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Prediction Equations for Internal Temperature and Yields of Chicken Patties During Deep Fat Frying

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닭고기 Patty를 튀길 때 Patty 내부온도와 수율 예측

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Abstract

Copper constantan thermocouples connecting to a recording potentiometer were inserted at the center of the patties and the samples were fried. In general, the internal temperature of the patty samples increased approximately 11.1℃ after the samples were removed from the fryer. The desired internal temperature and maximum internal end-point temperature, at different frying temperatures, can be obtained by adjusting the frying time. The yields of the patties decreased as maximum internal end-point temperature increased or as frying time increased. The internal temperature and maximum internal end-point temperature of the patty samples at three frying temperatures were predicted using polynominal regression of a third-order model with one independent variable, frying time. Polynominal regression of a second-order model with maximum internal end-point temperature as the independent variable was used to predict frying yields at three frying temperatures.

Key words : chicken patties, internal temperature polynominal regression

Introduction

Frying is one of the most important methods of food preparation; yet it may be the least understood. Deep fat frying is a simple method of preparing food products. Cooking is accomplished in a relatively short period of time due to great temperature differences between the heat source and the food, and to the comparatively small size of the individual food units. The end-product quality and economy of deep fat fried food products are controllable through the appropriate selection and use of materials, processing equipment and conditions, and frying fat[1].

In deep fat frying, the food is completely surrounded by the heat transfer medium. It is faster than boiling in water as the temperatures used in frying are higher causing more rapid heat penetration. In addition to transferring heat, the fat also reacts with protein and carbohydrate components of the food, developing unique flavors and odors which have definite appeal to consumers[2]. The normal temperature of the fat range from 163 to 196℃, depending on the food to be fried. Although lower temperatures will bring about frying, the length of time required for thorough cooking would make the operation unsuitable. Temperatures above 196℃ would result in rapid degradation of the frying fat. In addition, excessively high temperatures would cause the product to be undercooked internally; while the exterior might be overcooked or even burned[2].

There are very few reports in the literature concerning the measurements of the thermal property of foods. One reason for this lack of data is difficulty in taking these measurements. However, thermal property data are needed to design the processing equipment and operating conditions[3]. There has been increased interest in the poultry industry to produce precooked or prefried products. One of the most popular of these is the prefried chicken patty. There is a need for information concerning the doneness and final yield of this type product.

The purpose of this experiment is to examine the relationship between frying time and internal temperature of chicken patties; between frying time and maximum internal end-point temperatures; and between

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maximum internal end-point temperatures and frying yields at different frying temperatures to provide information concerning chicken patty frying operation.

Materials and Methods

Sample preparation

Frozen, raw, battered and breaded chicken breast meat patties were obtained from a poultry processing plant immediately after manufacturing. The composition was 39.9% breast meat with skin and tender loin, 26.6% water and/or ice, 19.9% skin, 12.3% soy protein, 1.0% seasonings and 0.3% polyphosphates. All ingredients were mixed by a Bold Blender (Western Springs Engineering, La Grange, IL, USA). The samples were formed in a Formax forming machine (Formax Inc., Mekena, IL, USA), battered, and breaded. The patties averaged 9.5 mm in thickness and 85.5g in weight. The patty samples were removed from a processing line randomly prior to fry processing. The samples were then covered with wax paper, frozen via dry ice, transported to the laboratory and stored at −18℃.

Frying and internal temperature measurement

The samples were tempered to an internal temperature of 0± 1.1℃ in a 2∼4℃ refrigerator. Copper constantan thermocouple wires (Thermo Electric Co., Saddle Brock, NJ, USA) were inserted at the center of the patties and were connected to a Speedomax M Multipoint Recording Potentiometer (Leeds and Northrup Co., North Wales, PA, USA). The chicken patties were fried in a commercial deep fat fryer (Frialator, J.C. Pitman & Sons, Inc., Concord, NH, USA) at 168.3, 179.4, and 190.6℃ to various internal temperatures ranging from 48.9 to 71.1℃. Approximately 30 samples were fried at each frying temperature.

Frying yields

After frying, the chicken patties were removed from the fryer and cooled about 10 min at room temperature. The percent frying yield was obtained by dividing the fried patty's weight by the raw weight and multiplying by 100.

Statistical analysis

Regression analysis as described by Neter *et al.*[4], was used to calculate the prediction equations of internal temperature (℃), maximum internal end-point temperature (℃), and frying yields (%) of the chicken patties at different frying temperatures using the UNIVAC 1100 model computer. The internal temperature and maximum internal end-point temperature of patty samples at three frying temperatures were predicted using polynominal regression of third-order model with one independent variable, frying time. Polynominal regression of second-order model with maximum internal end-point temperature as an independent variable was used to predict the frying yields at three frying temperatures.

