日本調理科学会誌 Vol. 43, No. 3, 184～191 (2010) [Article]

Effects of Controlled Oil Temperature on the Center Temperature of Prepared Frozen Foods during Frying

Kyoko Ohishi*§ Koyomi Watanabe** Shoko Shibukawa***

The frying time of prepared frozen foods was judged by their surface colors, and their center temperatures were not researched. In our project, we investigated the center temperatures of the frozen croquettes and meatballs during deep-frying, and aimed to find an appropriate frying method to meet the adequate surface color and the proper inside temperature.

When the samples were fried at commonly-used high oil temperature, the heat did not sufficiently conduct to the center parts even after the surface colors were adequate. This tendency remarkably appeared in the meatballs that had no batter. The best frying method with meatballs was to fry them at a low temperature in the early stage, and then switch the oil to a higher level when the samples' center reached 0℃. As a result, the final center temperatures were high enough with the adequate surface colors and their harder and brittle textures were preferred.

Key word : prepared frozen foods, deep-fry, center temperature, oil temperature, Induction Heating (IH)

Introduction

To enrich our dietary lives, we have many kinds of cooking methods: such as boiling, deep-frying, sautéing, marinating, and so on. Among the various approaches, deep-fried food is very popular especially in families with teenagers. In such households, it is reported that the usage of this cooking method occurs about once or twice a week (Ito et al., 2000).

In addition, since the Cold Chain Improvement Project was initiated by the Japanese government in 1968, frozen foods have become more popular, and the amount of consumption of them in families has increased (Minami and Sato, 1974). For many families, even if the cook stays at home, they still use the frozen foods once or twice a week (Miyazawa et al., 1996).

Among all frozen foods, prepared frozen foods have the highest percentage of production. At the present time, prepared frozen croquettes are very popular, and the amount of production of this item is the largest among the prepared frozen foods for over ten years (Japan Frozen Food Association, 2007). Moreover, Fukaya (1995) has reported that people of any age, including seniors, are frequent users.

When prepared frozen foods are deep-fried, they are generally put in a high oil temperature of 160 to 180℃ without thawing. Frying is finished when the surfaces of the foods turn into an adequate brown color, and at the same time, the adequate inside temperatures are also required. However, there are a limited number of research projects that are focused on the inside temperature of the frozen foods during deep-frying. In the case of frozen foods with no batter, it often happens that the inside of the foods are not cooked enough even if their outside surfaces look finished (Tanabiki, 1974).

In order to resolve this problem, we investigated the center temperatures of the frozen croquettes and meatballs during deep-frying. And we aimed to find an appropriate frying method to meet the adequate inside temperature and the proper brown color of the frozen foods.

Materials and methods

1. Croquette and meatball samples

Prepared frozen crab cream-croquettes and meatballs were used as samples. Every sample was for professional use, and cooked at the factories. From both of these items, two different sizes were selected. The smaller croquette made by company N was labeled Croquette S. This sample contained onion, crab, wheat flour, whey powder, fats and oils, seasonings, and batter (bread crumbs, wheat flour, powdered oil, starch, saccharides). And the bigger one made by company A was labeled Croquette L. This item contained crab, fat free milk powder, onion, milk, wheat flour, starch, sweetened condensed milk, fats and oils, seasonings, and batter (bread crumbs, wheat flour, tomato paste, powdered oil, starch, saccharides). These croquettes had not been completely cooked before freezing at their factories. The smaller meatball

* Former faculty member of Seitoku University
** Panasonic Corporation, Home Appliances Company
*** Former faculty member of Yokohama National University
§ inquiry 1369 West 64th Ave., Vancouver, B. C., V6P 2N3 Canada

Table 1. Forms and weights of the samples

Sample	Major axis (mm)	Minor axis (mm)	Height (mm)	Weight (g)
Croquette S	55.7±1.1	53.5±0.5	18.3±0.8	31.1±0.4
Croquette L	83.9±2.4	80.0±1.1	22.5±0.6	79.9±4.0
Meatball S	33.9±2.0	30.7±0.6	26.3±0.7	14.7±0.2
Meatball L	42.0±1.7	37.7±1.8	34.8±1.7	30.0±0.9

Mean values ± S. D. (n=20).

made by company K was labeled Meatball S. The ingredients of this sample were ground chicken, onion, bread crumbs, starch, egg whites, vegetable protein granules, fats and oils, and seasonings. And the bigger one made by the same company as Meatball S was labeled Meatball L. This item contained ground pork, ground chicken, onion, starch, bread crumbs, egg whites, vegetable protein granules, lard, and seasonings. These meatballs had been fully cooked before freezing. See Table 1 for the forms and weights of these samples. These samples were kept in a room where the temperature was −30℃.

