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Fat Absorption in Commercial French Fries Depending on Oil Type and Coating

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Abstract
This study examines the effect of edible coatings, type of oil used, and cooking method on the fat content of commercially available French fries. In contrast to earlier studies that examined laboratory prepared French fries, this study assesses commercially available French fries and cooking oils. This study also measured the fat content in oven baked French fries, comparing the two cooking methods in addition to the comparisons of different coatings' oil uptake. The findings of this study were that the type of oil used did have a significant impact on the final oil content of the uncoated and seasoned fries. The fries coated in modified food starch and fried in peanut and soy oils had what appeared to be significantly higher oil content than those fried in corn oil or baked, but the difference was not statistically significant. Additionally, fat content in French fries with hydrocollidial coatings that were prepared in corn oil were not significantly different than French fries with the same coating that were baked.

Keywords
French fries, fat absorption, fat content, hydrocollidial coatings, frying

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INTRODUCTION

In 1953 the J.R. Simplot Company patented the frozen potato French fry. Since that time, frozen potatoes consumption has steadily increased. In 1960, Americans consumed a yearly average of 7.6 pounds of frozen potatoes and 81 pounds of fresh potatoes (Buzby & Farah, 2006). By 1993, frozen potato consumption exceeded fresh (Buzby & Farah). According to the United States Department of Agriculture's (USDA) Economic Research Service (ERS), Americans ate 56.4 pounds of frozen potatoes in 2004, mostly French fries, and 46.5 pounds of fresh potatoes (2006).

Before World War II, French fries were rarely consumed because the preparation required peeling, cutting and frying. Without expensive machinery, making a French fry took much time; innovations in food processing techniques allowed centralized French fry production. Today, French fries are typically produced in a few central locations where they are frozen at -40 degrees and shipped to the point of consumption (Schlosser, 2002).

PREPARATION METHODS

Over 90% of United States French fries consumption happens in quick service restaurants (Buzby & Farah, 2006). French fries are primarily prepared by deep fat frying: an easy, fast, and relatively low cost process where heat is transferred and oil is absorbed by the food concurrently (Krokida et al., 2001). Factors affecting this process include the type and shape of the food, the temperature of the oil, and the type of pre-treatment. French fries can alternatively be oven-baked, which is perceived to be a healthier preparation method. Many French fry manufacturers provide directions for baking.

HEALTH IMPLICATIONS

In 2006, 35.3% of American adults were classified as obese. The last few decades, the population of individuals who are either obese or overweight in the United States has steadily increased (Ogden, Carroll, McDowell, & Flegal, 2007). It is well known that a surplus of saturated fat in diet is the chief contributor to high blood cholesterol, high blood pressure and coronary heart disease (Saguy & Dana, 2003). Consumer awareness of the links among food, nutrition, and health has led to interest in limiting oil consumption. In a survey of over 1,500 consumers, over half described themselves as "Fried Food Curtailers" or "Fried Food Avoiders" (Services, 2003).

During the deep fat frying method, oil not only serves as a heating medium but also absorbs into the food, increasing the total fat content. Several methods have been studied to reduce oil uptake in French fries: edible coatings, oil type, oil temperature and frying time. "Oven-frying" French fries is a growing trend in institutional foodservice, as it is considered a healthier alternative (Van Eijck, 2007; Weisberg, 2009; White, 2009). However, peer reviewed research supporting health benefits of baked French fries has been limited.

LITERATURE REVIEW

As consumer interest in low fat food increases, restaurateurs must adapt to meet customer demand. Oil type, oil temperature, frying time and edible coatings have the greatest affect on oil uptake, a major contributor to total fat content in deep fried foods. This study examines oil type and edible coatings effect on French fries. Baked French fries will also be examined to explore the greater picture of healthier food products.

