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SUPERHEATED STEAM AS PRETREATMENT TO REDUCE OIL UPTAKE DURING DEEP FRYING OF CHICKEN NUGGETS

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Abstract

To reduce oil uptake during deep frying, chicken nuggets were pretreated with superheated steam (SHS) at 110 and 140°C for 3 and 5 min prior to deep frying. The SHS gauge pressure (5 kPa) and steam flow rate (11.23 kg/h) were kept constant in all pretreatments. After the steam treatment, nuggets were cooled and fried at 160°C for a period of 50-100 s, where the frying time was a function of the pretreatment conditions. Control samples were fried in fresh sunflower oil at 160°C for 3 min. Absorbed oil by nuggets was determined by the extraction with petroleum ether following a standard procedure. Also, color crust and texture were measured. Crust of control nuggets resulted in 24.0% w.b. oil content, which was greater than the oil absorbed by crust in the pretreated with SHS nuggets ($p<0.05$). Higher oil uptake was measured when higher steam temperature was applied. It was probably related to a formation of a larger pore size in the SHS treated nuggets. The lowest oil content in crust (7.3%, w.b.) was obtained for nuggets pretreated with SHS at 110°C for 5 min. Crust

texture was not affected by the SHS pretreatment. However, color of pretreated samples had lighter appearance than control samples.

Introduction

Frying is one of the oldest processes used in preparation of foods. In many countries, fried food is preferable because of its desirable physical sensory characteristics. In deep-fat frying, food is fully immersed in hot liquefied fat or oil. Such a process retains flavor and juices from food in the crisp crust formed in the fried surface (Moreira et al., 1999). Typical examples of commonly deep-fat fried products available on the market are: potato chips, tortilla chips, bakery products (donuts, pies), meats and seafoods. These convenient foods are produced by large companies specialized in deep-fat frying and high quality requirements in frying parameters are of importance to these companies.

It is known that cardiovascular problems and obesity are related to a high fat diet. Therefore, there is a consumer-driven tendency to avoid or at least to reduce the consumption of high fat/oil content products. To lower the oil content in fried products, new processes or combination of processes have been developed, but to reach the similar (with respect to fried products only) sensory and physical characteristics is still a challenge. Garayo and Moreira (2002) studied the deep-fat frying of potato chips under vacuum, getting lower oil absorption, better texture and color in comparison to chips fried under atmospheric pressure. To reduce oil uptake by fried products, Lloyd et al. (2004) combined frying with radiant or oven heating as the finishing step. They obtained more acceptable color of the final product with a sensory evaluation being no different than the product processed only by frying.

Superheated steam (SHS) impingement has been used to dry and bake foods without oil. Moreira et al. (1999) used SHS impingement to process tostadas and they observed that brittleness of tostadas was affected by SHS parameters, therefore, it was suggested that frying should follow the SHS frying step. Processing food with SHS is a technique with numerous advantages, such as reduced environmental impact, improved drying efficiency, and improved product quality (Tang et al., 2000). Application of SHS to foods designated for deep-fat frying such as tortilla chips and potato chips has been explored by Li et al. (1998) and Moreira et al. (1999), respectively. Both research groups concluded that the use of SHS resulted in reduced final oil content and promoted a desirable crunchy texture in fried products.

Thus, the objective of this study was to compare the final moisture content, oil uptake and the quality attributes (color, texture, density thermal conductivity) of deep-fat fried chicken nuggets with those pretreated with SHS prior to frying.

Methodology

Sample preparation

Fresh Granny`s boneless and skinless chicken breasts were purchased at a local grocery store in Winnipeg, Manitoba. The chicken breasts were cut into small strips (5 cm long, 3 cm wide and 1 cm thick). Individual pieces were soaked for 3 min in two-egg batter formulated with 0.5 g of salt and then drained for 5 s. Next, the battered pieces were placed on a layer of bread crumbs for 5 s on each side. Finally, the battered and breaded pieces were placed on a sheet of aluminum foil waiting to be deep-fat fried.

