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Influence of Partial Drying on Oil Uptake & Quality Attributes of French Fries

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Abstract: Today's customers are looking for non-fat or low-fat containing products. One of the methods to reduce oil absorption in fried products is partial drying before frying. In this study, influence of partial drying (10 min, 20 min, 30 min) on oil absorption and quality attributes of three potato cultivars (Agria, Satina, kenebek) was evaluated. Our results reveled that in Agria, partial drying leads to an increase in oil absorption compared with non-dried sample ($p<0.05$). In kenebek, partial drying reduced the oil absorption and improved the texture and color of the produced French fries ($p<0.05$). Similar results were observed with Satina as with kenebek. In all three varieties, partial drying increased the dry matter, color quality and required cutting force of the French fries ($p<0.05$).

Key words: French fries, partial drying, oil absorption.

1. Introduction

Potato (*Solanum tuberusum*) is a tetraploid plant which belongs to Solanum species and Solanaceae family. This crop with a world production of 400 million ton is the most important agricultural crop after wheat, corn, and rice[1]. It can be used as a fresh product, animal feed, or can be processed into starch, powders, and fried products (e.g., chips and French fries). French fries are potato pieces with cross section of 1×1 cm^2 and 6-7 cm length, which are fried in hot oil[2].

Deep fat frying is a dry-cooking process which is mainly immersing food pieces in hot vegetable oil[3]. It is extensively used in the preparation of flavored foods with internal wet, soft texture and a tender and crispy crust[4]. During the frying process, physical, chemical and organoleptical properties of food are changed. The main goal of deep fat frying is to maintain the food flavor inside a tenderized and crispy crust[3]. Quality attributes in fried products includes dry matter content, oil content, color, and texture. There are many factors affecting the quality of fried products such as potato variety, frying temperature, frying time, and pre-frying treatments (partial drying, blanching and coating)[5].

Oil content is one of the important quality attributes in fried products. Fried potato products with low oil content have a hard and unfavorable texture. On the other hand, high oil consumption is not cost-effective for manufacturers and products with high oil content are fatty and sometimes tasteless[6]. Today, consumers are looking for food products with lower oil content; therefore it is important to find the ways that can reduce the oil content of fried products.

Oil absorption during deep fat frying is controlled by some parameters including oil quality, frying temperature and time, food composition (e.g., its moisture content, porosity), pre-frying treatments (partial drying and blanching), coating and food size[5, 7-10].

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During deep fat frying, there is a simultaneous heat and mass transfer. When food is added into hot oil, its surface temperature increases and the water at the surface starts to evaporate which brings about surface drying and shrinkage[11]. Due to heat transfer from oil into the food, the internal moisture evaporates and causes a pressure gradient inside the food. This pressure gradient inside the capillary tubes and internal channels slowly pumps out the water from central points of the food to its surface and then evaporates at the surface during frying. At the same time, oil is absorbed at the damaged areas on to the surface of food and enters into the vacant spaces which are created by water vapor removal[12]. In fact, that is why food moisture content is the factor that mostly determines the amount of oil absorption[9, 13-16]. Therefore, partial drying of foods such as potato can be an effective method for reducing oil absorption[17]. Foods which have high moisture loss can have higher oil absorption[13]. Some workers claim that the total volume of absorbed oil during frying is equal to the total amount of water removed from food[18].

Partial drying in hot air before frying can improve the texture of fried products and reduce their oil absorption. With the removal of water from surface, crust formation is commenced and channels in the food are reduced. During drying due to shrinkage, moisture removal is faster as some of it has been removed before, then frying time is shortened[3, 5, 14, 17, 19, 20]. By considering this, we aimed at finding the best variety of potato which can be processed into French fries with lower oil contents and evaluating the influence of partial drying before frying on these varieties.

2. Materials and Methods

2.1 Production of French Fries

Three potato varieties, namely Agria, Satina and Knebek which are extensively cultivated in Golestan province of Iran were supplied by Agricultural Research center of Golestan. Then, their physico-chemical properties were analyzed immediately and moved to a cold store at 5-7 ℃ with a relative humidity of 80%. Before frying, potatoes were removed from cold store and kept at ambient temperature for two weeks in order to decrease the amount of reducing sugars which have been increased at cold storage. After peeling with an abrasive peeler (Esfahan machine, Iran), samples were converted to pieces of 6×1×1 cm^3 by means of a domestic striper. The blanching was performed in boiling water (90-95℃) for 4 min and the products were washed immediately with cool water. After blanching, partial drying of French fries was conducted in an oven (PJ300; Memmert, Germany) at 105 ℃ for 10 min, 20 min and 30 min. Deep-frying of the French fries was completed in a domestic deep fryer (Tefal) filled with frying oil at 175 ℃ for 2.5 min. In order to drain extra oil, fried potato pieces were placed on a sieve and their temperature was reduced to ambient.

