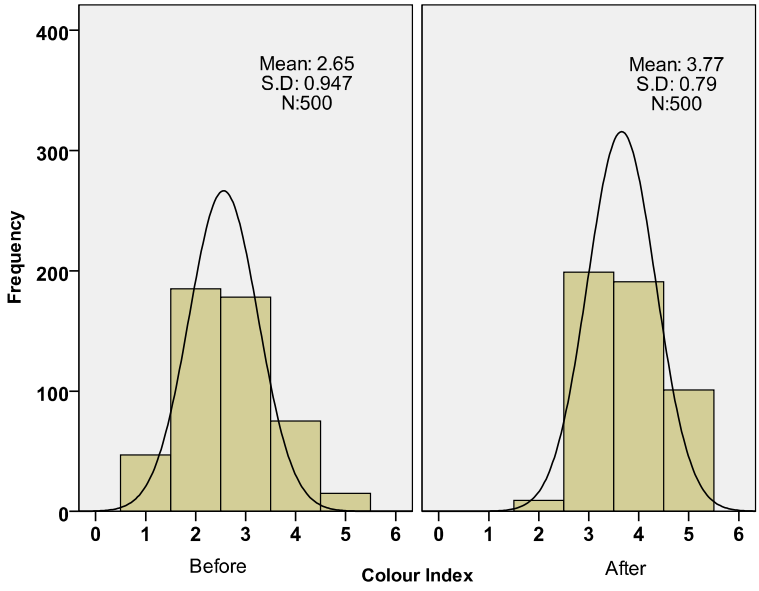

Figure16. ***Colour*** *measurement under* ***blanching condition A (80°C, 10min)*** *before and after getting complete instructions. Y-axis indicates the frequency numbers of French fries. X-axis indicates the colour results before and after complete instructions. Mean is the mean value of colour results, SD is standard deviation. N is the number of French fries used for colour analyzing.*

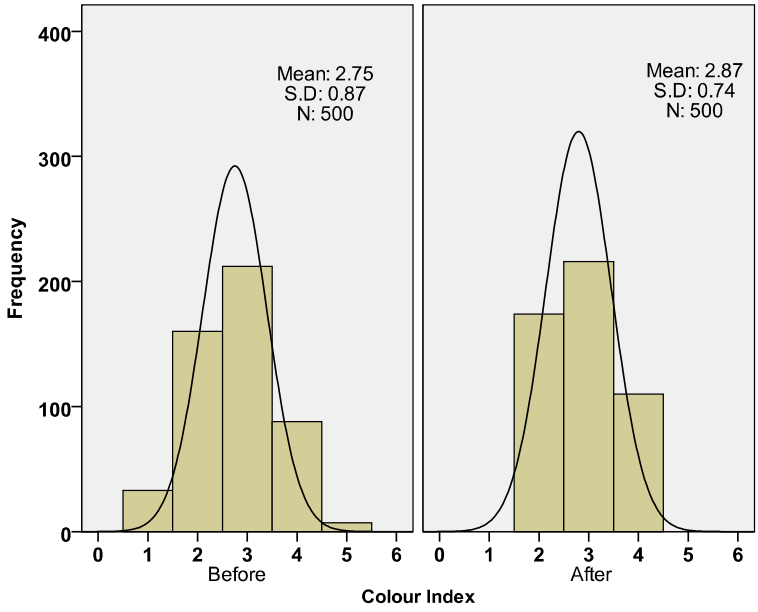

Figure 17: ***Colour*** *measurement under* ***blanching condition B (70°C, 30min)*** *before and after getting complete instructions. Y-axis indicates the frequency numbers of French fries. X-axis indicates the colour results before and after complete instructions. Mean is the mean value of colour results, SD is standard deviation. N is the number of French fries used for colour analyzing.*

From both the figures above (Figure 16 and Figure 17) we can see that no matter which blanching condition was used, the effect of complete instructions on the standard deviation of colour can be observed. The standard deviation of the colour for blanching condition A was much lower after getting complete instructions (0.79) than it was getting simple instructions (0.95). In addition, the mean value of colour is less before complete instructions, because the average frying time for blanching condition A before instructions was 2.7minutes, and the required frying time was 4minutes, the colour became darker (from 2.65 to 3.77) since the frying time increased.

Regarding blanching condition B, it had the similar results as blanching condition A, the standard deviation of colour also decreased after instructions (0.74) compared the colour before instructions (0.87). The average frying time for portion B before instruction was 3.5minutes which is quite similar to 4 minutes, so the colour only became a little bit darker after instructions (from 2.75 to 2.87).

