Effect of frying on physicochemical properties of chicken

A study on the effects of frying temperature and time on physiochemical properties of chicken nuggets, and its effect on moisture and oil content of jackfruit chips during conventional and microwave frying were investigated.

The results indicated that an increase in frying temperature leads to moisture content reduction. Oil content of chicken nuggets increased as frying time increased. Frying temperature significantly affected oil content of coating part but had no effect on the core part. L* value decreased and a* value increased with increase in frying temperature and time. The hardness also increased with frying temperature and time. Comparing between conventional and microwave frying, it was observed that microwave fried chicken nuggets had higher moisture content in coating part and lower moisture content in core part.

Frying temperature and time also significantly affected moisture and oil content of jackfruit chips. Microwave frying provided the lower moisture and oil content of fried jackfruit chips compared to conventional frying at the same frying conditions.

In addition, the sensory acceptability of both fried products was evaluated. Results showed that using different frying conditions did significantly affect (p <0. 05) all the sensory attributes. It was observed that conventional and microwave frying of chicken nuggets for 3 and 2 min, respectively at the same frying temperature (160°C) were the most preferred by panelists. For jackfruit chips, microwave frying at 160°C for 11 min and conventional frying at 180°C for 12 min produced significantly better overall acceptance. These results showed microwave frying required shorter frying time to obtain the same sensory quality of conventional fried product.

CHAPTER 1

INTRODUCTION

1. 1 General background

Frying is a popular process for cooking and preparation of foods. It not only provides unique characteristics to the fried products in terms of flavor, color and texture, but also makes food more palatable and desirable. The various types of food materials used to produce fried products include meats, grains, fruits and vegetables. Many kinds of fried product shapes and forms are available in the market. For example, chips, sticks, rings and nuggets. Thus, fried products have become a popular food consumed worldwide.

Deep frying is commonly process used for cooking in food industries, restaurants as well as household levels. A wide variety of the food market today consists of fried products from different materials including tubers, cereals, bananas, jackfruit, plantain, fish and chicken. Such products are obtained by atmospheric deep fat frying. Frying has been defined as the immersion of a food product in edible oil heated above the boiling point of water. The high temperature causes an evaporation of the water, which moves away from the food and through the surrounding oil. Oil is absorbed by food, replacing some of lost water. Oil absorption of the food is affected by many factors including frying conditions (temperature, time), pre-treatment of the food (such as blanching and pre-drying), physico-chemical characteristics of food, oil origin, chemical composition of oil and others.

Longer times and lower frying temperatures usually lead to higher final oil contents in fried food products (Moyano & Predreschi, 2006; Pedreschi & Moyano, 2005; Rossell, 2001).

Microwave frying is an alternative way to improve the quality of fried foods. Microwaves offer tremendous advantages in certain food processing operations. Especially in food dehydration, microwaves accelerate falling rate period, which consequently reduces drying time significantly. Oztop et al. (2007) reported the use of microwave frying provided lower oil uptake in potato strips. Products with similar qualities were obtained in microwave frying as compared to conventional deep-fat frying in a shorter time. Similarly, instant noodles fried using microwave oven was found to reduce oil content up to 8. 13% (Preechakul, 2008). Although microwave frying was found to reduce oil content, a study by Chen et al. (2009) showed microwave fried crust of fish nuggets did not have lower oil content compared to the conventional deep fat fried crusts. However, there are few studies about the usage of microwaves in deep-fat frying process.

Most of the research found in literature is related to conventional deep frying of foods and there are very few studies on the effect microwave frying on the moisture content, oil content, color, and texture. Therefore, in this study, chicken nugget and jackfruit were used as the samples to study the effect of frying conditions on the change of physiochemical properties during conventional and microwave frying.

1. 2 Objectives

The main objective of this study was to compare the effect of frying conditions on the physiochemical properties during conventional and microwave frying. The specific objectives were:

1. To compare the effect of frying temperature and time on physiochemical properties of chicken nuggets, and its effect on moisture and oil content of jackfruit chips during conventional and microwave frying.

2. To evaluate the sensory acceptability of conventional and microwave fried chicken nuggets and jackfruit chips.

CHAPTER 2

LITERATURE REVIEW

2. 1 Coated fried food products

Meat, poultry and seafood products are largely consumed worldwide for decades. The increased consumption of these products leads to faster development and innovation in food industry. The coated fried products are one of the most preferred foods since they provide a golden crust color and an enjoyable crispy texture of coated part while the core part remains moist and juicy. Today, coated food products are available in the market in various sizes and shapes such as chicken nuggets, chicken pops, fish sticks and calamari rings.