Edible Coatings

Coatings are used on French fries to reduce oil uptake (Khalil, 1999). Hydrocolloids are an excellent coating because they exhibit good barrier properties to oxygen, carbon dioxide, and lipids (Albert & Mittal, 2002; Garcia et al., 2004; Mallikarjunan, Chinnan, Balasubramaniam, & Phillips, 1997; Martelli, Carvalho, Sobral, & Santos, 2008). Hydrocolloids used in French fries include proteins, cellulose derivatives, alginates, pectins, and starches (e.g. agar-agar, carrageenan, modified food starch). Incorporating low levels of hydrocolloids

such as powdered cellulose reduces oil uptake in fried foods (Ang, 1993; Mallikarjunan et al., 1997). Cellulose derivatives such as methyl cellulose, hydroxypropyl cellulose and hydroxypropylmethyl cellulose not only reduced oil uptake but also increased water retention during the frying process. Preserving water levels is important because moisture affects the mouth feel of fried food products (Albert & Mittal, 2002; Rimac-Brncic, Lelas, Rade, & Simundic, 2004). However, no studies have explored commercially available French fries. This study addresses this limitation by testing commercially available French fries with various coatings.

Frying Oils

Flavor and heat characteristics vary by oil, with significant effects on the end product (Warner & Mounts, 1993). Thus, care must be taken in deep fat frying oil selection. A good quality deep fat frying oil should be bland in flavor to avoid flavor transference. Oil should be stable at high temperatures; have a high smoke point, preferably over 400°F; and a flash point above 600°F (Mackay, 2000). Frying oil with low linolenic acids and high in monoenoic acids is desired because oils with high linolenic acids quickly degrade when exposed to frying conditions (Ruiz-Mendez & Mancha, 2003; Yaghmur, Aserin, Mizrahi, Nerd, & Garti, 2001). Currently, in foodservice establishments the main types of frying mediums are palm, olive, peanut, sunflower and soy oils (Kita, Lisinska, & Powolny, 2005). Although no studies have found the type of oil used to be a statistically significant factor in oil absorption, no studies have examined commercially available French fries (Hazebroek, 2000; Rimac-Brncic et al., 2004).

Many studies have investigated the effects of temperature on oil (Agblor & Scanlon, 2000; Du Pont, Kirby, & Smith, 1992; Kita & Lisinska, 2005; Kita et al., 2005; Moreira, Sun, & Chen, 1997; Rimac-Brncic et al., 2004; Ruiz-Mendez & Mancha, 2003; Saguy & Dana, 2003; Ufheil & Escher, 1996; Yaghmur et al., 2001). These studies found that the degradation of frying medium can greatly affect the oil absorption during the deep fat frying process. Oil degradation is caused by prolonged high temperature combined with the presence of moisture and oxygen and results in hydrolysis (i.e., hydrogen added to the oil), oxidation, and the changing of the chemical compound in fats. This converts unsaturated fats to saturated fats and changes the length of the fat molecules. The result of oil degradation is that more energy is required to heat the oil, lowered heat capacity, decreased surface tension, and increased contact time between the oil and food product (Mackay, 2000). Because, the effects of oil degradation have been established, this study will not be looking at this oil degradation as a factor in the analysis of the results.

Baking of French Fries

The Oxford English Dictionary defines baking as "cook by dry heat without direct exposure to flame, typically in an oven or hot surface" (Dictionary, 2004). At face value it seems that oven baking adds no additional fat to French fries. However, in a literature search conducted by the authors found only one peer

reviewed article that found that oven baked French fries had lower oil content than their deep fat fried counterparts. That article concluded that there was not a statistically significant difference in lipid content between baked French fries and deep fat fried French fries (Lloyd, Farkas, & Keener, 2004). However, anecdotal evidence shows that institutional food service has started to bake their French fries as a healthier alternative for their patrons (Van Eijck, 2007). The reason that baked fires have such high oil content is that the most often purchase frozen French fries have been par-fried. Par-frying is the process of deep fat frying potatoes until they are partially cooked; this inherently adds fat to the product.

Purpose of Study

An extensive literature search conducted by the authors found several studies on the effects of hydrocolloid coatings and oil types on fried foods (Albert & Mittal, 2002; M. K. Krokida, Oreopoulou, Maroulis, & Marinos-Kouris, 2001a; Mallikarjunan et al., 1997; Suárez, Campañone, García, & Zaritzky, 2008; Ufheil & Escher, 1996). However, in those studies the authors prepared the coatings specifically formulated to test the properties of certain compounds; as mentioned previously, restaurants often do not prepare their own French fries (Albert & Mittal, 2002; Ang, 1993; Garcia et al., 2004; Haase & Weber, 2003; Kita & Lisinska, 2005; Kita et al., 2005; M. K. Krokida et al., 2001a; M. K. Krokida, Oreopoulou, Maroulis, & Marinos-Kouris, 2001b). Because the average restaurant purchases their French fries commercially with coatings that are designed to extend holding times and improve flavor in addition to reducing oil absorption, the results of those studies may not accurately reflect the results seen in a restaurant operation. This study will evaluate coatings on commercially available French fries and aims to fill this literature gap by analyzing fat content in commercially available French fries.

