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Effect of Different Pre-treatments and Oils on Oil uptake Kinetics of Potato Chips

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ABSTRACT

Frequently deep-fried, potato chips are a favorite snack that use a lot of oil to fry them. The kinetics of oil uptake and absorption in potato chips were investigated by researchers. In this investigation, we studied the effects of several pre-treatments on the rate of oil absorption by potato chips during frying. There were five different treatment procedures chosen (T1, T2, T3, T4, and T5). Before deep-frying, potato chips underwent pre-treatments and the rate of oil absorption was assessed. Comparing T1 that was fried in mustard oil to sunflower oil, ground nut oil and canola oil, the results showed that T1 had the highest oil absorption percentage and oil uptake kinetics. The oil uptake was determined after deep-frying the prepped potato chips at a regulated temperature of 180°C.

Keywords : Potato chips, Oil uptake kinetics, Pre-treatment, Deep-frying

In the potato chip process, raw potatoes are washed, peeled, sorted and cut into slices. Some potato processing plants use blanching in hot water and drying with warm air until moisture content of 60 g/ 100 g (w.b.) is reached, prior to frying. After this, potato slices are usually fried in a continuous fryer with hot oil (170-190ºC), where they remain until the moisture level is less than 2 g/100 g (w.b.). Finally, potato chips are salted, cooled in ambient air and packaged. The blanching step improves the color and texture and could reduce the oil uptake by gelatinization of the surface starch (Adedeji *et al.,* 2011).

Aguilera and Gloria, 1997 found that when moisture removal proceed towards equilibrium, oil absorption reaches its maximum and this indicates that moisture content during frying has a significant impact on oil absorption. Condition of frying Oil content of potato slices was shown to be impacted by both the type of oil used for frying and the temperature at which it was fried (Aguilera and Gloria, 2000).

According to (Baumann and Escher, 1995), coloring oil is used to identify the several types of oil: suggested surface oil (SO), which describes the oil's adhesion on the sample's surface after cooling; structural oil (STO), which refers to the oil inside the sample and penetrated surface oil (PSO), which defines the various oil fractions.

Frying is one of the oldest cooking methods widely used to prepare tasty and crispy foods; with fried potato products being one of its largest applications. Potato chips have been popular salty snacks for 150 years and its retail sales in US are about $6 billion/ year representing 33 per cent of the total sales on this market (Bunger *et al.,* 2003) Deep-fat frying is one of the oldest processes of food preparation and consists basically in the immersion of food pieces in hot oil. The high temperature causes an evaporation of the water, which moves away from the food and through the surrounding oil. Oil is absorbed by food, replacing some of lost water. The aim of deep-fat frying is to seal the food by immersing it in the hot oil

so that all flavors and the juices are retained by the crisp crust (Califano and Calyelo, 1987).

Potato chips were invented in 1853, in the USA and became popular throughout the world. In developing countries such as India, they are the most popular potato product. Deep fat frying is a widespread operation used in food processing industries to prepare tasty and crispy foods-fried potato products are of its largest applications. Potato chips have a unique texture flavor combination, which makes them so desirable in market (Clark, 2003 and Duran *et al.,* 2007).

Frying is one of the oldest processes of food preparation. For decades, consumers have desired fried foods because of their unique combination of flavor and texture. The quality of the products from frying depends not only on the frying conditions, but also on the type of oils and the pre-treatment method of material during the process (Garayo and Moreira, 2002). Many approaches to reduce oil absorption in fried products have been reported in the literature. For instance, soaking of potato strips in NaCl solutions reduced oil uptake in French fries (Hindra and Baik, 2006). Frying has shown that water evaporation as well as oil absorption occurred during frying, which resulted in crispy taste property of potato chips. The whole frying processing was related to a series of physical and chemical changes, including protein denaturation, starch gelatinization, Maillard reaction, caramelization and other process the potato chips have a special flavour (Kita *et al.,* 2007). Moisture removal during frying leads to uptake of oil that equals to 35-40 per cent of the mass of the product (Mellema, 2003). To decrease this high oil absorption, pretreatment by citric acid, NaCl and calcium chloride can be used (Mestdagh *et al.,* 2007). On the other hand, the addition of NaCl, $CaCl_2$ or citric acid might also change the oil uptake (Moreira *et al.,* 1995; Moreira *et al.,* 1997 and Pedreschi *et al.,* 2008). With higher temperature, speeds up the process of development of thicker crust resulting in the reduction of moisture and limiting oil uptake, while lower temperature requires longer frying time resulting in higher fat content. Continuous deep frying thus appears to lead to more water loss and thicker crust formation favourable to oil absorption (Pedreschi *et al.,* 2007 and Rimac *et al.,* 2004). According to (Shiyu and Hwang, 2001), oil does absorb more slowly during frying and fills the pores that are created throughout the process after it cools. The situation changed once the chips cooled with the absorbed 65 and 64 per cent total oil content and the rest of the oil remained at the surface. The temperature change affects the oil distribution during frying and cooling (Vitrac *et al.,* 2000 and Zhang *et al.,* 2016).