Coated food products consist of two main parts namely, the core part (inner layer) and coating part (outer layer). The core part can be made from a wide source of raw food materials such as chicken, pork, shrimp and fish, including fruits and vegetables. The coating part is usually made from batter and breading. Batter is defined as a liquid mixture comprised of water, flour, starch, and seasonings into which food products are dipped prior to cooking (Suderman, 1983). The main ingredients of batter formula are wheat flour and corn flour (Loewe, 1993). In addition, soy flour and rice flour, gums and leavening agents are also the important ingredients of batter (Dogan, Sahin &Sumnu, 2005; Fiszman and Salvador, 2003). Breading is defined as a dry mixture of flour, starch, and seasonings, coarse in nature, and applied to moistened or battered food products prior to cooking (Suderman, 1983). Application of batter and breading for coating the product provides the food more desirable by creating a desired crispy and crunchy texture and improving the appearance of fried product, resulting in a golden color and enhancing the taste.

The basic steps for coated food production in food industry are preparing of batter and breading, preparing of raw materials, coating products, cooking, freezing and packaging. After preparing the formulation of batter and breading, the prepared products are then coated and cooked. The coated products are normally cooked by deep frying. The range of oil temperature for frying is between 150°C-190°C. After frying, products are immediately frozen and then packed. The finished products are stored in freezer at -5°C to -10°C before distribution to the market. A schematic flow diagram of coated fried food production is shown in Figure 2. 1.

2. 2 Fried fruit and vegetable products

Fruits and vegetables serve as the main sources of vitamins and minerals, antioxidants, and dietary fiber for human diet. However, most fruits and vegetables contain more than 80% water, which are highly perishable food. Thus, processing of fruits and vegetables is an alternative way to extend shelf life and add value of these produces. Nowadays, frying is one popular method used to produce fruits and vegetables based snacks. Thus there are various types of fried fruit and vegetable products available in the markets.

The suitable fruits and vegetables used for frying are mainly composed of starch and have less water and sugar content. The ripe fruits with high sugar content are not recommended for frying because high temperature used for deep frying leads to fruits burn before it is completely fried. Examples of vegetables and fruits used are banana, papaya, durian, jackfruit, potato, sweet potato, taro, carrot, and pumpkin.

The basic steps for preparing fruits and vegetables before frying are washing, peeling, and cutting. Pretreatment is also applied before frying to improve finish product characteristic such as color, texture, and less oil content. Then frying is carried out at specific temperature and time. After that fried products are allowed to cool at room temperature before packaging. Figure 2. 2 shows basic steps for deep frying of fruits and vegetables.

2. 3 Quality aspects of fried products

The quality of finish fried product is an important factor that influences consumer acceptability. The main quality parameters of fried food product are appearance, color, flavor and texture including nutritional aspects.

The appearance and color of fried products is the first quality parameter, which influence consumer’s visual perception and acceptance of the fried product. There is also the association of color with sensory quality of the product (Pedreschi et al., 2006). Color is generally measured by Hunter Lab (L, a, and b) and CIE system (L*, a*, and b*). In case of coated fried products, the golden crust color was developed due to Maillard reaction and caramelization of sugars during frying (Albert et al., 2009). The golden color of crust layer is considered very attractive by consumers, and the dark color of overcook of fried product is also undesirable.

Crispiness is the most unique textural characteristic of fried product desired by consumers. Fried products can be soft or hard crispy texture depended on raw material and process conditions. Crispiness is a complex textural characteristic. It is also related with other sensorial attributes such as hardness, brittleness and crunchiness. Several methods were developed to measure the crispiness of fried product, but there was no the best method for measuring crispiness. However, many researchers (Dogen et al., 2005; Kita et al., 2007; Qiao et al., 2007; Silva et al., 2008; Chen et al, 2009) have used puncture test and shear test to describe and estimate textural attributes in fried foods based on the obtained texture profile.

Oil content is very important as nutritional aspect in fried product, since it is associated with health concerns. The fried food can absorb the oil up to 80% after frying. The high oil absorbed in fried food is unpleasant. Moreover, moisture content in fried product is also important because it has an influence on the texture desirability of the fried food. Thus, it is necessity to minimize moisture content of fried product to maintain the quality of the fried product. In addition, the amount of fat absorbed can be influenced by moisture content due to the oil absorption as a replacement of moisture loss from the food.