2. Heating appliance

The heating appliance (3 G-7 EMRS, 749 mm in length, 577 mm in width, 230 mm in depth) had three heaters, and during our experiment, one of the IH heaters was used. The maximum power consumption of this IH heater was 3 kW, and the heating power was adjusted by ten levels. This heater was equipped with the deep-frying function and controlled the oil by seven levels from 140 to 200℃ at intervals of 10℃.

3. Method of deep-frying

The use of an exclusive fryer pot (220 mm in diameter, 85 mm in height) for this IH heater was put on the center of the heater, and a round grid (190 mm in diameter, 10 mm in height, made from stainless steel) was put inside the pot. This was because the result of our preliminary experiment turned out to be that the samples fried on this grid were more of a uniform color of cooking than the ones put directly into the pot. The 1,100 g of oil (Nisshin Salad Oil, Nisshin Oillio Group) was preheated. The reason for this oil volume was that the samples were soaked completely into the cooking oil. After hearing the digital voice of the appliance that announced the finish of preheating, four croquettes or six meatballs were put into the oil at the same time. During frying, all the research samples were turned down at intervals of one minute. After frying, the samples were taken out from the pot and kept on a cooling rack, therefore the extra oil dropped off from these items. The oil residues were removed after each frying and the new oil was added to be adjusted to 1,100 g. The entire oil was changed after every third frying.

4. Measurement of temperature

To measure the temperature, the portable types of thermometers (AM-7012 L, Anritsu Meter Co.) and chromel-alumel thermocouple cables (ϕ1.2 mm, BS-91 K-010-GM 2-ANP, Anritsu Meter Co.) were used.

To measure the center temperature of the samples, the thermocouple cable was inserted into each item. The method was as follows: the maximum axis of the sample was measured by using a vernier caliper, and half of this length was calculated. A portion of this length was marked from the measuring tip of the thermocouple cable, and then at this point, the cable was bent and inserted into the sample to the limit; see Figure 1. By this method, the thermocouple cable could measure the temperature of the center position of the sample. Among four croquettes or six meatballs, two of them were set with this measuring system, and put into the oil with the rest of the samples. While the samples were deep-fried, these thermocouple cables were held by hand above the pot. To measure the oil temperature, the thermocouple cable was put in the oil along the side of the pot. The tip of this cable was adjusted to the center of the oil's depth, and fixed to the pot with metalized tape. All temperatures were measured at intervals of five seconds.

5. Frying conditions

The samples were deep-fried by three different frying

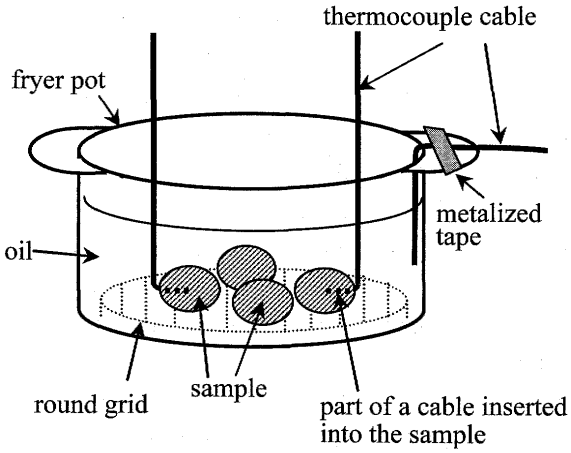

Figure 1. Conceptual figure of cooking system. Four croquettes or six meatballs were put into 1,100 g of oil. A round grid was put on the bottom of the fryer pot and the samples were put on it. The thermocouple cables were inserted into only two of the samples. The third cable was put in the oil along the side of the pot and fixed with metalized tape.

conditions. We labeled each condition as 'Automatic Type', 'Slow Frying Type', and 'Two-Step Type'.