Material and Methods

At the Laboratory of Agro Processing Centre, Department of Agricultural Engineering, College of Post Harvest Technology and Food Processing, S.V.P. University of Agriculture & Technology, Meerut (U.P.), India, experiments were carried out to examine the 'Effect of different pretreatments and oils on oil uptake kinetics of potato' from January to April 2023. Experiments were conducted to examine the chemical properties of freshly fried potato chips made with mustard oil, sunflower oil, groundnut oil and canola oil. Various tools and techniques employed throughout the research are listed under the following headings.

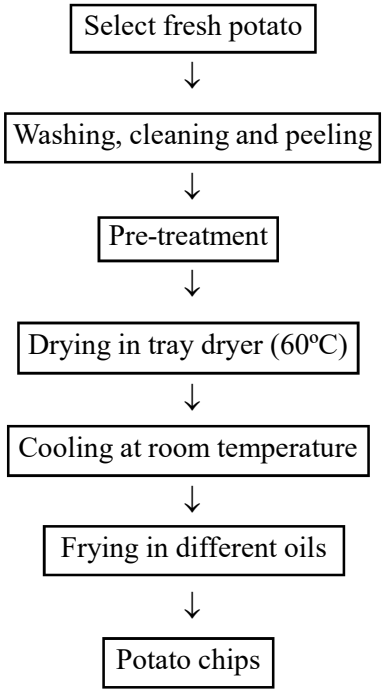
Raw Materials

Fresh vegetables were purchased from the neighborhood market in Meerut, India (U.P). With a knife with a sharp edge, the leaves and end portion were removed. Then, the surface was washed with tap water to remove the dust and dirt. Using a chips cutter to cut slices after being peeled and given another water wash. The several treatments were applied to the chips once they had dried and been cut into weight samples for each pre-treatment and drying process.

Preparation of Potato Chips

The Laboratory of Agro Processing Centre, Department of Agricultural Engineering, College of Post Harvest Technology and Food Processing, S.V.P. University of Agriculture & Technology, Meerut (U.P), India develop the potato chips and tested them

in a comparative analysis. Studies on the oil uptake and oil uptake kinetics of potato chips in various oils were also conducted. The flowchart and the following method were used to make potato chips.



Flowchart for Development of Potato Chips

Pre-treatments : The potato slices received pretreatments and a control sample was left untreated. Slices were pre-treated using the following substances: salt (NaCl), potassium meta-bisulphate (KMS), citric acid (CA) and calcium chloride ($CaCl_2$) :

T1 : Blanching with 90ºC for 5 min,

T2 : Blanching with 1% Nacl at 90ºC for 5 min

T3 : Blanching with 0.5% KMS + 1.0% NaCl at 90ºC for 5 min.

T4 : Blanching with 0.5% KMS + 1% NaCl + 0.5% CA at 90°C for 5 min.

T5 : Blanching with 1% $CaCl_2$ + 1% NaCl at 90°C for 5 min.

The slices were then taken out of the solution, the surface wetness was wiped off with blotting paper, and they were spread out in trays that were dried in a tray dryer at 60 °C.

Slicer

Vegetables were cut into slices using a slicer. Slices range in thickness from 2 to 3 mm depending on the slice blade.