Frying process

An electric kitchen deep-fryer (Model 35015C, Proctor-Silex, Picton, ON) was used in deep-fat frying experiments. The frying pot was filled with 2 L of sunflower oil 100% pure. The ratio between the chicken nuggets (breaded samples) and oil was maintained at 1/12 allowing 10 nuggets to be fried at the same time. The breaded chicken samples were fried at 160°C for 3 min and served as control. Then, they were drained in a frying basket from excess oil for 30 s and placed on paper towel for 1 minute to absorb excess oil from the surface of the samples, and then the pieces were cooled at room temperature on aluminum foil for 20 min. The fried sample nuggets were stored in plastic bags till further analysis.

Combination of super heated steam (SHS) pre-treatment and frying

A superheated steam (SHS) chamber developed at the Biosystems Engineering Department, University of Manitoba (Pronyk et al., 2008) was employed for the pretreatment of chicken nuggets. One chicken nugget at a time (non-breaded or breaded) was placed in the SHS chamber in a mesh cell with the No.12 openings Two temperatures of SHS (110 and 140°C) were used in the pretreatment experiments with the SHS exposure time of 3 and 5 min. The distance between the steam injector and the sample was 15 cm. The SHS gauge pressure (5 kPa) and the SHS flow rate (11.2 ±0.2 kg/h) were kept constant in all pretreatments. After the steam treatment, the nuggets were cooled at room temperature for 6 min and stored in plastic bags till frying. The pre-treated nuggets were deep-fat fried in sunflower oil at 160°C for a period of 50-100 s, where the frying time was a function of the pretreatment conditions (Table 1). After frying, samples were drained, cooled and stored under the same conditions as non-breaded samples.

Table 1
Conditions used in combined SHS and deep-fat frying of chicken nuggets in our studies.

Variable	Conditions				
	Control	1	2	3	4
Steam temperature (°C)	-	110	110	140	140
SHS treatment time (min)	-	3	5	3	5
Frying time at 160°C (s)	180	100	60	70	50

Temperature measurements

Temperature history of the nuggets during SHS treatment and deep-fat frying was recorded with type J thermocouples. A calibrated thermocouple was inserted in the geometric centre of a sample nugget. The temperature was recorded every 5 s by a data acquisition system (Agilent Model 34970A, Agilent Technologies, Loveland, CO)

Moisture and oil contents analysis

Crust and core of the chicken nuggets were analyzed separately. Therefore, crust was removed from the individual nuggets. Moisture content was determined by method 7.003 (AOAC, 1995), whereas oil content was quantified by 78 min extraction with petroleum ether using a Soxtec system (Model 2050, Foss Analytical, Hilleroed, Denmark).

Quality attributes determination

The texture of fried nuggets was measured by a puncture test using the Texture Analyzer (Model TA-XT2, Texture Technologies, Corp., Scardale, NY). The 2 mm diameter probe was allowed to penetrate 15% of the sample thickness at a velocity of 5 mm/s.

Crust color was measured at two spots on each nugget using a colorimeter (Model CR-400, Minolta Corp., Ramsey, NJ). The color values were expressed in the L, a, b Hunter scale.

Physical properties determination

Apparent density of nuggets was determined based on mass of a single nugget and its volume. The volume of nuggets was measured with the displaced method using canola seeds as the measuring medium. The volume displacement apparatus was calibrated with metal spheres of known volume.

Thermal conductivity of nuggets was measured with a Thermal Properties Analyzer (Model KY-2, Decagon Devices, Inc., Pullman WA) where the fine probe was inserted into three nuggets.