Comparing the results of blanching condition A and blanching condition B, it is in line with the results from Chapter 5, the variation of colour for blanching condition A (both before and after complete instructions) was larger, and the colour was darker for portion A in the same frying condition.

7.5 Effect of knowledge of the participants on the variation of texture and colour of French fries

7.5.1 Introduction

The participants were asked four questions (Appendix 1: questions from 9 to 12) about their knowledge regarding French fries and some factors which could influence the quality attributes during frying. Every correct answer could get one point of knowledge, the maximum points of knowledge is four. There are 55% of the participants (11 persons) achieved full points of knowledge, others are with lower points.

In order to investigate the correlation between knowledge of the food handlers and the texture/colour variation, participants who achieved all four correct answers composed group one (N = 11), people in group one are people who has very high knowledge of French fries. Whereas participants who did not answer all questions right composed group two (N = 9). The standard deviations of the results of the participants were examined against knowledge score of the participants.

7.5.2 Variation of texture results and knowledge of the participates

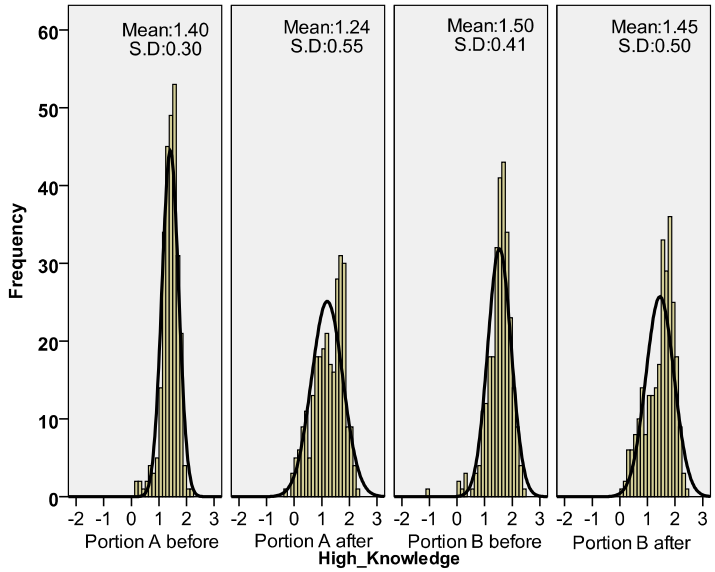

Figure 18: ***Peak force*** *data of French fries before and after complete instructions frying by participates with* ***high knowledge (group 1)****. X-axis indicates the log peak force results after frying for portions with different blanching conditions. Y-axis indicates the frequency numbers of French fries. Mean is the mean value of log peak force results, SD means standard deviation.*

**Portion A before= blanching condition A(80℃, 10minutes) before getting complete instructions*
**Portion A after= blanching condition A(80℃, 10minutes) after getting complete instructions*
**Portion B before= blanching condition B(70℃, 30minutes) before getting complete instructions*
**Portion B after= blanching condition B(70℃, 30minutes) after getting complete instructions*

For people who had very high knowledge of French fries, the figure above (Figure 18) shows that the standard deviation increased after getting complete instructions (0.55) than before instructions (0.30) for blanching condition A. The variation also increased after instructions (from 0.41 to 0.50) for blanching condition B. Therefore, higher knowledge might not be considered as a factor which can reduce the variation of texture.

With respect to the mean peak force value, they had the similar results with the pervious blanching tests in chapter 5. Blanching condition B (blanching 70°C, 30mins) had higher peak force after frying at 180°C for 4 minutes.