The Automatic Type was the condition when the samples were deep-fried according to the directions written on the packages. The directions were as follows: Croquettes S should be fried at 170℃ for 5 minutes, while Croquettes L should be fried at 170℃ for 7 minutes. Meatballs S and Meatballs L should be fried at 160℃ and each frying time was 3 minutes and 4.5 minutes, respectively. The oil temperatures were controlled automatically by using the deep-frying function of the IH cooking appliance.

The Slow Frying Type was the condition when the samples were fried at 120℃ for 12.5 minutes and the oil temperature was adjusted by touching the manual power panel of the IH cooking appliance. The frying was finished when the surface colors of the samples were the same as those of the Automatic Type.

The Two-Step Type was the condition when the samples were put into the oil of 150℃, and the heating power was changed to Level 1 immediately by manual adjustment. When the center temperatures of the samples reached 0℃, the heating power was changed to Level 5, and the cooking was finished when the surface colors of the samples were the same as those of the Automatic Type. Level 1 of the IH cooking appliance is about 235 W and this power level corresponds to a low heat. Level 5 is about 1 kW and corresponds to a medium-high heat.

6. Measurement of weights

Before frying, the weights of the samples were measured by using an electronic scale. After frying, the foods were kept at room temperature for 30 minutes, and then their weights were measured by the same scale. Then, the ratio of change in weight was calculated.

7. Measurement of colors

The colors of the fried foods were measured by using a colorimeter (NF 333, Nihon Denshoku Kogyo Co.). Two points of the surface of the fried food were selected, and L*, a* and b* values of each point were measured.

8. Sensory test

The panel was composed of 21 people and they were members of Seitoku University who ranged in age from 18 to 33 years. The samples of the sensory test were the Automatic Type, the Slow Frying Type, and the Two-Step Type of Meatballs L, and the test was conducted 30 minutes after frying. Four question items were presented: Preference in Appearance, Preference in Texture, Strength in Oily Taste, and Overall Acceptability. The results were evaluated by a ranking method. Significant differences were calculated using the Newell and MacFarlane multiple comparison.

9. Rupture strength test

The breaking properties were measured by using a creep meter (Rheoner RE-3305, Yamaden Co.) under the following conditions: load cell, 2 kgf; plunger, cylinder 2 mm in diameter; plunger speed, 0.5 mm/sec. Meatballs L of the Automatic Type, the Slow Frying Type, and the Two-Step Type were cut completely in half in a horizontal direction 30 minutes after frying. These items were put on the sample stage, one at a time, and a plunger was inserted from the upper surface. The creep curves were drawn on the display and analyzed with software developed for creep analysis (Ver. 1.1, Yamaden Co.). The measurements were repeated eight times.

Results and discussion

1. Oil temperature control of the deep-frying function

First of all, the performance of the deep-frying function of the IH cooking appliance was investigated. For that purpose, the real oil temperatures at 150℃, 160℃, and 170℃ were measured with the use of the deep-frying automatic function. The thermocouple cables were set in the center and to the side of the oil.

As shown in Figure 2, each oil temperature was almost kept constant for 5 minutes, and there was no difference between the side and the center of the oil. When the deep-frying function was set at 150℃, the average temperature of the oil was 162.6±1.4℃. When the set was at 160℃, the average was 170.4±0.9℃, and when the set was at 170℃, the average was 182.7±0.7 ℃. These results revealed that the oil temperatures were kept about 10℃ higher than the setting temperatures of the automatic deep-frying function. Based on this data, when we used this function the setting temperature was 10℃ lower than the actual temperature. Moreover, it turned out that the oil temperatures were the same at any point. Therefore, the measuring point of oil was adopted at the side because of easier access to the measurements of the temperature.