Statistical analysis

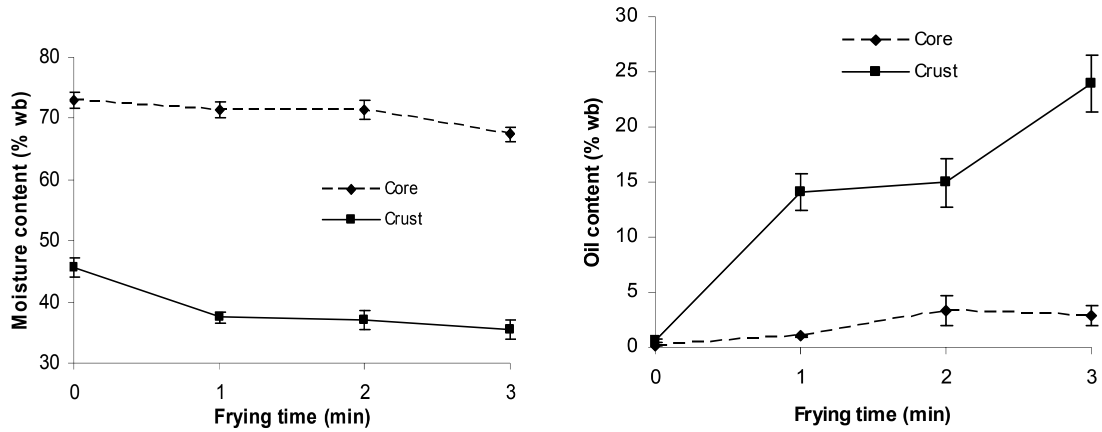
All experiments were done in triplicate. The obtained data were subjected to the analysis of variance (ANOVA), and means were separated using Tukey´s method (Minitab Release 14, Minitab Inc., State Collage, PA) at a significance level of 0.05.

Results and discussion

Moisture loss and oil gain during deep-fat frying

Core moisture content of nuggets decreased slowly during their deep-fat frying, diminishing from 72.9% (w.b.) to 67.4%. Similar trend was reported by Vélez-Ruiz et al. (2002) for frying of chicken strips. Moisture content of the crust of the nuggets was reduced from 45.7% to 35.5% (Fig 1a). In the first two minutes of frying, the oil content of the nuggets core increased and then it reached a plateau at 2.5% (Fig. 1b). This characteristic behavior was reported by Balasubramanian (1995) during deep-fat frying of nuggets with edible film, and was attributed to the saturation phenomenon of capillaries. Oil content of nuggets' crust increased quickly during the first minute of frying, and at the 3rd minute it reached 24.0%.

Thus, mass transfer (both moisture loss and oil gain) during the deep-fat frying of nuggets occurred mainly in the crust, because of the type of ingredients used in batter (fresh eggs containing water), and bread crumbs (with the capacity to absorb oil).



(a) (b)

Fig. 1. (a) Moisture loss and (b) oil gain during deep-fat frying of chicken nuggets at 160°C

Moisture and oil content of SHS pre-treated nuggets

Moisture and oil contents in the fried nuggets were affected by the SHS treatment ($p<0.05$). For all the SHS conditions, a higher moisture content for both the core and the crust were measured with respect to the non-treated nuggets (Table 2).That increase in moisture in the core was in the range of 1.7 to 3.7% w.b. for 110 °C SHS and 0.9 to 3.5% w.b. for 140 °C steam treatment. For the same two SHS temperatures of 110 and 140 °C, the moisture increase in the crust was in the range between 13.5 -18.8% w.b. and 7.0 -13.5% w.b., respectively. Higher final moisture levels were attributed to the initial condensation of steam on a sample surface after placing them in the SHS chamber.

On the other hand, and as a positive result, lower oil contents were measured in all the pre-treated nuggets. The SHS temperature affected the oil content in fried nuggets, giving a higher oil content in nuggets pre-treated with SHS at 140°C (Table 2, conditions 3 & 4) in comparison to those pre-treated at 110°C (conditions 1 & 2) giving the decrease in oil uptake by 2.5% w.b. The higher processing temperature of 140°C probably caused the expansion of capillaries resulting in higher oil absorption capacity.