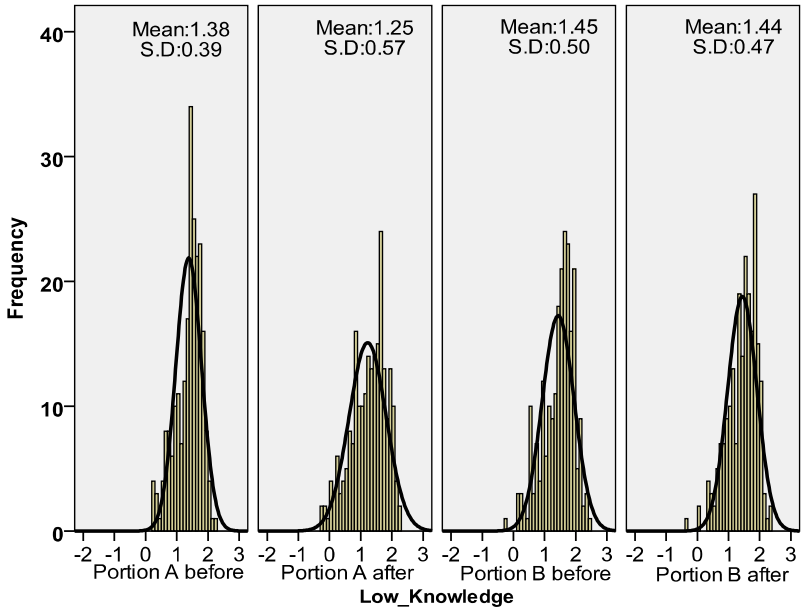

Figure 19: ***Peak force*** *data of French fries before and after complete instructions frying by participates with* ***low knowledge (group 2)****. X-axis indicates the log peak force results after frying for portions with different blanching conditions. Y-axis indicates the frequency numbers of French fries. Mean is the mean value of log peak force results, SD means standard deviation.*

**Portion A before= blanching condition A(80℃, 10minutes) before getting complete instructions*
**Portion A after= blanching condition A(80℃, 10minutes) after getting complete instructions*
**Portion B before= blanching condition B(70℃, 30minutes) before getting complete instructions*
**Portion B after= blanching condition B(70℃, 30minutes) after getting complete instructions*

Figure 19 shows that people who with less knowledge had similar results with group 1 under blanching condition A, the standard deviation increased (from 0.39 to 0.57) after getting complete instructions. However, in case of blanching condition B, the variation after getting complete instructions (0.47) reduced compared with the variation before complete instructions (0.50). The peak force mean value was also in line with the pervious blanching experiment.

The frying time used before and after complete instructions can explain the reason here. In case of blanching condition A, people used 2.67 minutes to fry before complete instruction, the frying time was significantly less than 4 minutes, the temperature of the oil changes during frying, and the frying time highly changes the peak force of French fries (Figure 15), so more variation can be observed under

blanching condition B.

7.5.3 Variation of colour results and knowledge of the participates

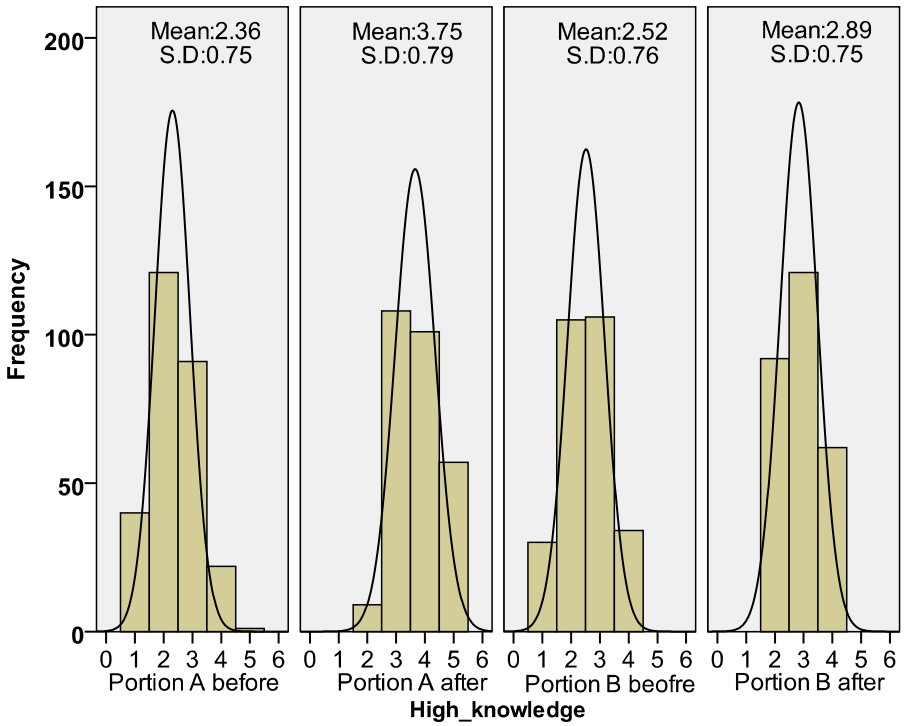

Figure 20: ***Colour*** *data of French fries before and after complete instructions frying by participates with* ***high knowledge (group 1)****. X-axis indicates the colour results after frying for portions with different blanching conditions. Y-axis indicates the frequency numbers of French fries. Mean is the mean value of colour results, SD means standard deviation.*

**Portion A before= blanching condition A(80℃, 10minutes) before getting complete instructions*
**Portion A after= blanching condition A(80℃, 10minutes) after getting complete instructions*
**Portion B before= blanching condition B(70℃, 30minutes) before getting complete instructions*
**Portion B after= blanching condition B(70℃, 30minutes) after getting complete instructions*

Participates in group 1 are considered to have high level of knowledge about French fries, however, no difference can be found in variation of colour before and after getting complete instructions under both two blanching conditions. For mean value of the colour, because more frying time was required in the complete instruction, darker colour was observed in both blanching conditions after 4 minutes of frying. Same conclusion can be drawn as the texture results here, higher knowledge can not reduce the variation of colour neither.