2. Oil and sample center temperatures in the Automatic Type

Four kinds of prepared frozen foods: Croquettes S, Croquettes L, Meatballs S, and Meatballs L were deep-fried with the automatic function of the IH cooking appliance. Each frying temperature and the time used was the same as stated in the direction on the package. The de-

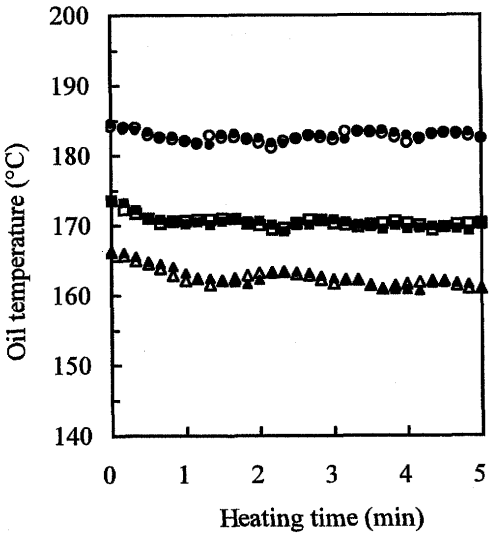

Figure 2. Oil temperature controlled by the automatic deep-frying function.
Setting temperature and measuring point: ▲, 150℃ and the side position; △, 150℃ and the center position; ■, 160℃ and the side position; □, 160℃ and the center position; ●, 170℃ and the side position; ○, 170℃ and the center position.
The deep-frying function was set at 150℃, 160℃, or 170℃, and the thermocouple cable was inserted into the oil. At the end of preheating, the oil temperature was measured for 5 mins.

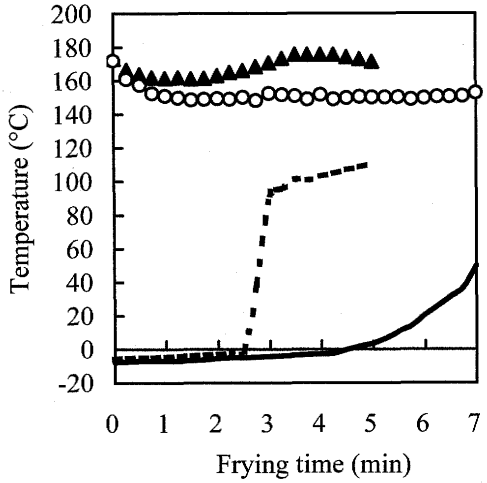

Figure 3. Representative curves of the oil and center temperatures of Croquettes S and Croquettes L in the Automatic Type.
▲, controlled oil temperature during frying of Croquettes S; ○, controlled oil temperature during frying of Croquettes L; (·····), center temperature of Croquettes S; (——), center temperature of Croquettes L.
Croquettes were deep-fried with the automatic frying function set at 160℃.
The frying time was 5 mins for Croquettes S and 7 mins for Croquettes L.
Each test was repeated six times.

tails about our procedure were described in Materials and Methods.

On the basis of the results of the former experiment (Fig. 2), the setting temperature of the automatic function was actually 10℃ lower than the temperatures stated on the packages.

Figure 3 illustrates the representative curves of the oil and center part temperatures of Croquettes S and Croquettes L. As for Croquettes S, the oil temperature decreased once, but recovered and the average temperature of the oil for 5 minutes was 165.5±4.5℃. The center temperature of Croquettes S increased very slowly at first, and about 2.6 minutes later, reached 0℃ and then increased remarkably. The final average center temperature of Croquettes S was 109.7±10.3℃. As for Croquettes L, the oil temperature decreased gradually after beginning to fry, and it was kept around 150℃. The average of the oil temperature during frying was 151.0±4.6℃. The center temperature of the samples increased at a slow pace, and 4.7 minutes later reached 0℃. Then, the center temperature increased gradually, and the final result was 51.5±11.7℃.

Figure 4 exhibits the representative curves of the oil and center part temperatures of Meatballs S and Meatballs L. The oil temperatures outside of these samples decreased a little, but kept almost constant. The average oil temperature during frying of Meatballs S was 149.7±3.1℃ and that of Meatballs L was 143.1±4.8℃. As for the center temperatures of the samples, both of them did not increase a significant amount during frying. In the case of Meatballs S, the center temperature reached 0℃ about 2.8 minutes later, and the final temperature was 3.7±5.9℃. As for Meatballs L, the center temperature was kept under 0℃ during frying, and produced an unacceptable final result with a temperature at −5.1±0.4℃. Table 2 shows the characteristics of colors of each fried sample. Every sample was adequate in color.