Acrylamide content is one nutritional aspect of fried product because it is neurotoxic and classified as a probable human carcinogen by the International Agency for Research on Cancer (Barutcu et al., 2009 referred to IARC, 1994). The formation of acrylamide during frying is a complex system. However, the main cause is the Maillard reaction occurring during frying process. Frying temperature and time are also the important factors which influence on acrylamide content in fried product (Mottram et al., 2002; Gokmen et al., 2006). Recently, the alternative frying processes was used to reduce acrylamide content. Granda and Moreira (2005) showed that vacuum fried potato chips had lower acrylamide content than conventional (atmospheric) fried potato chips. As the same result in microwave frying, the lower acrylamide content was observed in microwave fried potato strips compared to those fried in conventional deep fryer (Sahin et al., 2007).

2. 4 Deep frying

Deep frying is one of the most major operations for cooking and preparing of food. It involves simultaneous heat and mass transfer (Hubbard & Farkas, 1999). When foods are immersed in hot oil, the surface of food is heated by convective heat transfer from surrounding oil, and then conductive heat transfer occurs inside food. Both of these cause the water to evaporate and move away from food surface to the oil, and cause the oil to penetrate into the food, resulting in the moisture loss and oil uptake in fried food product. The loss of some food nutrients and the leaching of liquefied food components from the food also occur during frying process (Blumenthal, 1991).

Deep frying is not only used in food industry, but also in food restaurants and household levels. The main purpose of frying is to develop the characteristics of fried products which are color, flavor and aroma, and crust texture (Fellow, 1988). Generally, foods are deep fried by immersing in hot oil at the temperature range of 130-190°C for a specific time. The commonly products from deep frying are potato chips, banana chips, tortilla chips, fish sticks and fried chicken products. However, the quality characteristics of fried products can be affected by many factors such as process conditions (temperature, time), pretreatment, oil types, food properties, and coating.

2. 5 Factors affecting the quality of fried products

2. 5. 1 Pretreatment

Several researchers have studied on pretreatment prior to frying process and its effect on physical and chemical properties of fried products. The main purpose of this process is to improve the quality of fried products. In general, blanching, freezing, pre-drying and osmotic dehydration are often used as a pretreatment.

Taiwo and Baik (2007) evaluated the effect of different pretreatments (blanching, freezing, air drying and NaCl soaking) prior to deep frying on physical properties of fried sweet potatoes. They reported that pretreatment of sweet potatoes by blanching, air drying and NaCl soaking provides the fried samples less sticky compared to frozen and control samples.

According to Bunger et al. (2003), they used sodium chloride for soaking treatment after blanching to reduce oil uptake in fried potato strips. Their results suggested that the suitable condition (3% NaCl solution for 50 min) showed significant oil reduction and increased texture parameters in the fried product. Moreover, it was found that sodium chloride soaking treatment before frying showed greater decrease in the amount of acrylamide content in potato chips (Pedreschi et al., 2007).

It has been reported that pre-drying of blanched potato slices prior to frying significantly reduced the oil content and increased the crispiness of final fried potato chips (Pedreschi and Moyano, 2005). A similar result for oil content in fried ribbon snack made from chickpea flour that was pre-dried. The less oil content of fried ribbon snack was observed in pre-dried samples compared to those without pre-drying. (Debnatha et al., 2003). Recently, the usage of microwave as pre-drying treatment before frying coated chicken nuggets has been studied (Adedeji et al., 2009; Ngadi et al., 2009). It was shown that microwave pretreated chicken nuggets had lower oil content after frying compared to the untreated chicken nuggets.

2. 5. 2 Type of frying medium

Various types of fats and oils are used for frying such as hydrogenated vegetable, oils vegetable oils and animal oils, including margarines and shortenings. The vegetable oils are commonly used for frying include palm, soybean, corn, cottonseed, olive, canola, safflower and sunflower oil.

Kita et al. (2007) found that the amount of oil absorbed by potato crisps was influenced by frying oil used. It was found frying oil strongly affected texture of potato crisps, particular at highest frying temperature. However, it has been found that frying oil had no significant effect on oil uptake in fried potato strips (Rimac-Brncic et al., 2004). The effect of frying oil on color parameters of potato strips during deep fat frying was investigated by Krokida et al. (2001). They showed that the use of different frying oils, namely refined cotton seed oil, hydrogenated cotton seed oil and a mixture of those two oils had no effect on the color of potato strips during deep fat frying.