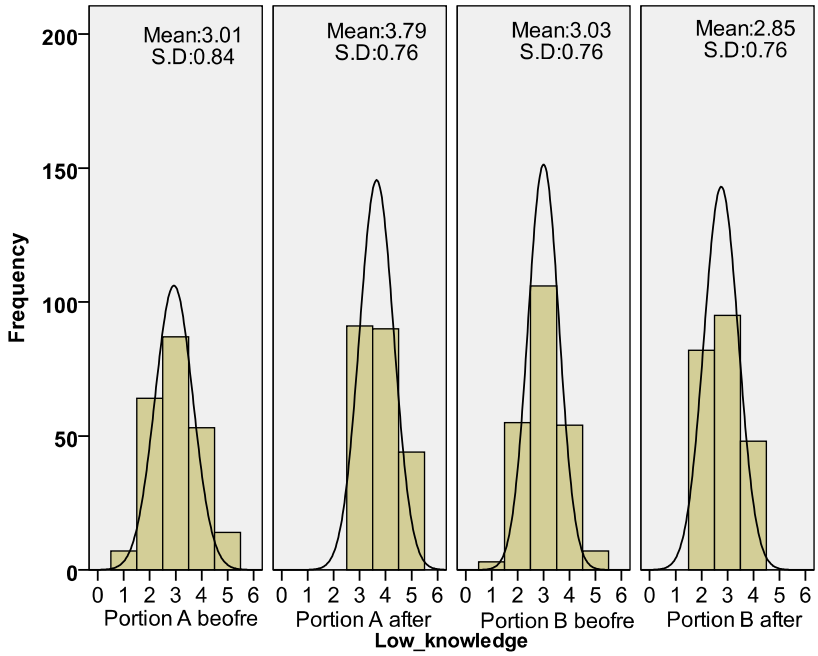

Figure 21: ***Colour*** *data of French fries before and after complete instructions frying by participates with* ***low knowledge (group 2)****. X-axis indicates the colour results after frying for portions with different blanching conditions. Y-axis indicates the frequency numbers of French fries. Mean is the mean value of colour results, SD means standard deviation.*

**Portion A before= blanching condition A(80℃, 10minutes) before getting complete instructions*
**Portion A after= blanching condition A(80℃, 10minutes) after getting complete instructions*
**Portion B before= blanching condition B(70℃, 30minutes) before getting complete instructions*
**Portion B after= blanching condition B(70℃, 30minutes) after getting complete instructions*

.

Participates in group 2 had less knowledge of French fries compared with group 1; however, they tended to fry French fries with significant less variation (0.76) of colour after instructions for blanching condition A. The variation was the same for blanching condition B before and after complete instructions.

To summarize, no matter participates with higher or lower knowledge, they tend to increase the variation after getting complete instructions under blanching condition A, this is due to the long frying time (4 minutes) after getting complete instructions. However, in case of blanching condition B, similar frying times (3.51 and 4 minutes) were used before and after getting complete instructions, people with higher knowledge still increased the variation of texture after complete instructions. With respect to colour, the variation before and after getting complete instructions were

very similar to each other (0.75 and 0.79 for blanching condition A, 0.76 and 0.75 for blanching condition B) for people who have high knowledge. Therefore, improve the knowledge of people is not an effective way to reduce the variation of texture and colour of French fries.

7.6 Effect of quality attitude of the participants on the variation of texture and colour of French fries

7.6.1 Quality attitude of the participates

The participants were asked whether they follow the instructions described on the food packages in the questionnaire. Four questions were asked about the quality attitude (Do you always read the instructions written on the package prior to frying? Can you fully understand the instructions written on the package? Do you believe that following the instructions, your food will be cooked properly? Do you always follow the instructions?), people who followed the instructions were considered higher quality attitude food handlers than the people who do not follow. The answer which related to high obedience gets 2 points, if the answer is opposite, 0 points can be gained and the answer in between get 1 point. So the full points for four questions are 8. Half of the participants had more than 6 points, and the others got 5 to 3 points. Group 1 is composed by participants who had more than 6 points (N=10), the others (N=10) are in group 2.

The standard deviations of the results of the participants were examined again with respect to the quality attitude of the participants.