2.2 Experiments

Dry matter and moisture content of the raw potatoes and French fries were analyzed based on AOAC methods[21]. For the determination of specific gravity of raw potatoes, we used the following relationship:

$$\text{Specific gravity} = \frac{\text{Weight of sample in air}}{\text{Weight of sample in air water}} \quad (1)$$

Analysis of reducing sugars, total carbohydrate content and sucrose was performed by the Lin Aynon (Fehling) method as described by AOAC methods[21]. Fat content of samples was measured by soxhelet apparatus. 5 g of French fries was extracted by petroleum ether in 6 hours (AOAC methods, 2005, 18th edition). For color analysis, we used color parameters (Hunter L, a, b) of a Hunter lab system (Data color 3, Text flesh 4, USA). Total color difference (ΔE) was calculated by:

$$\Delta E = \left[\left(\Delta L^2\right) + \left(\Delta a^2\right) + \left(\Delta b^2\right)\right]^{1/2} \quad (2)$$

For color determination, three readings were taken from three different points of the French fries (central point & two end points) at ambient conditions and the mean value was calculated[22].

Finally, for texture analysis we used an Instron (1140, UK) and a method developed by Warner-Bratzler Shear.

For statistical analysis, the samples were selected randomly and multi-range Duncan test was used to compare the mean values of the results at confidence level of 95%. All the experiments were conducted in 4 replications and SAS software (2001) was used to perform the statistical analysis[23].

3. Results and Discussion

We found that there is a significant difference ($p<0.05$) among three studied varieties in terms of dry matter content (Table 1). The highest value was in kenebek (20.39%). Although there can be a relationship between specific gravity and dry matter content, our results revealed there is no significant difference ($P>0.05$) in the values of specific gravity among the studied varieties.

Some previous works[24-27] have suggested that potatoes with higher specific gravity can produce French fries with better flavor, tendered texture and lower oil contents. Thus, it can be expected that kenbek variety leads to fried products with lower oil and better texture compared with other two varieties because it has the highest dry matter and specific gravity.

The other result is that no significant difference ($P>0.05$) can be found in reducing sugars values of the studied varieties (Table 1). It has been shown that for fried products (French fries and chips), lower contents of reducing sugars is favorable[28]. Since Satina variety has the highest value of reducing sugars, its fried products can be darker with more intense color. We found that Satina had the highest amounts of sucrose (non-reducing sugar), so production of reducing sugars due to cold storage and inversion can be higher in this variety and it is not appropriate for potato chips production, particularly when we are expecting a bright yellow color in the final product. It is possible to use this variety to production French fries with a reddish color, but by controlling the storage condition, as been described by Dokhani[29].

3.1 Influence of Partial Drying on Satina French Fries

As it can be seen in Table 2, partial-dried products had a lower oil content than blank samples ($p<0.05$) and by increasing the drying time, oil content in fried products is reducing. It can be related to blocking of capillary tubes and collapse of the porous structure of potato pieces due to drying and this prevents the oil absorption during the frying process. The same results have been reported elsewhere[3, 7, 8, 10, 14, 17, 19, 20].

Our results (Table 2) showed that moisture content of final products is reducing by partial drying. Higher the drying time, lower the moisture content ($P>0.05$). Also, partial drying leads to an increase in the required force for cutting the potato pieces which are directly proportional to the drying time (Table 2). In fact, there is a significant difference in the texture of dried products at various times and blank sample ($p<0.05$).

In terms of color, L parameter (darkness) increased in partial-dried products (Table 2), due to Maillard reaction or starch gelatinization. The same trend was observed in a (redness) parameter. But, the difference between dried samples and the blank one was not significant ($P>0.05$). Increase in a parameter by drying can also be related to higher browning reactions (Maillard) or starch gelatinization. Change in b parameter is similar to a parameter. Our results showed that ΔE was changing similar to other three color factors. The highest and lowest ΔE values were related to 30 min dried samples and blank samples, respectively.

3.2 Influence of Partial Drying on Kenebek French Fries

Our results (Table 3) revealed that partial drying reduces the oil content of fried products. As long as there is no increase in porosity of potato structure, drying can prevent oil penetration into texture by creating a crust at the surface of French fries and blocking the surface pores. The major part of oil absorption takes place during the frying process, remo-

Table 1 Physicochemical properties of three potato variety cultivated in Golestan province of Iran.

Variety	Dry matter content (%)	Moisture content (%)	Specific gravity	Sucrose (%)	Reducing sugar (%)
Satina	16.54[b]	83.46[a]	1.074[a]	1.47[a]	0.81[a]
Agria	17.03[ab]	82.97[ab]	1.067[a]	0.88[b]	0.72[a]
Kenebek	20.39[a]	79.61[b]	1.086[a]	0.76[c]	0.62[a]

Means with the same letter in a column are not significantly different at 95% level.

Table 2 Influence of partial drying on quality attributes of potato French fries of Satina variety.