From these results, some facts were evident. The oil temperature fell to about 10℃ after samples were put into the oil, but it was kept constant during deep-frying. For this reason, it would be said that the deep-frying automatic function of the IH cooking appliance worked well. Another indication was that when the prepared frozen foods were deep-fried according to the directions on the packages, the end results were positive in terms of their appearances.

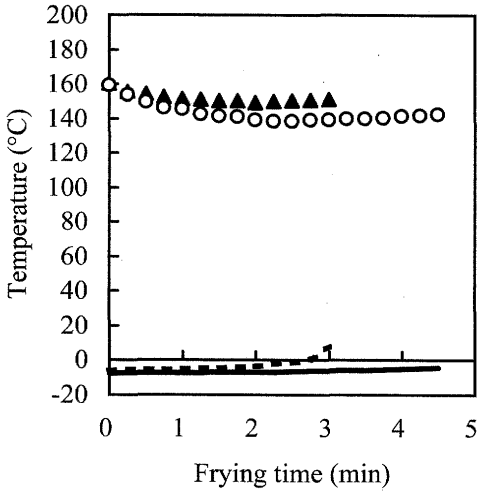

Figure 4. Representative curves of the oil and center temperatures of Meatballs S and Meatballs L in the Automatic Type.
▲, controlled oil temperature during frying of Meatballs S; ○, controlled oil temperature during frying of Meatballs L; (·····), center temperature of Meatballs S; (——), center temperature of Meatballs L. Meatballs were deep-fried with the automatic frying function set at 150℃. The frying time was 3 mins for Meatballs S and 4.5 mins for Meatballs L. Each test was repeated six times.

Table 2. Characteristics of color of the Automatic Type samples

Sample	Color		
	L*	a*	b*
Croquette S	51.0±2.0	8.9±1.2	29.4±2.3
Croquette L	48.7±1.9	8.0±1.4	25.9±1.8
Meatball S	38.0±9.0	9.4±1.3	15.3±2.0
Meatball L	39.8±5.6	8.2±2.6	10.3±6.4

Mean values ± S. D. (n=6).
The frying condition of each sample is described below in Fig. 3 and Fig. 4.

However, our results also indicated that the deep-fried foods had a problem concerning their center temperatures. The final temperatures of Croquettes S were adequate, but those of Croquettes L were about 52℃. As for Meatballs S, the center temperatures increased very little, while the final center temperatures of Meatballs L did not reach 0℃. Among the same kinds of samples, the larger ones delayed the increase of the center temperatures in comparison to the smaller ones.

These results pointed out that the center temperatures of Meatballs S and Meatballs L were markedly lower than those of Croquettes S and Croquettes L. This difference in temperature was caused by the absence of batter. When the surfaces of the meatballs reached an adequate brown color, the temperatures of their centers were too low in comparison to the temperatures of the exterior parts.

Even if the prepared frozen foods are perfectly cooked products, when they are reheated, the final center temperatures must reach over 60℃ from the aspects of the starch gelatinization and food taste.

Therefore, we next examined the deep-frying condition that satisfied the results of the appearance and the final center temperature of the Meatballs L. These samples were used because they had no batter and the size was larger, and these factors produced the worst result among the four kinds of items.

3. Oil and sample center temperatures in the Slow Frying Type

To meet the requirements of the final temperature over 60℃ and the adequate surface colors, we fried Meatballs L at various oil temperatures from 110℃ to 150℃. And we concluded that the highest temperature for satisfying these requirements was 120℃ with 12.5 minutes for frying time.