The main purpose of this study is to examine the effect of edible coatings, type of oil used, and cooking method on the fat content of commercially available French fries. As oven baking French fries are gaining in popularity in response to consumers' demands for healthier products, it is important to look at the product's oil content rather than just the oil uptake. By including measures of the fat levels in oven baked French fries, this study offers a comparison of the two cooking methods in addition to comparisons of different coatings' oil uptake.

Methodology

French Fries

The authors investigated popular brands sold by a national grocery store and found that most French fry manufactures listed modified food starch as one of the ingredients in their coatings. Therefore, this study investigated modified food starch coatings used by various commercial French fry manufacturers. Considering the premise of this study, several brands of frozen French fries were

bought from a local restaurant supply store. The French fries used in this study were selected because they represent the three major classes of French fries available: coated with modified food starch, uncoated and heavily seasoned.

Cooking Methods

A commercial deep fat fryer was used to prepare the deep fried French fries. The fryer was filled with to the manufacturers' recommend fill line with oil. The frying basket was filled with a half-pound of French fries per batch. The oils that were chosen are peanut, corn and soybean oil. The oils used were selected for their variation in monoenoic and linoleic acids and differences in inherent stability as shown in Table 1.

Manufacturer cooking instructions were followed for each of the different French fries. The recommended oil temperature for all fries used in this study was 350°F (177°C). To reduce the potential impact of oil degradation, new oil was used and the order in which the different fries were cooked was rotated between trials. The cooking time was three minutes for both coated with modified food starch and uncoated French fries and 2.75 minutes for heavily seasoned French fries as recommended by the manufacturer.

A combination oven was used to prepare the oven-baked French fries the. The fries were placed on a sheet tray with 1 lb. of French fries and baked in combination mode for 12 minutes at 400°F (204°C) in accordance with manufacturers' instructions; this method of preparation is also used in previous studies.(Weisberg, 2009; White, 2009).

DATA COLLECTION AND ANALYSIS

The French fries were prepared either by deep fat frying or baking. After the fries were prepared each batch was frozen overnight on a sheet tray with with the temperature of the freezer set at 0°F (-18°C). The frozen samples were then ground with a Bamix® hand blender. The ground samples were placed extraction thimbles of known weight then weighed. The ground samples were then dried a gravity drier for 36 hours at 212°F (100°C). To determine moisture content drying the samples were weighed again. Fat content for the fries was determined by using a Soxhlet extraction method (M. Krokida, Oreopoulou, & Maroulis, 2000). The dry samples were placed in a Soxhlet and the fat was extracted with petroleum ether for six hours. The samples were again dried in a gravity dryer for two hours at 212°F (100°C) then weighed. Percent fat was calculated wet basis by subtracting the weight of the French fry solids and moisture content from the starting product then dividing it by weight of starting product. Analyses were conducted in duplicate. Experimental data were analyzed by analysis of variance (ANOVA). The Tukey test was used to make pairwise comparisons. Differences between samples at the 5% ($p \leq 0.05$) were considered statistically significant. All statistical analyses were performed using the SAS software program.

Table 1
Characteristics of Frying Oils

Fat Type	Lipid Content	Inherent Stability
Sunflower	High oleate	6.8
Canola	High oleate	5.5
	Low linolenate	
Soybean	High oleate	7.0
	Low linolenate	
Peanut	High oleate	3.7
High-oleic Sunflower	High oleate	1.9
	Low linolenate	
Corn Oil	High linolenate	5.8
	Low oleate	

RESULTS & DISCUSSION

Effects of Oil type

The effects of oil type, cooking method and hydrocolloid coating on the final oil content of French fries is shown in Table 2. To fully understand the impact of cooking, the percent moisture and solid content were also reported in Tables 3 and 4, respectively. The contents of the frozen fries as purchased are also included in the tables. They are labeled as "Par-Fried." This is to indicate that all fries used in this study had undergone the standard par-frying procedure prior to being frozen and packed for shipment.