Oil Absorption Percentage

The change in the initial weight of the potato chips per unit of initial weight of the potato chips multiplied by 100 was used to calculate the oil absorption percentage.

$$\text{Oil Absorption (\%)} = \frac{\text{Final Weight - Initial Weight}}{\text{Initial Weight}} \times 100$$

Oil Uptake

How much oil absorption was needed in order to fry potato chips entirely was to be determined in seconds. It is the proportion of chips' oil absorption across different oil situations.

Oil Uptake Kinetics

Changes in Final Weight and Initial Weight were measured per unit of time using oil uptake kinetics.

$$\text{Oil uptake kinetics} = \frac{Wf - Wi}{t} \text{ g/s}$$

Where,

Wf = fried weight (g)

Wi = initial weight (g)

T = time (Second)

Spread Ratio

Vernier calipers were used to measure the diameter (mm) and thickness (mm). The following formula was used to obtain the spread ratio.

$$\text{Spread ratio (SR)} = \frac{\text{Diameter (mm)}}{\text{Thickness (mm)}}$$

Mass

Using an electronic balance, the weight of the chips in g was calculated as the average of the values of 10 different chips.

Results and Discussion

The experimental data for changes in oil uptake and changes in the rate at which oil is absorbed by potato chips fried in mustard oil, sunflower oil, groundnut oil and canola oil are presented in Tables 1 and 2. Following several pretreatments applied to potato chips fried in mustard oil, the oil uptake altered. The results showed that sample T1 had the greatest fried weight, oil absorption percentage and oil uptake kinetics as 26.05 g, 29.99 per cent and 0.46, respectively, after 13 seconds of frying. Following a 44-second frying period, sample T4 had the lowest fried weight and oil absorption percentage (21.58% and 24.33 g, respectively), whereas sample T5 had the slowest rate of oil absorption (0.07). Depend on the several pretreatments used before the potato chips were fried in sunflower oil, the oil uptake varied. After 25 seconds of frying, sample T5 had the greatest fried weight and oil absorption rate, which were determined to be 24.50 g and 22.31 per cent, respectively. Sample T3 had the highest in Table 2 oil uptake kinetics, which was found to be 0.25 after 15 seconds of frying. The sample T2 had the lowest fried weight and oil absorption percentage after 25 seconds of frying (22.00 g and 09.34%, respectively), whereas the sample T4 had the lowest

Table 1

Effect of pre-treatment and frying in mustard oil on oil uptake and oil uptake kinetics of potato chips

Treatments	Mustard oil				
	Initial Weight (gram)	Final Weight (gram)	Time (second)	Oil Absorption (%)	Oil Uptake Kinetic gram/ second
T1	20.04 ± 0.24	26.05 ± 0.12	13	29.99	0.46
T2	20.05 ± 0.02	25.03 ± 0.38	25	24.83	0.20
T3	20.18 ± 0.19	25.56 ± 0.12	20	26.66	0.27
T4	20.01 ± 0.21	24.33 ± 0.22	44	21.58	0.09
T5	20.17 ± 0.32	25.40 ± 0.21	69	25.92	0.07

Table 2

Effect of pre-treatment and frying in sunflower oil on oil uptake and oil uptake kinetics of potato chips

Treatments	Sunflower oil				
	Initial Weight (gram)	Final Weight (gram)	Time (second)	Oil Absorption (%)	Oil Uptake Kinetic gram/ second
T1	20.66 ± 0.91	23.50 ± 1.10	22	13.74	0.13
T2	20.12 ± 1.74	22.00 ± 1.86	25	09.34	0.07
T3	20.17 ± 2.02	24.01 ± 2.10	15	19.03	0.25
T4	20.04 ± 1.48	22.50 ± 1.58	46	12.27	0.05
T5	20.03 ± 0.80	24.50 ± 0.97	25	22.31	0.18