Figure 5 depicts the representative curves of the oil and the center temperatures of Meatballs L. The oil temperature was adjusted at 120℃ by manual control. The center temperature reached 0℃ about 7 minutes later,

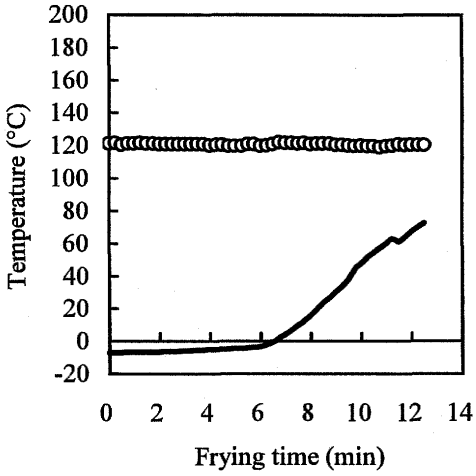

Figure 5. Representative curves of the oil and center temperatures of Meatballs L in the Slow Frying Type.
○, oil temperature; (——), center temperature of Meatballs L.
Meatballs L were deep-fried at 120℃ by manual adjustment. The frying was finished when the surface colors of the samples were the same as those of the Automatic Type; 12.5 minutes was needed.
Each test was repeated six times.

Table 3. Ratio of change in weight and the characteristics of color of each heating condition of Meatballs L

Frying condition	Ratio of change in weight	Color		
		L*	a*	b*
Automatic Type	0.96±0.01[b]	39.8±5.6[a]	8.2±2.6[a]	10.3±6.4[a]
Slow Frying Type	0.94±0.02[a]	40.4±2.3[a]	6.0±2.1[a]	13.9±5.0[a]
Two-Step Type	0.89±0.05[c]	42.4±7.8[a]	8.0±3.5[a]	10.2±5.1[a]

Mean values ± S. D. (n=6).
The data of the Automatic Type is the same as Meatballs L of Table 2.
The frying condition of each sample is described below in Fig. 4, Fig. 5, and Fig. 6.
Values followed by the same letters in the same column are not significantly different ($p<0.05$).

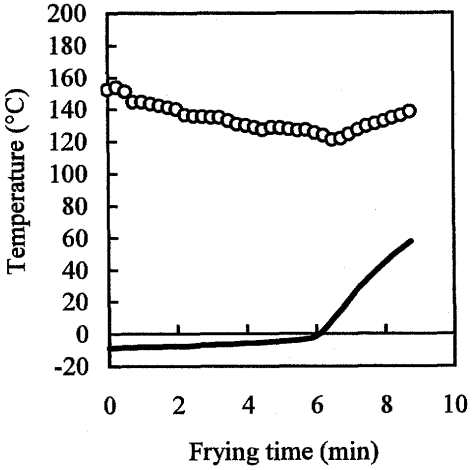

Figure 6. Representative curves of the oil and center temperatures of Meatballs L in the Two-Step Type.
○, oil temperature; (——), center temperature of Meatballs L.
Meatballs L were put in the oil of 150℃, and the heating power was changed to Level 1 by manual adjustment. When the center temperatures of the samples reached 0℃, the heating power changed to Level 5. Frying was finished when the surface colors of the samples were the same as those of the Automatic Type; 9.1±0.1 minutes was needed.
Each test was repeated six times.

and then increased gradually. The final center temperature obtained was 87.0±11.9℃.

Table 3 shows the ratio of change in weight and the characteristics of colors of the Slow Frying Type samples. Each color value of the Slow Frying Type was the same as that of the Automatic Type. Therefore, the surface colors of the Slow Frying Type were adequate like the Automatic Type. However, a group of our researchers felt that the Slow Frying Type meatballs had too oily a taste. The frying time of 12.5 minutes was too long and could have caused this unpleasant effect.

4. Oil and sample center temperatures in the Two-Step Type

The results of the Slow Frying Type experiment showed that frying at a low oil temperature contributed to the raising of the center temperature, however the taste was unacceptable. Next, for improving the taste quality, we fried with the following method: at first, the meatballs were deep-fried at a low oil temperature, and when the sample center temperature reached 0℃, the oil was switched to a higher level. The details of this frying condition were written in Materials and Methods.

The representative curves of the oil and center temperatures of Meatballs L were shown in Figure 6. Table 3 includes the ratio of change in weight and the characteristics of colors of the Two-Step Type samples.