7.6.2 Variation of texture results and quality attitude of the participates

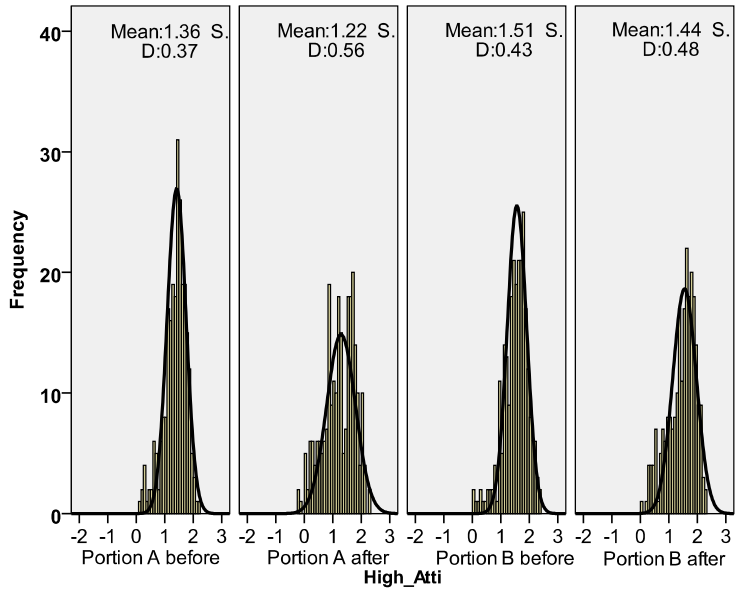

Figure 22: ***Peak force*** *data of French fries before and after complete instructions frying by participates with* ***high quality attitude*** *(**group 1**). X-axis indicates the log peak force results after frying for portions with different blanching conditions. Y-axis indicates the frequency numbers of French fries. Mean is the mean value of log peak force results, SD means standard deviation.*

**Portion A before= blanching condition A(80℃, 10minutes) before getting complete instructions*
**Portion A after= blanching condition A(80℃, 10minutes) after getting complete instructions*
**Portion B before= blanching condition B(70℃, 30minutes) before getting complete instructions*
**Portion B after= blanching condition B(70℃, 30minutes) after getting complete instructions*

Regarding people in group 1, it was observed that there was an increase in standard deviation after getting complete instructions under both blanching conditions (from 0.37 to 0.56 in blanching condition A, from 0.43 to 0.48 in blanching condition B). High attitude can not lead to less variation of texture after getting complete instructions.

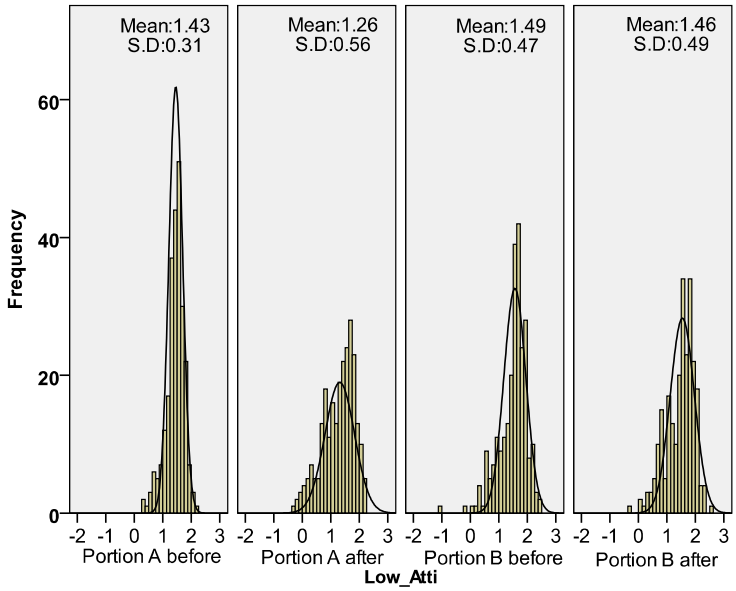

Figure 23: ***Peak force*** *data of French fries before and after complete instructions frying by participates with* ***low quality attitude (group 2)****. X-axis indicates the log peak force results after frying for portions with different blanching conditions. Y-axis indicates the frequency numbers of French fries. Mean is the mean value of log peak force results, SD means standard deviation.*

**Portion A before= blanching condition A(80℃, 10minutes) before getting complete instructions*
**Portion A after= blanching condition A(80℃, 10minutes) after getting complete instructions*
**Portion B before= blanching condition B(70℃, 30minutes) before getting complete instructions*
**Portion B after= blanching condition B(70℃, 30minutes) after getting complete instructions*

Concerning group 2 which people had lower quality attitude towards instructions, the standard deviation also increased after getting complete instructions under both blanching conditions. The standard deviation went to 0.56 and 0.49 from 0.31 and 0.47 respectively. People with low attitude also increased variation on texture of French fries.