The lowest crust oil content was measured when nuggets were pretreated with SSH at 110°C for 5 min, reaching only 7.3% w.b. in comparison to 24.0% w.b. for non-treated nuggets. That means a reduction in oil absorption by 16.7% w.b. or 70 percentage points.

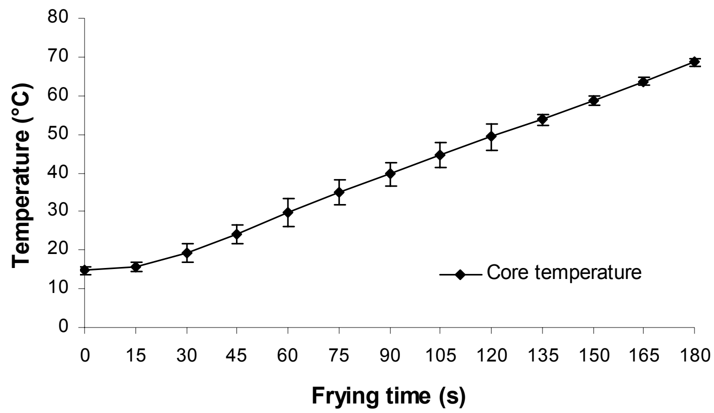
Table 2
Moisture and oil content in non-treated and SSH pre-treated nuggets after deep-fat frying

Conditions	Final moisture content (% w.b.)		Final oil content (% w.b.)	
	Core	Crust	Core	Crust
Control	67.4 ± 1.2^{a}	37.4 ± 2.6^{a}	2.9 ± 0.9^{a}	24.0 ± 2.6^{a}
1	69.1 ± 0.3^{a}	50.9 ± 0.9^{b}	0.3 ± 0.1^{b}	11.0 ± 0.0^{b}
2	71.1 ± 0.0^{b}	56.2 ± 1.2^{c}	0.4 ± 0.2^{b}	7.3 ± 1.6^{b}
3	70.9 ± 0.1^{ab}	44.4 ± 0.5^{d}	1.2 ± 0.3^{ab}	18.1 ± 0.2^{c}
4	68.3 ± 0.4^{a}	50.9 ± 1.4^{b}	3.2 ± 1.6^{a}	16.1 ± 0.6^{c}

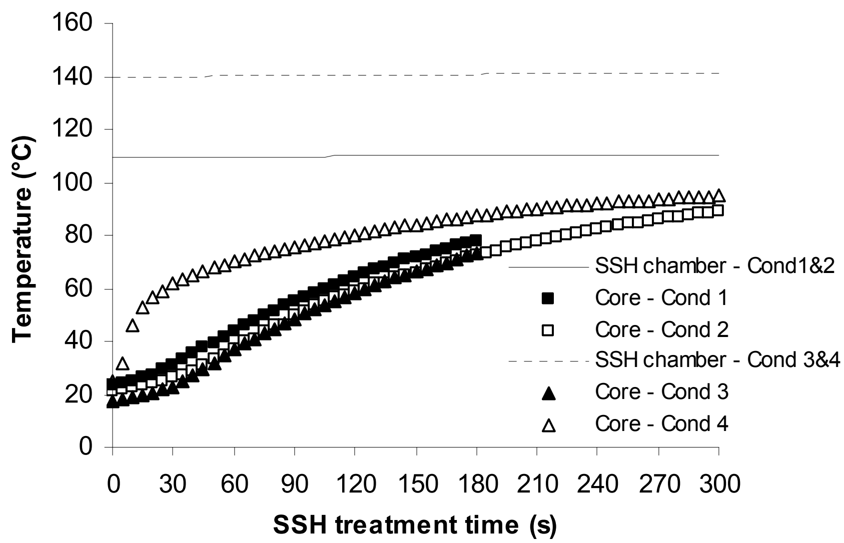
Means with the same letter indicate no significant difference ($p>0.05$)

Temperature profiles during deep-fat frying and SSH treatment

The temperature in the geometric centre (core temperature) of the control samples reached almost 70°C during the deep-fat frying (Fig. 2a). In all samples that were treated with SS, the core temperature exceeded 70°C at the end of the pre-treatment (Fig. 2b). That means that nuggets were cooked after the SHS treatment.