2. 5. 3 Frying temperature and time

Frying temperature and time are the main factors influencing the characteristics of fried food such as color, texture and oil content. The following studies have been reported the effect of frying temperature and time.

Krokida et al. (2000) studied the effect of different frying temperatures (150, 170 and 190°C) on moisture loss and oil uptake during deep frying of french fries and found that moisture content of french fries decreased while the oil content increased with increasing of frying temperature. Similarly, Kita et al. (2007) suggested that the increase in frying temperature led to lower oil uptake of potato crisps. In contrast with oil uptake of cassava chips, the lower frying temperature (140°C) resulted in a lower oil uptake at the same frying time compared with cassava chips fried at 160°C (Vitrac et al., 2002). As the same results were found by Moreira et al. (1995), the lower oil absorbed in tortilla chips was found when frying at low temperature (155°C) compared to those fried at high temperature (190°C).

The color change of french fries as influenced by frying temperature has been investigated by Krokida et al. (2001). They found that the color of fried potatoes was significantly affected by frying temperature as a function of time. A decrease in lightness of fried potatoes was observed when frying temperature increased, whereas the redness and yellowness of fried potatoes increased during deep frying. Similar results were observed for color change of fried tofu (Baik and Mittal, 2003).

Frying time also affected the color development of product during frying. In case of fried plantain chips, a decrease in lightness (L*) and yellowness (b*) and increase in redness (a*) were observed when frying time increased from 5 to 10 minutes (Ikoko and Kuri, 2007).

2. 5. 4 Film and edible coating

The application of film and edible coating in fried products has been studied by several researchers. Balasubramaniam et al. (1997) reported that 17. 9% and 33. 7% reduction in oil content in the surface layer and the core of chicken nuggets were observed when edible HPMC coating was applied. It was also reported that potato balls coated with edible film (CZ, MC and HPMC) reduced moisture loss and fat uptake during frying compared to uncoated potato balls (Mallikarjunan et al., 1997). Rayner et al. (2000) demonstrated that the oil content in doughnuts can be reduced by coating with soy protein film. The use of hydrocolloids to decrease oil absorption in banana chips was investigated by Singthong and Thongkaew (2009). They found that pectin was the most effective hydrocolloid for low fat fried banana chip production. In addition, soy and rice flour applied to batter formulation have been reported for reducing oil uptake in battered products (Llorca et al., 2003; Dogan et al., 2005).

2. 6 The use of microwave as an alternative frying process

Microwave heating can be used in various food processes such as baking, drying, and thawing. The major advantages of microwave processing are short processing time and energy efficiency. For example in drying technology, the use of microwave to dry parsley flakes provided good quality of dried parsley, and greatly reduced the drying time (Soysal, 2004). It is low energy consumption and reduces drying time of pumpkin when microwave was combined with hot air drying (Alibas, 2007). Thus, using microwaves for frying of foods to improve the quality of fried products can be a good alternative to conventional frying.

Microwaves are the portion of the electromagnetic spectrum with wavelengths from 1 mm to 1 m with corresponding frequencies between 300 MHz and 300 GHz. The two most commonly used frequencies in food technology applications are 0. 915 and 2. 45 GHz. When microwaves interact with materials, their energy content is manifested as heat due to the appearance of several energy conversion mechanisms. The most important when referring to a food material and microwave frequencies are the ionic conduction and the dipolar rotation. Both are based on the influence of the electric fields on charge units, which promotes conversion of electric energy into kinetic energy and this into heat (Fito et al., 2001).

2. 7 Microwave applications in food frying

Recently, Cheng and Peng (2006) developed the combined microwave/frying apparatus for food frying, which provides a beneficial in terms of short frying time and uniform heating comparing a typical frying device. A frying device, a microwave-generating device, and a supporting member are included in this apparatus.

Generally, microwave frying was achieved by heating oil at room temperature to the specific frying temperature, after that food is placed in heated oil and frying is carried out at the desired power level for a specified frying time.

Sahin et al. (2007) investigated the effects of processing conditions and oil types on quality of microwave fried potatoes. They found that the increase in microwave power increased the moisture loss during frying for all of the oil types. The quality of microwave fried potatoes in terms of color and texture was similar to conventionally fried potatoes. However, microwave fried potatoes lost more moisture as compared with conventionally fried ones.