7.6.3 Variation of colour results and quality attitude of the participates

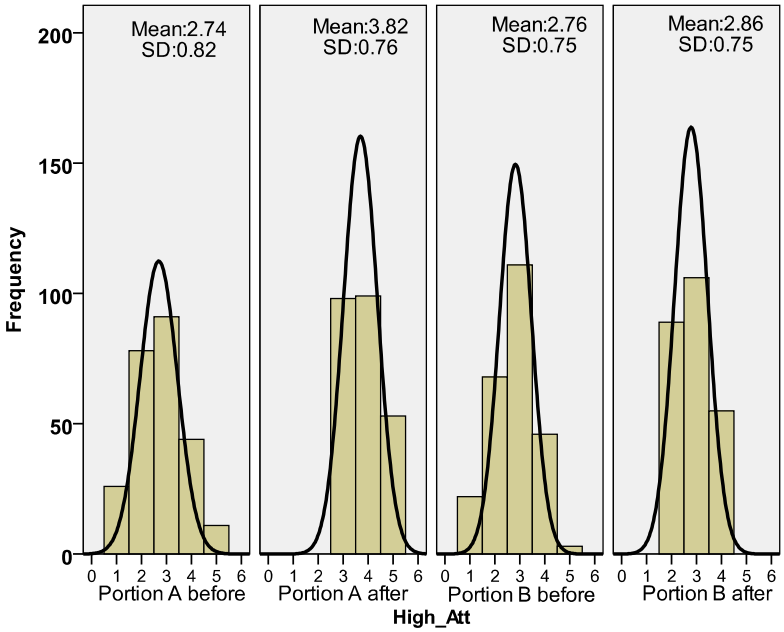

Figure 24: ***Colour*** *data of French fries before and after complete instructions frying by participates with* ***high quality attitude*** *(**group 1**). X-axis indicates the colour results after frying for portions with different blanching conditions. Y-axis indicates the frequency numbers of French fries. Mean is the mean value of colour results, SD means standard deviation.*

**Portion A before= blanching condition A(80℃, 10minutes) before getting complete instructions*
**Portion A after= blanching condition A(80℃, 10minutes) after getting complete instructions*
**Portion B before= blanching condition B(70℃, 30minutes) before getting complete instructions*
**Portion B after= blanching condition B(70℃, 30minutes) after getting complete instructions*

Regarding the people in group 1 who had high attitude, there was a clear effect of instructions on the standard deviations under blanching condition A before and after getting complete instructions. The standard deviation of colour for group 1 decreased after getting complete instructions under blanching condition A, the variation changes from 0.82 to 0.76. The standard variation did not change for blanching condition B before and after instructions.

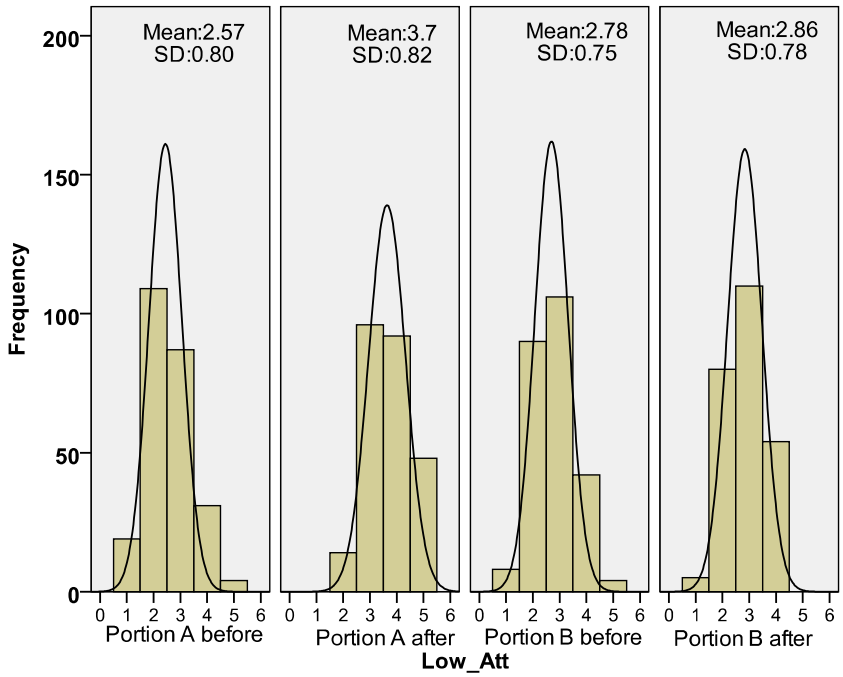

Figure 25: ***Colour*** *data of French fries before and after complete instructions frying by participates with* ***low quality attitude (group 2)****. X-axis indicates the colour results after frying for portions with different blanching conditions. Y-axis indicates the frequency numbers of French fries. Mean is the mean value of colour results, SD means standard deviation.*