As shown in Figure 6, while the oil temperature decreased gradually, the sample center temperature increased, and 6.6±0.1 minutes later, the center part reached 0℃. At this moment, the oil temperature was 120.6±3.5℃, and the average oil temperature during 6.6 minutes was 132.8±3.1℃. When the sample center temperature reached 0℃, the IH heating power was turned up and the oil temperature increased. Also, when the oil temperature reached 138.7±0.3℃, the frying was finished because the average center temperature of the samples was 62.1±2.7℃ and all of the surface colors of the samples were the same as those of the Automatic Type food items. The frying time was reduced to 9.1±0.1 minutes and this time was 73% of the previous Slow Frying Type experiment. Table 3 shows that there were no differences in color values between the Two-Step Type and the Automatic Type, and it was proved that the visual judgment was adequate.

These results indicated that the two-step frying condition satisfied the raising of the center temperatures of the samples, the adequate levels of surface colors, and the reduction of the frying time.

5. Sensory Test

The taste of Meatballs L in the Automatic Type, the Slow Frying Type, and the Two-Step Type were evaluated by a sensory test; see Table 4. The result of the ranking method indicated that the Preference in Texture of the Slow Frying Type was at the lowest level, and that

Table 4. Sensory test by a ranking method

Frying condition	Preference in Appearance	Preference in Texture	Strength in Oily Taste	Overall Acceptability
Automatic Type	35[a]	43[ab]	36[a]	42[a]
Slow Frying Type	46[a]	50[a]	43[a]	49[a]
Two-Step Type	45[a]	33[b]	47[a]	35[a]

Each value is the total sum of the rank.
The Panel was composed of 21 people. Meatballs L of each frying condition were used as samples.
Values followed by the same letters in the same column are not significantly different ($p<0.05$).

of the Two-Step Type was at the highest. Relating to the other three question items, that is Preference in Appearance, Strength in Oily Taste, and Overall Acceptability, there were no meaningful differences among the three types of samples.

6. Rupture strength test

The breaking properties of Meatballs L of the Automatic Type, the Slow Frying Type, and the Two-Step Type were measured. As shown in Figure 7, the breaking force and the brittleness force of the Two-Step Type were at the highest level among the three frying conditions, and the lowest level was of the Automatic Type. Between these two types, there were significant differences.

This result showed that the Two-Step Type samples were harder and more brittle. The Preference in texture of the Two-Step Type samples was assessed as most positive as shown in Table 4. Therefore, we could judge that the Two-Step Type samples were preferred because of their highest levels of the hardness and brittleness.

From these results, it was concluded that if the prepared frozen croquettes and meatballs were fried at commonly-used high oil temperatures according to the directions on their packages, all samples got adequate brown surface color. But the meatballs that are the frying materials with no batter had a predominantly inadequate result from the aspect of their center temperature after frying. To resolve this problem, we explored a more effective frying condition. That is, foods were fried at a low oil temperature at first, and when their center temperatures reached 0℃, the oil temperature was raised. By this method, the center temperatures of the foods increased enough, and the surface colors of the fried foods were adequate. The longer frying time caused the surface textures to be harder and more brittle, but their textures were preferred.

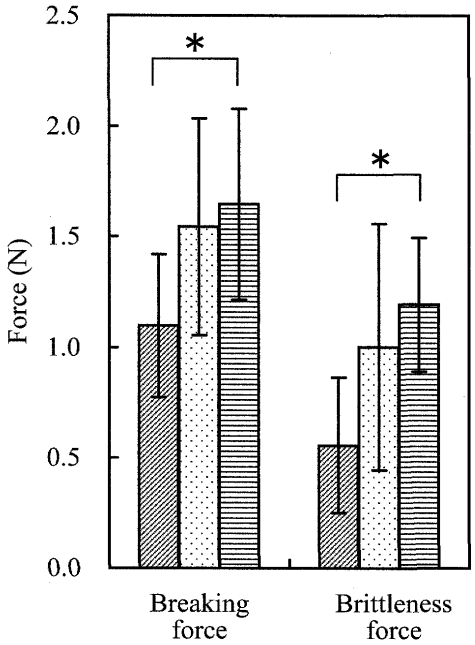

Figure 7. Breaking properties of Meatballs L of each frying condition.
▨ Automatic Type; ▩ Slow Frying Type; ▤ Two-Step Type. *$p<0.05$.
The condition of creep meter was as follows: load cell, 2 kgf; plunger, cylinder 2 mm in diameter; plunger speed, 0.5 mm/sec. Meatballs L of the Automatic Type, the Slow Frying Type, and the Two-Step Type were cut completely in half in a horizontal direction. These items were put on the sample stage one at a time and a plunger was inserted from the upper surface. The measurements were repeated eight times.