Table 2.
Means of Fat (percent wet basis) in Different French Fry Coatings by Oil Type Used.

	Modified Food Starch	Uncoated	Seasoned
Peanut	0.083a	0.097a	0.079a
Soy	0.083a	0.058b	0.056b
Corn	0.063a	0.089a	0.051b
Baked	0.049a	0.059b	0.050b
Par-fried	0.052a	0.054b	0.037b

Note. Same letters in each column indicate that there were no statistically significant difference found ($p \leq 0.05$) between means.

The type of oil used did have a significant impact that final oil content of the uncoated and seasoned fries. While the fries coated in modified food starch and fried in peanut and soy oils had what appeared to be a significantly higher oil content than those fried in corn oil or baked, the difference was not statistically significant. The reason for this was the high variance between samples. Three additional analyses were performed on the frozen samples for the modified food starch coated fries because of the variance. However, the when those additional analyses were included there was no change is the results. The reason for the unusually wide variation is not readily apparent. All fries from each treatment were ground together prior to chemical analysis the variation should have been smaller. More study is needed to determine the reasons behind the vide variation for the modified food starch coated fries.

For the seasoned French fries, the fries cooked in peanut oil had significantly higher fact content (see Table 2). The other three cooking methods did not vary significantly from each other. While the difference was not statically significant, it appears that all method of cooking resulted in an increase in the fat increase compared to the par-fried or partially cooked fries. This does not necessarily mean that they absorbed more oil during the cooking process. No oil was used in the baking process but the fat content increased during cooking. The reason for this was that fries lost weight in form of water evaporation during cooking (see Table 3). As a result the oil accounted for a larger percentage of the final product as the weight of the fries dropped.

Table 3.
Means of Water Content (percent wet basis) in Different French Fry Coatings by Oil Type Used.

	Modified Food Starch	Uncoated	Seasoned
Par-fried	0.67a	0.69a	0.68a
Baked	0.53b	0.54b	0.47c
Soy	0.50c	0.52b	0.49bc
Peanut	0.49c	0.52b	0.50b
Corn	0.46d	0.54b	0.49bc

Note. Same letters in each column indicate that there were no statistically significant difference found ($p \leq 0.05$) between means.

The uncoated fries appeared to absorb the peanuts and soy oil during cooking, but not the corn oil. The fat content of the uncoated fries fried in corn oil had roughly the same fat content as the baked fries (see Table 2).

Table 4 contains the final solid contents after cooking. The total amount of solids was expected to be relatively constant during cooking. For the coated fries, very small amounts of the coatings came off during cooking. As

expected, in all case the solid content increased compared to the par-fried only fries as each of the fries lost moisture during cooking.

Table 4.
Means of Solid Content (percent wet basis) in Different French Fry Coatings by Oil Type Used.

	Modified Food Starch	Uncoated	Seasoned
Corn	0.48a	0.47a	0.46b
Baked	0.42b	0.40b	0.48a
Soy	0.41b	0.42b	0.45b
Peanut	0.43b	0.38c	0.42c
Par-fried	0.28c	0.26d	0.28d

Note. Same letters in each column indicate that there were no statistically significant difference found ($p \leq 0.05$) between means.

Effects of Coating

There was a significant difference ($p \leq 0.05$) between uncoated French fries and all other coatings (see Table 5), however, the modified food starch was only partially different from the uncoated. Uncoated French fries absorbed more oil than all other fries because there was no barrier for absorption.

Table 5.
Means of Oil Absorption (percent wet basis) in Different Cooking Methods by Coating.

	Peanut	Soy	Corn	Baked	Par-fried
Uncoated	0.097a	0.059a	0.088a	0.059a	0.054a
Seasoned	0.079b	0.056a	0.052b	0.050b	0.037a
Modified Food Starch	0.083b	0.083a	0.063b	0.049c	0.052a

Note. Same letters in each column indicate that there were no statistically significant difference found ($p \leq 0.05$) between means.

Commercially prepared French fries are par-fried; this means that regardless of preparation method used in a restaurant they will contain some fat. It is important to note that uncoated French fries and both types of coated fries, and par-fried only, did not have significantly different fat content than each other, due to the par frying. This study's findings clearly show that French fries absorbed more peanut oil than other types of oil. This could be due to its higher concentration of monounsaturated fats and lower concentration of

polyunsaturated fats. The mono unsaturated fats may have an easier time moving through the coatings (Mackay, 2000).