Treatment	Fat content (%)	Dry matter content (%)	Moisture content (%)	Required cutting force	L	a	b	ΔE
blank	11.46[a]	41.12[a]	58.88[a]	35.5[d]	59.63[b]	0.40[a]	20.21[a]	63.77[a]
10 min pre dried sample	9.85[ab]	47.01[a]	52.99[a]	56.5[c]	60.46[a]	0.53[a]	22.27[a]	65.41[a]
20 min pre dried sample	8.45[ab]	50.40[a]	49. 60[a]	75.5[b]	61.41[a]	0.81[a]	23.63[a]	67.88[a]
30 min pre dried sample	6.83[b]	51.82[a]	48.18[a]	80.0[a]	63.60[a]	3.23[a]	26.92[a]	65.66[a]

Means with the same letter in a column are not significantly different at 95% level.

val of fried products from oil and cooling of product, so by partial drying before frying, there can be some moisture loss and increase in dry matter content. Due to moisture removal during frying, oil is absorbed and replaced in fried products, and so by moisture removal during partial drying, the oil absorption can be reduced[3, 7, 8, 10, 14, 17, 19, 20].

Interestingly we found that partial-dried samples of Kenebek variety at higher drying times had higher oil content than their 10 min counterparts (Table 3), which is opposed to the normal trend. This can be due to an increase in porosity and internal pores of the products during higher times of drying, which is in agreement with the literature[13]. Therefore, it can be recommended that for this variety, lower times of partial drying should be used.

Considering texture analysis, partial drying increases the required force for cutting Kenebek French fries ($p<0.05$) which is similar to Satina variety. As it can be seen in Table 3, by increasing the drying time, more force is needed to cut the pieces.

Regarding color, although partial-dried samples had high L values, the difference was not significant ($P>0.05$), similar to a value. There was just a significant difference between b value of 30 min dried sample and the blank one ($p<0.05$). The entire drying treatments resulted in ΔE increase, and the highest ΔE value was observed for 30 min drying treatment (Table 3). As discussed earlier, increase in a, b, and ΔE values during the partial drying process can be related to an increase in browning reactions (Maillard) or starch gelatinization and caramelisation.

3.3 Influence of Partial Drying on Agria French Fries

We found a different trend in Agria variety (Table 4), as by partial drying, oil absorption was increased in the resulted French fries. It can be concluded that partial drying rapidly evaporates the water from potato texture and causes high porosity in the texture, which have a high potential for oil absorption during the frying process[13]. By increasing the drying time, surface moisture is evaporated and a skin can be formed, which together with surface shrinkage leads to a decrease in oil absorption, as verified elsewhere[3, 7, 8, 10, 14, 17, 19, 20].

Our result in Table 4 showed that partial drying of Agria variety reduces the moisture content significantly ($p<0.05$). By rapid evaporation of water, porosity is increased and more space is provided for oil uptake and that is why partial drying in this variety increases the oil absorption. Texture analysis results of Agria are similar to the other two varieties and color analysis results have been presented in Table 4.

Table 3 Influence of partial drying on quality attributes of potato French fries of Kenebek variety.

Treatment	Fat content (%)	Dry matter content (%)	Moisture content (%)	Required cutting force	L	a	b	ΔE
Blank	14.11[a]	44.36[a]	55.64[a]	12.18[d]	66.18[a]	-0.98[a]	15.57[b]	15.52[b]
10 min pre dried sample	9.5[b]	44.92[a]	55.08[a]	14.97[a]	70.11[a]	-0. 70[a]	19.03[b]	19.22[b]
20 min pre dried sample	10.48[b]	45.79[a]	54.21[a]	14.04[b]	69.60[a]	-0.74[a]	20.38[ab]	20.40[ab]
30 min pre dried sample	14.63[a]	50.44[a]	49.56[a]	13.63[c]	64.95[a]	2.08[a]	26.63[a]	26.77[a]

Means with the same letter in a column are not significantly different at 95% level.

Table 4 Influence of partial drying on quality attributes of potato French fries of Agria variety.

Treatment	Fat content (%)	Dry matter content (%)	Moisture content (%)	Required cutting force	L	a	b	ΔE
Blank	14.27[b]	60.03[c]	39.97[a]	46.50[d]	68.71[ab]	-0.36[a]	34.96[a]	77.93[a]
10 min pre dried sample	20.72[a]	67.82[bc]	32.18[ab]	55.50[c]	69.25[ab]	-19.61[a]	34.57[a]	83.61[a]
20 min pre dried sample	17.41[ab]	77.30[ab]	22.70[bc]	77.50[b]	71.65[a]	-1.24[a]	33.78[a]	79.26[a]
30 min pre dried sample	16.02[b]	78.75[a]	21.25[c]	92.50[a]	65.00[b]	-1.25[a]	30.28[a]	71.93[a]

Mean with the same letter in a column are not significantly different at 95% level.

4. Conclusions

We found that different potato varieties have different behaviors in terms of oil absorption after partial drying. In Satina and Kenebek, partial drying reduced the oil content of the final French fries, while in Agria, opposite trend was observed. Although fried products of Satina variety had low oil content, there was a high amount of reducing sugars and sucrose in this variety which is not favorable for the production of bright-yellow fried products. Our result showed that the required force for cutting is increased by partial drying of samples before frying. In general, there is an increase in L, a, b, and ΔE values of color with drying time that can be related to higher rates of browning reactions (Maillard). It can be concluded that partial drying prior to frying can decrease the oil uptake of French fries significantly, as long as the porosity of the texture is not increased.

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