**Portion A before= blanching condition A(80℃, 10minutes) before getting complete instructions*
**Portion A after= blanching condition A(80℃, 10minutes) after getting complete instructions*
**Portion B before= blanching condition B(70℃, 30minutes) before getting complete instructions*
**Portion B after= blanching condition B(70℃, 30minutes) after getting complete instructions*

Group 2 had different results compared with group 1, the variation even increased after instruction under blanching condition A (from 0.8 to 0.82) and blanching condition B (from 0.75 to 0.78).

To summarize, participates who high quality attitude points had only decreased the variation on colour after getting complete instructions, the texture variation increased after getting instructions. People in group 2 who do not care about the instructions on packages increased the variation of texture and colour after getting instructions. The variation of texture always increased after getting instructions under blanching condition A is due to the longer frying time, the effect of quality attitude can not be drawn here.

7.7 Conclusion of the effect of food handlers' frying behaviour on colour and texture of French fries

The variation of the texture all increased after getting complete instructions under blanching condition A, because the frying time was much longer (4 minutes) than the time used before complete instructions (2.67 minutes), variation increased during the frying step, so frying time played a bigger role on determining the variation here.

With regard to blanching condition B, the variation of texture and colour did not change before and after complete instructions in most situations, the effect of knowledge and attitude can not be drawn scientifically from the results.

To summarize, the hypothesis in chapter 6.3 (the variation of colour and texture will be reduced after participates getting more detailed instructions) is rejected, the variation of colour decreased after getting complete instructions under both blanching conditions (blanching condition A: from 0.95 to 0.79, blanching condition B, from 0.87 to 0.74), but the variation of texture increased in both blanching conditions, there main reason is due to the frying time, so the effect of complete instructions on variation on texture is unknown.

The other hypothesis in chapter 6.3 is that participates who have higher knowledge or higher quality attitude can lead to less variation after getting detail instructions. However, due to the wrong choice of frying time in complete instruction, the effect of knowledge and attitude can not be observed.

Chapter 8: Bottlenecks and solutions

8.1 Instruction

In this chapter, solutions which can deal with the bottlenecks will be introduced. Some mistakes have been made in the experiment design; several expected results can not be drawn after getting all the data, so the bottlenecks in this thesis are the points which need to be improved in the experiment design process.

8.2 Bottlenecks and solutions

The bottlenecks which need to improve in the experiment design are below:

Bottleneck 1: The minimum temperature used in the blanching condition was 60°C which can cause bacterial growth in potatoes.

According to Van Loon (2005), the minimum blanching temperature should be applied in practice is about 65 °C, otherwise spoilage due to bacterial growth may occur. Because of this, the blanching condition at 60°C was not considered as the frying condition in the following food handlers' frying experiment. In the food handlers' experiment, both blanching conditions which lead to the largest and smallest variation need to be selected, the blanching condition 80°C for 10 minutes (highest temperature shortest time) was the one with largest variation, and the blanching condition with lowest temperature and longest time (60°C, 30 minutes) has significant less variation, because the temperature (60°C) is too low for the real industry, the condition was rejected in the second food handler experiment.

Solution 1:

The experiment design can be improved if the temperature condition settings were: 65°C, 75°C and 85°C, then more data and results can be used in practice.

Bottleneck 2: The required frying time for participates in the complete instructions was 4 minutes which is too long.

Some conclusion can not be drawn in food handlers' frying experiment because the frying time choosing after complete instructions was too long (4 minutes), the average frying time for participates before getting complete instruction was 2.67 minutes, the longer frying time caused more variation after complete instructions, the effect of knowledge, attitude or the complete instructions on colour and texture can not be observed, the expected results were not shown after the experiment.

Solution 2:

The experiment can be improved if the required frying time in complete instruction is 3 minutes, then the effect of frying time on texture and colour can be reduced, and the effect food handlers' behviour on texture and colour might be observed.

Bottleneck 3: Only twenty participates were invited to the food handling experiment, some statistical results can not be drawn due to the small number of data.

Because of the limited time in the thesis making period, only twenty participates were invited to the food handlers' frying experiment, the number of data was too small for statistical analysis. In addition, most participates were the Wageningen students who were studying in food area, their knowledge about food was high compared with the other people.

Solution 3:

More participates are needed for the experiment (more than 40), invite people from different education background, with different ages can be more effective and reliable to get the experiment results.