oil uptake kinetics (0.04) after 46 seconds. Almost 75 per cent of the entire oil content was absorbed in the first 70 to 80 seconds of frying, indicating that oil absorption happened quite quickly. Table 1 to 5 overall oil content thereafter stayed quite steady until the frying operation was complete. According to (Ziaiifer *et al.,* 2008) also reported findings that were comparable. According to various pre-treatment applied to potato chips before they were fried in groundnut oil, the oil uptake changed. While sample T3 (0.26) had the fastest oil uptake kinetics after 16 seconds of frying, sample T5 had the highest fried weight and oil absorption percentage after 45 seconds of frying, at 25.00 g and 22.12 per cent, respectively. It was discovered that sample T2 had the lowest fried weight, oil absorption rate and oil uptake kinetics after 25 seconds of frying, with values of 21.75 g, 06.72 per cent and 0.05, respectively. With regard to the various pre-treatment applied before the potato chips were fried in canola oil, the oil uptake altered. After 72 seconds of frying, sample T5 was found to have the greatest fried weight and oil absorption percentage, which were 24.25 g and 19.97 per cent, respectively. Sample T1 had the highest oil uptake kinetics, which was found to be 0.14 after 20 seconds of frying. After 36 seconds of frying, sample T2 had the lowest fried weight and oil absorption percentage of 21.25 g, sample T3 had the lowest oil absorption percentage of 02.11 per cent and sample T2 had the lowest oil uptake kinetics of 0.02, all after 36 seconds of frying. Table 5, shows how the spread ratio of potato chips is affected by pretreatment procedures and frying in various oils. With the exception of canola oil, treatment T4 fried in mustard, sunflower and groundnut oils had the highest spread ratio. It was found in treatment T5 of canola oil. However, treatment T1, which was fried in canola, groundnut and sunflower oils but not mustard oil, had the lowest spread ratio. The treatment T3 had the lowest spread ratio when it came to mustard oil. Table 6 shows the effect of pre-treatment procedures and frying in various oils on the mass (g) of potato chips. When compared to other treatments and fried in different oils, treatment T1 had the highest mass when it came to oil absorption. However, treatment T3 fried in canola oil had the lowest oil absorption when compared to other treatments and frying oils.

After drying samples were fried in mustard oil, sunflower oil, groundnut oil and canola oil at 180ºC for a short period. Lightness value was highest in mustard oil T1 (75.98) following frying, T5 (36.26) had the lowest value, greatest a* T1 (-0.11), lowest a* T5 (+3.9), highest b* T1 (44.15) and lowest T5 (33.85), in that order. The highest value of light-colored sunflower fried potato chips oil L* T1 (70.11) lowest lightness value was found in L* T4 (34.08) fried potato chips at the temperature of 180 ºC. The sunflower with the highest a* value was oil T1 (2.89) and lowest a* value was found in T3 (-3.32). T1 (40.37) had the greatest value of b* when it came to fried sunflower oil in potato chips, whereas T3 (31.36) had the lowest value. According to (Viklud *et al.,* 2008), it is widely known that reducing sugars have the greatest effect on alterations in end color products. In a study (Teruel *et al.,* 2015), found that as frying time increased, the L* values of potato chips fried in sunflower oil at 180ºC. The whiteness index was indicated best in groundnut oil (18.20) fried potato chips as compared to mustard oil, sunflower oil and canola oil and lowest value of whiteness index was observed in mustard oil (09.50). The highest value of L* potato chips in groundnut oil L* T3 (61.20) lowest value of L* was found in canola oil L* T2 (46.52) potato chips at the temperature of 180ºC. The groundnut oil with the greatest a* value, T1 (2.70), produced more red color potato chips, while T3 (-3.15) produced the lowest amount of red color potato chips. When groundnut oil was fried potato chips, T3 (25.30) had the highest value of b* and the lowest value of b* (18.59). T3 resulted in more yellow-colored potato chips.

Highest results on color (L*) lightness was found in canola oil fried potato chips at the temperature of 180ºC *i.e.,* T1 (70.80). Near to the lightness and lowest lightness color was observed in canola oil in T5 (34.08) of potato chips. With the highest a* value (-0.51) for canola oil, the chips had a more red color and the lowest a* value (-2.49) for canola oil produced the greenest-colored chips. Sodium

benzoate (0.124 and 0.062%) and Nisin (0.0002 %) were added to the tender coconut water after it had been pasteurized at 85°C for 10 minutes and 90°C for 5 minutes in the first and second treatments (Adiyaman *et al.,* 2023). Using NaCl, Citric Acid, Calcium Chloride and Potassium per magnate chemical usage to blanch potato slices before frying is comparable to treatment T1-T5 of potato chips fried in various oils.