Seasoned French fries started out with a lower fat content than the other types of fries, however, after preparation both types of coated French fries had similar fat content. The findings also show that fries that are uncoated contain a greater amount of fat than either types of coated French fries after all types preparation including baking. The uncoated French fries had more fat after baking than the both types of coated fries because of moisture loss. This is likely due to the hydrocollidal coatings used on the coated French fries creating a barrier to moisture loss.

CONCLUSION

The type of coating and cooking method has an important role in the fat content of a French fry. The results of this study indicate that French fries prepared with a hydrocollidial coating have a significantly lower fat content than French fries which have no hydrocollidial coating. The implication of these results is that restaurants should discontinue the use of uncoated French fries.

Another finding from this study was, fat content in French fries with hydrocollidial coatings that are prepared in corn oil are not significantly different than French fries with the same coating that are baked. In a practical sense the seasoned French fries deep fat fried in corn oil had a fat content that was only .0011% greater than fries that were baked; while coated French fries deep fat fried have a fat content that was 0.0139% greater that its baked counterpart. It may seem counterintuitive that the difference of fat in baked and deep fried French fries is negligible. However, this effect happens because most of the French fries' fat content actually comes from being par fried during the manufacturing process. To lower the fat content the manufacturer should avoid par frying the French fries, however, this will worsen the texture of the fries greatly making this an unviable option (M. K. Krokida et al., 2001a; Suárez et al., 2008).

With no statistically significant difference and very little practical difference between baked French fries and corn oil deep fat fried, foodservice operators should be wary of changing their products for such little gains in consumer health. While the baked French fries seem intuitively healthier, they have a lower texture quality (Nonaka, 1980). Foodservice operators would do better by educating their customers that their deep fat fried French fries have better flavor while having only marginally more fat than their competitors "healthy" baked French fries. This would allow them to make their customers happy, while not needed to take on the capital costs of purchasing additional ovens, to bake French fries.

Table 6 shows the practical difference between 4oz of baked French fries and 4oz of traditionally cooked French fries. The difference between baked fries coated with modified food starch and French fries cooked in corn oil is only 1.58 grams of fat or approximately 14 calories. The difference uncoated fries cooked

in peanut oil and uncoated baked French fries, the group with the largest difference in fat, was about 40 calories or 2% of a 2000 calorie diet. In a practical sense 40 calories is less than half a banana.

Table 6.
Amount of fat (grams) in a four ounce serving of French fries

	Peanut	Soy	Corn	Baked
Uncoated	11.02	6.68	9.99	6.69
Modified Food Starch	9.40	9.41	7.11	5.53
Seasoned	8.95	6.40	5.80	5.68

Typically baked products are considered healthier than deep fat fried foods. Despite the fact that baked French fries had the least amount of fat; when compared to fries prepared in corn oil there were no statistically significant differences. This finding challenges the "healthy" status of baked French fries in popular culture. This is due to the par frying during the manufacturing process.

In order to provide consumers with healthier fries, manufacturers must increase research and development to find a manufacturing process that does not add fat to French fries. As this research shows foodservice operators are unable to significantly lower the fat content of French fries through preparation methods alone. Despite public view of baking as a health preparation method the capital expense required and the negligible health benefits of baking French fries within a restaurant suggest that the better strategy for healthier French fries is using French fries with hydocollidal coatings and avoiding frying oils that are high in saturated fats. Within the combinations of oils and French fries tested, uncoated French fries should be fried in soy oil and fries coated in modified food starch and seasoned fries should be prepared in corn oil to yield the lowest fat content. Operators should test their French fries with different oils to determine the combination with the lowest fat content.

Limitation and Future Research

This study examined only three types of commercial French fries, whereas the manufacturing process may differ in other French fry varieties. Additionally, only four types of cooking methods were used, French fry oil uptake may differ with other types of frying oils.

While the current study examined hydrocolloids coatings and preparation methods in French fries, other factors such as cook time, cook temperature, and oil degradation are factors that should be examined on commercially available French fries. Future research should be conducted on coatings that can better withstand oil absorption and making these coatings commercially viable. Furthermore, the type of fats being absorbed into the French fries should also be examined.

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