(a)



(b)

Fig. 2. Temperature profile measured during (a) deep-fat frying of chicken nuggets (control) and (b) the SHS treatment with conditions (Cond) 1 to 4. The label "Core" indicates the temperature in the geometric centre of the samples.

Comparison of quality and physical properties between non-treated and SHS treated chicken nuggets

The SHS treatment time had an effect on the texture, as lower force penetration was measured for pretreated nuggets for 3 min in comparison to control ($p<0.05$). The 5 min

SHS treatment of chicken nuggets gave the texture that was similar to the non-treated nuggets. The shorter 3 min frying time gave the same texture as 5 min frying.(Fig.3). Thus, 5 min SHS treatment (for both temperatures; 110 and 140°C) can be used as good pretreatment to get similar texture in the crust of chicken nuggets.

Also, the SHS treatment affected the crust color (Table 3) of fried nuggets ($p<0.05$). No treated nuggets had lower “L” values and higher “a” values with respect to control. It means lighter appearance and less reddish color. The SHS pretreatments at 110°C for 5 min and pretreatments at 140°C resulted in “b” values similar to non-treated with SHS samples.

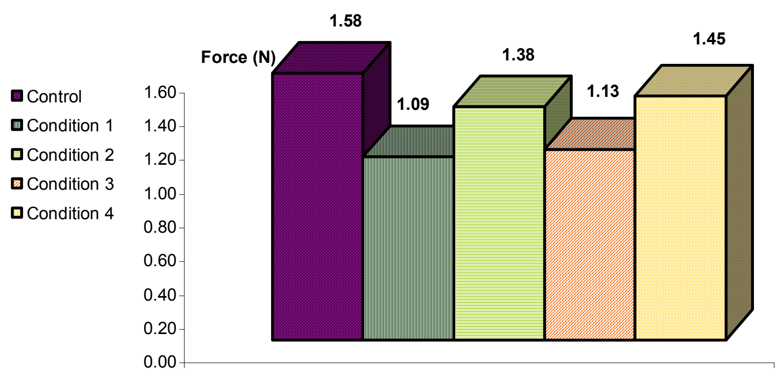


Fig. 3. The penetration force measured for chicken nuggets pretreated with SHS and fried (conditions 1 to 4) versus control.

Table 3. Comparison of color Hunter Lab parameters between no-treated (control) and SHS pre-treated fried nuggets

Conditions	L	a	b
Control	45.2 ± 0.2^{a}	11.1 ± 0.1^{a}	19.4 ± 0.1^{ac}
1	52.6 ± 0.1^{b}	8.1 ± 0.1^{bc}	20.6 ± 0.1^{b}
2	49.2 ± 0.8^{cd}	7.8 ± 0.2^{c}	19.1 ± 0.2^{c}
3	48.0 ± 0.5^{c}	9.1 ± 0.0^{d}	19.7 ± 0.3^{a}
4	50.1 ± 0.4^{d}	8.4 ± 0.1^{b}	19.8 ± 0.1^{a}

Means with the same letter indicate no significant difference ($p>0.05$)

As it was expected, density and thermal conductivity of chicken nuggets were not affected by the SHS treatments ($p>0.05$). Apparent nuggets density ranged between 886 and 980 kg/m^3 (Fig. 4). These vales were lower than values reported by Rao and Delaney (1995), who estimated a density of 1040 kg/m3 for breaded chicken pieces (including bone and peel). Thermal conductivity ranged between 0.46 and 0.49 W/m°C similar to those reported by Moreira et al. (1999), who reported a value of 0.41 W/m°C.