The Maillard reaction, acryl amide production and customer perception all directly connect to the color of potato chips, making it a crucial quality feature and essential criterion for the potato-processing sector (Pedreschi *et al.,* 2006). According to (Papadakis *et al.,* 2000), there are two chromatic components, a* (which goes from green to red) and b* (which goes from blue to yellow) and parameter L* (which goes from 0 to 100), which represents the luminance or brightness component. According to (Martinez and Anonymous, 1986), the color of fried potatoes is the outcome of non-enzymatic browning reactions called Mailard, which are influenced by the temperature, frying time, and the amount of superficially reducing sugar present.

Data indicatited in Table 1 concludes that treatment T4, which has lower oil absorption per cent and oil uptake kinetics, is more affected by potassium permanganate, sodium chloride and citric acid than by pre-treatment and frying in mustard oil. It is imperative to acknowledge that this particular method of producing potato chips is advantageous for individuals with lower dietary fat intake. Table 2 shows how potato chips' kinetics of oil uptake are affected by pretreatment and frying in sunflower oil.

TABLE 3

Effect of pre-treatment and frying in groundnut oil on oil uptake and oil uptake kinetics of potato chips

Treatments	Groundnut oil				
	Initial Weight (gram)	Final Weight (gram)	Time (second)	Oil Absorption (%)	Oil Uptake Kinetic gram/ second
T1	20.32 ± 2.22	23.75 ± 2.40	31	16.87	0.11
T2	20.38 ± 2.40	21.75 ± 2.64	25	06.72	0.05
T3	20.34 ± 1.74	24.50 ± 1.94	16	20.45	0.26
T4	20.14 ± 1.48	23.00 ± 1.58	42	14.20	0.07
T5	20.47 ± 2.42	25.00 ± 2.62	45	22.12	0.10

TABLE 4

Effect of pre-treatment and frying in canola oil on oil uptake and oil uptake kinetics of potato chips

Treatments	Canola oil				
	Initial Weight (gram)	Final Weight (gram)	Time (second)	Oil Absorption (%)	Oil Uptake Kineticgram/ second
T1	20.49 ± 2.10	23.25 ± 2.16	20	13.46	0.14
T2	20.41 ± 1.84	21.25 ± 1.54	36	04.11	0.02
T3	20.32 ± 1.74	21.75 ± 1.81	31	07.03	0.05
T4	20.32 ± 1.24	23.00 ± 1.44	65	13.18	0.04
T5	20.38 ± 1.12	24.25 ± 1.32	72	19.97	0.05

More effects are shown in product treatment T2, which requires longer to fry than other treatments (except from T4) and has a lower percentage of oil absorption. Treatment T2 also has greater effects on sodium chloride and sunflower oil, which absorb less oil. Table 3 shows how pretreatment and frying in groundnut oil affect the kinetics of potato chip oil uptake. The outcome of T2 treatment when fried in sunflower oil. Compared to other treatments, this one has very little oil absorption and minimal oil uptake kinetics. The combination of groundnut oil and sodium chloride is the cause. The impact of canola oil frying and pretreatment on the kinetics of potato chip oil uptake is shown in Table 4. More research is being done to determine the time and amount of oil absorption. The effect is comparable to potato chips fried in groundnut and sunflower oil. Table 5 studied the effects of pretreatment and frying in mustard, sunflower, groundnut and canola oils on the spread ratio of potato chips. It concludes that while increasing diameter increases spread ratio, decreasing product thickness occurs when treatment T4 fried in sunflower oil has the highest spread ratio when compared to other treatments and frying oils. Citric acid has a greater effect in treatment T4 on potato chip thickness reduction. Table 6, 'Effect of pretreatment and frying in mustard oil, sunflower oil, groundnut oil and canola oil on mass of potato chips studied' shows that treatment T1, which does not include any chemical preservative treatment, absorbed the most oil and increased weight in comparison to the other treatments. T3 has higher potassium permanganate and sodium chloride effects on canola oil treatment, resulting in lower oil absorption compared to other fried oil kinds and treatments. Fried in mustard oil, sunflower oil, groundnut oil and canola