Sahin et al. (2007) also investigated the effects of osmotic treatment on acrylamide content of microwave-fried potatoes. They reported osmotic pretreatment by using salt solution reduced the acrylamide content of microwave and conventionally fried potatoes. Although the moisture content of microwave fried potatoes (at 400 W for 1 min) were comparable with conventionally fried potatoes (at 170°C for 4. 5 min), the acrylamide content of microwave fried potatoes were significantly lower than that of conventionally fried potatoes. Short processing time was the reason for this result. However, when osmotic dehydration was applied, the difference between acrylamide contents of microwave- and conventionally fried potatoes was found insignificant.

In addition, Barutcu et al. (2009) reported that the use of microwave for frying chicken which coating different types of flours provided lower acrylamide content and lighter color as compared to those fried conventionally for 5 min. This highest reduction in acrylamide level was 34. 5% for rice flour containing batter.

Preechakul (2008) studied the effect of frying conditions on the oil content of microwave and deep fried instant noodles. The results showed that oil content of microwave fried instant noodles was reduced 6. 91- 8. 13% compared with deep fried instant noodles at the same frying condition. In contrast, Chen et al. reported that the higher oil content in fish nugget crusts was obtained when samples were fried by microwave frying method compared to conventional deep frying. However, they reported that microwave frying can reduce frying time and the same crusts qualities of final fried fish nugget were obtained compared to conventional frying.

CHAPTER 3

MATERIALS AND METHODS

3. 1 Materials

Frozen chicken nuggets (Fig. 3. 1) were purchased from a local manufacture (Talad Tai). The coating layer thickness was approximately 0. 1 cm, it comprised of wheat flour, wheat crumbs, spices, guar gum, salt and corn starch, while the core part basically composed of chicken breast. The frozen samples brought to refrigerator temperature (4 °C) for 24 h before frying. Chicken nuggets with similar size and shape were selected as test samples for the experiment.

Mature jackfruits purchased from a local market (Talad Tai) were used for the experiments. The fruit was peeled and the bulbs (edible portion) were removed from rind. The seed was removed by manually cut using stainless steel knife and the bulb was cut into quarter (Fig 3. 2).

3. 2 Frying

Chicken nuggets and jackfruit samples were tested in the same equipment for conventional and microwave frying.

Conventional deep frying was performed to the required temperature of frying (140, 160 and 180 °C) in stainless steel deep fryer (Fig 3. 3) containing 2 L of refined palm oil. Two pieces of samples were then fried for the interval of time. After frying, the sample was immediately removed from fryer and hold in a stainless steel grid to allow the sample cool to room temperature before further analysis.

For microwave frying, 2 L of refined palm oil was heated to temperature which was higher than the required temperature (140, 160 and 180 °C) about 5°C in order to prevent temperature decreased while the sample was placed in microwave. Then, two pieces of sample was placed in hot oil and fried for specific times. After frying, the sample was immediately removed and hold in a stainless steel grid to allow the sample cool to room temperature before further analysis. Figure 3. 4 shows experimental set up for microwave frying and schematic diagram of experimental microwave frying.

3. 3 Quality evaluation of fried samples

3. 3. 1 Moisture content

Approximately 5 g of each portion of sample were weighed, and then dried to a constant weight in hot air oven. Drying period was 24 h at a temperature of 105° C. The samples were placed in a desiccator to cool down, then weighed, and the moisture was determined by gravimetric method and was reported on a dry weight basis.

3. 3. 2 Oil content

Fat extraction and analysis were performed according to the AOAC standard procedure (AOAC, 2000), using the Soxhlet method. The dried samples were ground uniformly and two grams of grounded samples were placed in tube of soxtec extraction. The oil was extracted using petroleum ether. The oil content was computed on dry weight basis for each sample as the ratio of mass of oil extracted to mass of dried sample.

3. 3. 3 Color determination

The color of the fried chicken samples was measured using a Minolta Color Reader (CR-10, Minolta, Osaka, Japan). CIE L*, a*, b* color scale was used for color measurements. Triplicate readings were carried out at room temperature at three different locations of each sample, and mean value was recorded.