Results and Discussion

The increase in internal temperature of chicken patties during frying at 168.3, 179.4 and 190.6℃ is summarized in Fig. 1. In general, the internal temperature of the samples increased approximately 11.1℃ after removal of the product from the fryer. A similar result that showed a continued increase of internal temperatures of stuffed poultry products for a short time after removal from the heat source has been reported by Dawson *et al.*[5] In this study internal temperature is the temperature at the center of the sample during the frying process.

Using frying time as the independent variable, the internal temperature of patty samples at three different frying temperatures are predicted as (Fig. 1):

$$IT = -17.78 + 1.94 \times T - 0.0169 \times T^2 + 0.000052 \times T^3$$

$R^2 = 0.996$, $F = 1985.74$, $DW = 2.76$ (frying temperature; 168.3℃)

$$IT = -17.78 + 1.80 \times T - 0.0140 \times T^2 + 0.000043 \times T^3$$

$R^2 = 0.994$, $F = 1349.60$, $DW = 1.20$ (frying temperature 179.4℃)

$$IT = -17.78 + 2.12 \times T - 0.0192 \times T^2 + 0.000064 \times T^3$$

$R^2 = 0.988$, $F = 580.43$, $DW = 0.67$ (frying temperature 190.6℃)

where IT is Internal temperature (℃), R^2 is coefficient of determination, T is time (second) and DW is Durbin-Watson statistic.

The prediction equations are highly significant. The variation in internal temperature is explained 99.6%, 99.4%, and 98.8% by the variation in frying time at frying temperatures 168.3, 179.4, and 190.6℃, respectively. The calculated t-ratio of the first degree is greater than 2.0. Therefore, the regression coefficient of first degree is highly siginficant. The effective frying time ranged from 67 to 163 sec, from 58 to 127 sec, and from 50 to 114 sec for frying temperatures 168.3, 179.4, and 190.6℃, respectively.

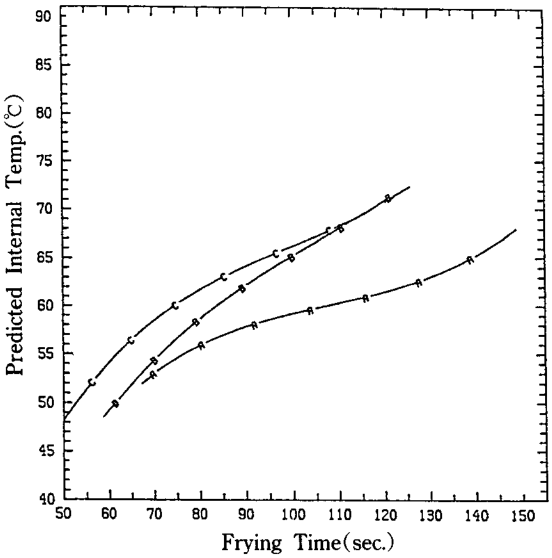

Fig. 1. Predicted chicken patty internal temperature
A, Fried at 168.3℃ ; B, Fried at 179.4℃ ; C, Fried at 190.6℃

The prediction of maximum internal end-point temperature of the patty samples at three different frying temperatures was made with using frying time as an independent variable. The prediction equations are expressed as below (Fig. 2):

$$IET = -17.78 + 2.39 \times T - 0.0202 \times T^2 + 0.000058 \times T^3$$
$R^2=0.998$, $F=3540.73$, $DW=2.11$ (frying temperature 168.3℃)

$$IET = -17.18 + 2.43 \times T - 0.0199 \times T^2 + 0.000059 \times T^3$$
$R^2=0.999$, $F=5427.30$, $DW=2.00$ (frying temperature 179.4℃)

$$IET = -17.78 + 3.36 \times T - 0.0394 \times T^2 + 0.000158 \times T^3$$
$R^2=0.998$, $F=4097.65$, $DW=1.00$ (frying temperature 190.6℃)

where IET is maximum internal end-point temperature (℃).

The regression equations are highly significant. The variation in maximum internal end-point temperature is explained 99.8%, 99.9%, and 99.8% by the variation in frying time at frying temperatures 168.3, 179.4, and 190.6℃, respectively. The absolute values of calculated t-ratio are all greater than 2.0. Therefore, all regression coefficients are highly significant. The desirable internal temperature and maximum internal end-point temperature of the chicken patty samples can be obtained by adjusting the frying time at different frying temperatures.