Chapter 9: evaluation phase

9.1 Evaluate the solutions

Two experiments (technological and managerial) have been done by PhD student Ali Muhammad and me during the thesis writing period. The literature review, preparation of experiments and the experiments performance took us around 4 months' time, after the data analyzing, I have a clear overview to all the steps in the experiments and the theory behind it, and problems came out after searching more literature and data analyzing, some ideas in the experiment design can be improved, the bottlenecks in chapter 8.2 are the main problems exist in my research, all solutions are feasible and they are not difficult to be put into practice. If the problems can be solved, more scientific and useful research results can be found in French fries area.

9.2 Evaluate the research

After doing this French fries research project for half a year, I would like to evaluate and judge the present research in terms of validity, relevance and reliability.

Regarding to chapter 1 and 2, background- problem feeling- theory analysis- problem definition and hypothesis are quite valid since the background part comes up with the reason why the French fries project was chosen. The problem feeling gives the idea that colour and texture quality is very important to French fries, and food handlers' frying behaviour can influence these two attributes. After theory analyzing, blanching was found to be a critical process when making French fries, and food handlers' behaviour is influenced by several factors. Therefore, problem definition and hypothesis comes up, all these parts are well connected to each other. All the literature analyzing are from recently published articles which are reliable.

Regarding to chapter 3, the research model was designed according to articles which are published in scientific magazines and journals, and the model is relevant to theory

analysis as well as problem definition part.

Regarding to chapter 4 to 7, two experiments which lasted for almost four months were made, and it went very well. All the instruments and measurements used were reliable and relevant to the experimental design. All the results were consistent to each other, and they can be explained by published articles.

Concerning to bottlenecks and solutions, the bottlenecks were derived from the experiment process combined with published articles. All the solutions are practical and useful for the future research.

9.3 Evaluation of the researcher

Here I also would like to evaluate and judge myself as researcher. I am very satisfied from my six months' thesis writing experience in the Product design and Quality management group of Wageningen University. I found myself a very hardworking and conscientious person; I put a lot of effort in this research and two experiments. During the experimental period, I sometimes came to the lab in weekends, and I even worked for 5 days during Christmas holidays.

Actually the experimental work is very difficult for me, because my background is business administration, it was very hard for me to do a research related to chemical, and this is the first time for me to design a experiment, however, with the help of the PhD student Muhammad Ali and the supervision of Mrs. Pieternel Luning, Mr. Geoffrey Hagelaar, all the problems and questions were solved, I learned a lot from this research, especially in the research methodology part. This experience made me definitely a better and more experienced researcher.

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Appendix 1

Questionnaire

Date:

Number of Participant:

Please fill the questionnaire and circle or write down your answer.

1) Gender:

- Male
- Female

2) Age:

3) Nationality:

4) Major (Background):

5) How often do you consume French fries at home or elsewhere?

- More than once per week
- Once per month
- Never

6) How often do you fry French fries at home?

- More than once per week
- More than once per month
- Never

7) I always wash my hands prior to the preparation of food.

- I Agree
- I Disagree

8) I always check the expiration day of a product before I buy it.

- I Agree
- I Disagree

9) The quality of the oil remains the same after frying many times with the same oil.

- I Agree
- I Disagree

10) The fresh products (vegetables, meat, fish, etc) tend to get spoiled easier than the processed ones (processed cheese, canned food, etc).

- I Agree
- I Disagree

11) What is acrylamide?

- It is a probable human carcinogen composed in fried French fries.
- It has nothing to do with French fries.
- It is a health promoting compound formed in fried French fries.
- I do not know

12) What is Maillard reaction?

- It is a chemical reaction between an amino acid and a reducing sugar
- It has nothing to do with French fries.
- It is a health promoting process when frying French fries.

- I do not know

13) Do you always read the instructions written on the package prior to frying?

- I **always** read the instructions written on the package prior to frying
- **Only the first time** that I fried I read the instructions written on the package.
- I **never** read the instructions written on the package prior to frying.

14) When you read, do you fully understand the instructions written on the package?

- The instructions written on the package are **always clear** to me.
- **Sometimes it is difficult** for me to understand the instructions written on the package.
- I **never** understand the instructions written on the package.

15) Do you believe that following the instructions, your food will be cooked properly?

- I **am fully convinced** that following the instructions, my food will be cooked properly.
- **I believe** that the instructions are useful but I also use **my own judgment**.
- I **am not convinced** that following the instructions my food will be cooked properly, so I use **my own judgment**.

16) Do you always follow the instructions?

- I **always** follow **exactly** the instructions written on the package.
- **Sometimes** I follow the instructions written on the package.
- I **never** follow the instructions written on the package.