3. 3. 4 Texture analysis

Texture analyzer was used to determine the hardness of fried chicken nuggets. A puncture test using a 6 mm cylindrical probe and a 50 kg load cell was used. The probe was allowed to penetrate throughout the thickness of the chicken nuggets at a speed 300 mm/min and the force values were recorded at a rate of five reading per second. All samples were tested within 15 min after frying. The maximum force values at first peak were recorded for each sample in both atmospheric and microwave fried nuggets.

The texture of jackfruit chips was measured by texture analyzer with five blades Kramer shear probe. The maximum force required was chosen to represent the hardness of jackfruit chips.

3. 3. 5 Sensory evaluation

The fried chicken nuggets and jackfruit were prepared according to process conditions. The fried samples were evaluated by 15 panelists. Five sensory attributes namely appearance, color, crispiness, juiciness and overall acceptance for chicken nuggets and five sensory attributes namely appearance, color, texture, flavor and overall acceptance for jackfruit chips were evaluated on a nine-point hedonic scale. Numerical values were assigned to each attribute on a 9-point scale in which one represents ‘ dislike extremely’ and nine represents ‘ like extremely’.

3. 6 Statistical analysis

Statistical analysis was performed using SPSS software for Windows, v. 11. 5. The obtained results were evaluated by analysis of variance (ANOVA). Mean differences were tested for significance by using Duncan's New Multiple range test (DMRT) at a significance level of 0. 05.

CHAPTER 4

RESULTS AND DISCUSSION

4. 1 Effect of frying temperature and time on physiochemical properties of chicken nuggets during conventional and microwave frying

Chicken nuggets were fried at different frying temperatures (140, 160 and 180°C) and times (1, 2, 3 and 4 minutes) to examine the effect of frying conditions on physio-chemical properties which are moisture and oil content, color and texture. The separated coat and core parts of chicken nuggets were analyzed for moisture and oil content.

4. 1. 1 Moisture content

The initial moisture content in coating and core parts of chicken nuggets was in range of 42. 1-42. 6% and 61. 1-61. 4% wet basis, respectively. It was found that moisture content in coating and core parts of chicken nuggets decreased with increasing in frying temperature and time (Table 4. 1 and 4. 2). Similar trend was observed for other fried food products (Krokida et al., 2001; Dogan et al., 2005; Rahman & Uddin, 2008; Maneerote et al., 2009; Adedeji et al., 2009). The statistical analysis showed that frying temperature and time significantly affected moisture content in both parts of conventional and microwave fried chicken nuggets. It was observed that coating part of microwave fried chicken nuggets had higher moisture content as compared to conventional fried chicken nuggets. In contrast, the lower moisture content in core part was found in microwave fried chicken nuggets compared to conventional fried chicken nuggets.

The obtained results were also observed that the moisture content in core part of chicken nugget decreased with frying time at a lower rate than the moisture content of coating part. The low rate of moisture loss might be due to the protective coating provided by outer layer surrounding the core. The similar trends were reported by Ngadi et al. (2006) and Adedeji et al. (2009).

4. 1. 2 Oil content

The initial oil content in coating parts of raw chicken nuggets was ranged from 33. 1 to 32. 7% dry basis. After frying, the oil content in coating parts of chicken nuggets was in range of 34. 4 – 37. 5% dry basis.

Oil content in coating parts of chicken nuggets was found to increase with increase in frying time as shown in Table 4. 3. The statistical analysis showed that frying temperature and time significantly affected oil content in coating parts of conventional and microwave fried chicken nuggets ($p < 0.05$). However, there was no significant different between oil content in coating parts of chicken nuggets fried at 3 and 4 min in both of frying method. It was found that the coating parts of microwave fried chicken nuggets had lower oil content compared to conventional fried chicken nuggets.

Table 4. 3 Oil content (g/100g dry basis) in coating part of chicken nuggets during conventional and microwave frying at different frying temperatures and times.

The oil contents in core parts of raw chicken nuggets were found between 25. 9-26. 5% dry basis and the core after frying ranged between 26. 9-28. 3% dry basis.

Table 4. 4 shows the oil contents in core parts of chicken nuggets during atmospheric and microwave frying at different frying conditions. For conventional frying, oil contents in core parts were significant affected by frying time. The oil content in core parts of chicken nuggets at frying temperature of 140 °C was slightly higher than at 160 and 180 °C as shown in Table 4. 4. However, frying temperature had no significant ($p > 0.05$) effect on oil content in core part. Similar results were obtained in microw