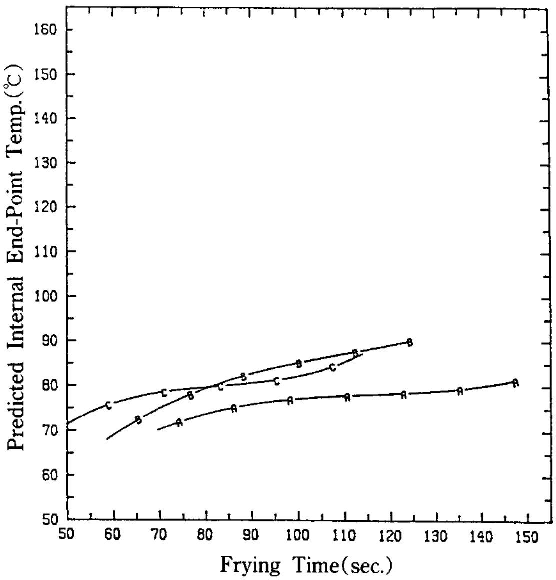

Fig. 2. Predicted chicken patty internal end-point temperature
A, Fried at 168.3℃ ; B, Fried at 179.4℃ ; C, Fried at 190.6℃

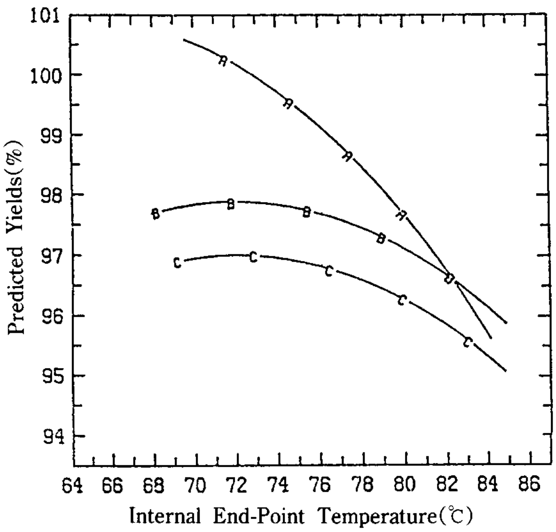

Fig. 3. Predicted chicken patty yields
A, Fried at 168.3℃ ; B, Fried at 179.4℃ ; C, Fried at 190.6℃

The frying yields of patty samples were predicted at three different frying temperatures with using maximum internal end-ponit temperatures as an independent variable. The regression equations for yields (YLD) are shown as follows (Fig. 3).

$$YLD = 38.57 + 1.91 \times IET - 0.01464 \times IET^2$$
$R^2 = 0.998$, $F = 7207.00$, $DW = 0.81$ (frying temperature 168.3℃)

$$YLD = 34.88 + 1.75 \times IET - 0.01215 \times IET^2$$
$R^2 = 0.9998$, $F = 56314.50$, $DW = 2.29$ (frying temperature 179.4℃)

$$YLD = 34.61 + 1.73 \times IET - 0.01199 \times IET^2$$
$R^2 = 0.999$, $F = 16548.57$, $DW = 1.07$ (frying temperature 190.6℃)

The regression equation are highly significant. The variation in yields is explained 99.8%, 99.9%, and 99.98 % by the variation in maximum internal end-point temperatures at frying temperatures 168.3, 179.4, and 190.6 ℃, respectively. The absolute values of calculated t-ratio are greater than 2.0. Therefore, all regression coefficients are highly significant. The valid maximum internal end-point temperature ranged from 64.4 to 86.7℃, from 68.3 to 93.3℃, and from 68.3 to 88.9℃, for frying temperatures 168.3, 179.4, and 190.6℃, respectively. The prediction of frying yields of the patty samples can be made at different frying temperatures when the maximum internal end-point temperature is known.

As expected, the yields of the chicken patties decreased as maximum internal end-point temperature increased or as frying time increased. This cooking loss of meat or meat products increase as the internal temperature or cooking temperature increased has been reported by several researchers[6-10]. Results clearly indicated that the internal temperature, maximum internal end-point temperature and yields in chicken patty frying process can be adjusted using the above stated equation. Industry can operate under optimal frying condition for maximal yields.

요 약

냉동된 닭 가슴살 patty를 계육 가공공장으로부터 얻어서 내부온도가 0± 1.1℃가 되도록 조절하였다. Potentiometer에 연결된 thermocouple을 patty 중심에 삽입한 뒤 168.3, 179.4, 190.6℃에서 튀겨 내부온도의 범위가 48.9℃에서 71.7℃가 되도록 하였다. 일반적으로 patty 내부온도는 튀김 솥(frier)에서 제거한 뒤 튀기는 온도나 내부온도와 관계없이 약 11.1℃ 증가하였으며, 각각 다른 튀김온도에서 원하는 내부온도와 최종 내부온도는 튀기는 시간을 조절하므로써 얻을 수 있었다. 세 종류의 튀기는 온도에서 튀기는 시간이 독립변수인 3차 회귀다항식으로 시료 내부온도와 최종 내부온도를 예측하였고 최종 내부온도가 독립변수인 2차 회귀다항식으로 수율을 예측하였다.

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