Based on our research, we suggest that when the frozen frying materials, especially with no batter, are deep-fried, they should be at first cooked at a lower oil temperature around 130-140℃. Then, the temperature should be raised to a higher level at the last stage of frying.

Summary

(1) Unequal sizes of prepared frozen croquettes and meatballs were deep-fried at high oil temperatures following the directions on their packages. As a result, all samples were adequate in terms of their appearances. However, among the same kinds of samples, the larger ones delayed the increase of the center temperatures in comparison to the smaller ones. Moreover, the center temperatures of the meatballs were markedly low compared to the croquettes.

Therefore, it was indicated that the absence of batter caused the rapid coloring of the surface, and resulted in the insufficient heating to the center parts when the frying was finished.

(2) When the frozen meatballs were fried at a low temperature of 120℃, the surface colors of them were an adequate brown and the inside temperatures were over 60℃. However, the frying time was too long.

(3) When the frozen meatballs were fried in a two-step frying method, the samples were first fried at a low oil temperature (132.8±3.1℃), and 6.6±0.1 minutes later, the samples were fried at a higher oil temperature. This method increased the center temperature and the colors of the samples were of an adequate brown.

(4) The rupture strength test and the sensory test indicated that the meatballs fried in a two-step frying process were harder and more brittle and their textures were judged as a positive result.

To conduct our experiments Satomi Oyake and Yuki Nakayama, now graduates of Seitoku University, gave us their assistance. We appreciated their cooperation. And we are deeply grateful to Margaret Simpson who proofread our English text.

Reference

Fukaya, S. (1995), *Reitoushokuhin no mirai, Wakaremichi ni tatsu nihon no shoku* (in Japanese), p. 48-49, Co-op book, Tokyo

Ito, T., et al. (2000), Survey on the Edible Oils Used for Deep Frying in the Home, *Journal of Cookery Science of Japan* (in Japanese), **33**(2), 236-243

Minami, H. and Sato T. (1974), An Investigation Concerning the Utilzation of Frozen Foods, *Journal of the Nagoya Women's College* (in Japanese), **20**, 15-21

Miyazawa, Y., Uchida, H., Ogura, R. (1996), A Study on Use of Frozen Foods (Part I): Utilization of Women Student's Families, *Journal of Nagoya Bunri College* (in Japanese), **21**, 135-140

Japan Frozen Food Association (2007), Statistics of Frozen Foods

Tanabiki, S. (1974), Studies on the Fried Cooking of Prepared Frozen Foods (Part I), *Journal of the Kenmei Women's Junior College* (in Japanese), **13**, 79-84

(Received Sep, 19, 2009 Accepted Feb, 1, 2010)

油温の管理が調理済み冷凍食品の中心温度に与える影響

大石恭子* 渡邊 暦** 渋川祥子***

和文抄録

調理済み冷凍食品の揚げ上がりは表面の色で判断されることが多く，中心温度は調べられていない。そこで，冷凍コロッケとミートボールを用いて揚げ調理中の中心温度の変化を調べ，適度な揚げ色と中心温度を満たす揚げ条件について検討した。

一般的に用いられる油温で揚げると，適度な揚げ色になった時点では中心温度の上昇は十分ではなかった。この傾向はコロッケよりもミートボールのような揚げ衣のない揚げ種の方が著しかった。ミートボールを揚げるには，加熱初期に低温の油で揚げ，中心温度が0℃ に達した時点で火力を上げるのが最も良い方法であり，加熱終了時の中心温度は十分に上昇し，かつ揚げ色も適度であった。この条件で揚げたミートボールは，表層はより硬く，もろくなり，揚げ物として好まれるテクスチャーであった。

キーワード：調理済み冷凍食品，揚げ物，中心温度，油温，電磁誘導加熱

* 元 聖徳大学
** パナソニックホームアプライアンス社
*** 元 横浜国立大学