TABLE 5

Effect of pre-treatment and frying in Mustard oil, Sunflower oil, Groundnut oil and Canola oil on spread ratio of potato chips

Treatments	Before frying	After Frying			
		Mustard oil	Sunflower oil	Groundnut oil	Canola oil
T1	18.15 ± 0.87	18.45 ± 1.64	22.70 ± 1.89	18.10 ± 3.07	20.23 ± 2.50
T2	16.14 ± 0.36	26.91 ± 1.87	23.09 ± 4.16	30.78 ± 5.13	21.94 ± 2.19
T3	17.75 ± 1.52	17.77 ± 3.03	29.20 ± 9.90	30.02 ± 2.93	25.11 ± 4.97
T4	16.58 ± 1.24	35.72 ± 4.20	46.26 ± 17.15	37.63 ±17.48	26.75 ± 3.60
T5	19.30 ± 2.71	27.25 ± 3.38	43.03 ± 24.39	30.22 ± 1.49	37.10 ± 5.00

TABLE 6

Effect of pre-treatment and frying in Mustard oil, Sunflower oil, Groundnut oil and Canola oil on mass (gram) of potato chips (n=10)

Treatments	After Frying			
	Mustard oil (gram)	Sunflower oil (gram)	Groundnut oil (gram)	Canola oil (gram)
T1	11.83 ± 0.62	11 ± 0.40	07 ± 0.40	4.50 ± 0.40
T2	09.83 ± 0.47	10 ± 0.40	06 ± 0.40	4.50 ± 0.40
T3	11.33 ± 00.84	9.33 ± 0.62	07.33 ± 0.62	4.23 ± 0.20
T4	11.33 ± 1.24	07 ± 0.40	07.66 ± 0.62	5.00 ± 0.40
T5	10.50 ± 1.47	10 ± 0.81	05.66 ± 0.62	5.13 ± 0.26

TABLE 7

Effect of color L*,a*,b* value and whiteness index on potato chips

		Temperature	L*	a*	b*	W.I
Mustard oil						
Frying oil	T1	180 ºC	75.98	-0.11	44.15	24.80
	T2	180 ºC	69.62	-0.68	41.86	19.60
	T3	180 ºC	45.14	-3.30	38.19	16.50
	T4	180 ºC	44.55	-2.80	37.16	17.20
	T5	180 ºC	36.26	+3.9	33.85	09.50
Sunflower oil						
Frying oil	T1	180 ºC	70.11	2.89	40.37	16.60
	T2	180 ºC	58.40	1.26	40.01	23.90
	T3	180 ºC	66.85	-3.32	31.36	18.40
	T4	180 ºC	53.67	0.28	39.96	09.90
	T5	180 ºC	68.79	-0.77	34.63	17.60
Groundnut oil						
Frying oil	T1	180 ºC	59.91	2.70	36.66	21.10
	T2	180 ºC	46.52	0.06	19.46	12.70
	T3	180 ºC	61.20	-3.15	18.59	25.30
	T4	180 ºC	59.49	-2.31	29.25	18.70
	T5	180 ºC	59.01	-1.63	27.15	18.20
Canola oil						
Frying oil	T1	180 ºC	70.80	-0.51	31.19	13.60
	T2	180 ºC	45.53	-2.34	19.08	14.10
	T3	180 ºC	48.13	-2.49	15.96	13.60
	T4	180 ºC	42.25	-1.45	16.63	12.70
	T5	180 ºC	34.08	-1.14	7.33	14.60

oil, the effects of color L*, a*, b* value and whiteness index are studied in Table 7. The treatment T1 with the highest lightness color indicates that the fried potato chips in mustard oil had the best color, followed by those fried in canola, sunflower and groundnut oils, all of which are appealing to consumers. When compared to other treatments, treatment T3, which was fried in mustard oil, had the highest greenish color. This was followed by sunflower oil, groundnut oil and canola oil. The treatment T1 that was fried in mustard oil had a higher b* value than the other treatments, indicating that the product had a more yellowish color. This was followed by treatments that were fried in sunflower oil, groundnut oil and canola oil. More fried in mustard oil potato chips in treatment T1, sunflower oil T2 and groundnut oil T3 and canola oil T5 were shown to have a higher whiteness index.

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