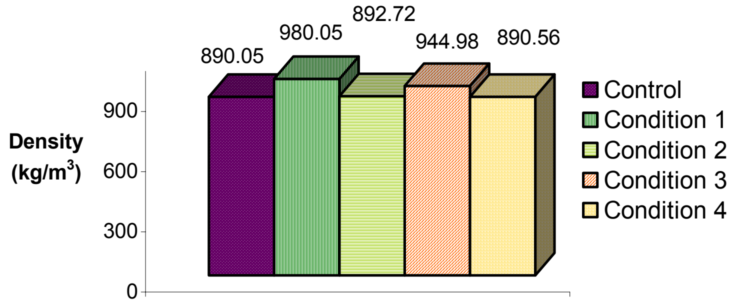


Fig. 4. Density of fried nuggets as compared to control and SHS pre-treated samples).

Conclusions

Mass transfer during the deep fat frying of chicken nuggets occurred mainly in the crust than in the core of the chicken nuggets. In comparison to 3-min deep-fat frying at 160°C, the SHS pre-treatment at 110°C for 5 min, followed by deep-fat frying at 160°C for 60 s, reduced an average oil uptake of the core and the crust by 2.5% w.b. and 16.7% w.b., respectively. At the same time the SHS treatment of nuggets at 110°C resulted in a higher moisture content of the core and the crust by 1.7 - 3.7% w.b. and 13.5 -18.8% w.b., respectively. The crust had similar texture but lighter and more yellowish color, and due to a higher moisture uptake, the SHS treatment gave a softer product as compared to deep-fat frying only. SHS did not affect the density and the thermal conductivity of the nuggets. Due to its reduced oil up-take in comparison to deep-fat frying alone, the SHS pre-treatment has a high application potential in processing of chicken nuggets.

References

AOAC (1995). *Official methods of analysis*. Association of Official Analytical Chemists. Washington, DC.

Balasubramaniam V.M., Mallikarjunan P. & Chinnan M.S. (1995). Heat and mass transfer during deep-fat frying of chicken nuggets coated with edible film: influence of initial fat content. *CoFE*. 103-106.

Garayo J. and Moreira R. 2002. Vaccuum frying of potato chips. *Journal of Food Engineering* 55, 181-191.

Li Y. B., Yamsaengsung R., Moreira R. G. and Seyed-Yagoobi J. 1998. Superheated steam impingement drying of tortilla chips. IFT Annual meeting. Atlanta, GA. June 20-24

Lloyd B. J, Farkas B. E. and Keener K. M. 2004. Quality comparison of French fry style potatoes produced by oven heating, immersion frying and controlled dynamic radiant heating. *Journal of Food Processing and Preservation* 28, 460-472.

Moreira, R.G., Castell-Perez, M.E. & Barrufet M.A. (1999). *Deep-fat frying. Fundamentals and Applications*. Aspen Publishers, Inc.: Gaithersburg, MD.

Pronyk, C., S. Cenkowski, W.E. Muir, and O.M. Lukow. 2008. Effect of superheated steam processing on the textural and physical properties of Asian noodles. *Drying Technology* 26: 192-203.

Rao, V.N.M. & Delaney, R.A.M. (1995). An engineering perspective on deep-fat frying of breaded chicken pieces. *Food Technology* 49(4), 138-141.

Tang, Z., Cenkowski, S. and Muir, W.E. (2000). Dehydration of sugar-beet pulp in superheated steam and hot air. *Transactions of the ASAE* 43(3): 685-689.
Vélez-Ruiz J.F., Vergara-Balderas F.T., Sosa-Morales M.E. & Xique-Hernández J. (2002). Effect of temperature on the physical properties of chicken strips during deep-fat frying. *International Journal of Food Properties* 5(1), 127-144.