Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 24, Issue 3, 2024
PRINT ISSN 2284-7995, E-ISSN 2285-3952

MEASURING THE COLOR CHANGE OF POTATO STICKS AND PLANT OIL DURING FRYING PROCESSES

Tarek FOUDA, Nourhan KASSAB

Tanta University, Faculty of Agriculture, Agriculture Engineering Department, Egypt, E-mails: tfouda628@gmail.com, andnour_kassab2308@gmail.com

Corresponding author: tfouda628@gmail.com

Abstract

The aim of this study is measuring the differences in color properties of potato sticks and oil by frying using Wock Skillet during three separate frying sessions. The measurements indicators were optical properties, RGB Bands: (Red, Green, Blue Bands), Intensity, and browning index of potato sticks and oil. The research was conducted in the laboratory of the Agricultural Engineering Department. The results showed a clear color change in the potato slices with the time of frying, and they also showed a clear color change in the number of times the oil was fried. The relationship between the oil browning index and the frying duration were happened. the oil browning index increased from 67.81 at the beginning of frying to 72.24 at the second minute, then to 75.18 in the fourth minute, then to 82.35 in the sixth minute, then to 84.49 in the eighth minute until it reached 87.75 at the tenth minute it end of the first frying process. The second frying time increased from 75.97 at the beginning of frying to 77.15 in the second minute, then to 78.92 in the fourth minute, then to 83.52 in the sixth minute, then to 86.93 in the eighth minute until it reached 88.18 in the tenth minute. In the third time also, the values increased from 76.44, 78.72, 82.54, 84.91, 88.53 and 90.15 in minutes 2, 4, 6, 8 and 10, respectively. While it was predicted that there would be a direct relationship between the potato browning index and the period of frying. And also, a direct relationship between the potato browning index and the number of frying times. as it increased from 48.11 in the fourth minute, then to 54.24 in the sixth minute, then to 61.83 in the eighth minute until it reached 69.50 in the tenth minute at the end of the first frying process.

Key words: *French fries, frying, potato, colour properties*

INTRODUCTION

With the world population growing at a rapid pace, achieving the aim of food security will be extremely difficult and will call for great efforts to integrate more alternative food sources. Plant-based foods, which make up the majority of the daily diet of humans, have shown an annual development of more than 7%. Nevertheless, more work has to be done in the areas of research, production, and preservation technology [14].

One of the most important food crops in the world, potatoes (*Solanumtuberosum* L.) are grown in more than 100 nations in temperate, subtropical, and tropical climates. The plant was grown on over 22 million hectares, and in 2019 it produced near to 370 million tons worldwide. FAO, 2021. The potato plant is a staple food for a large number of people worldwide, coming in second only to rice in terms of global distribution. Asia accounts for about 34% of the world's potato crop production [5].

Potatoes (*Solanumtuberosum* L.) are the first important non-cereal crop and the fourth most important crop overall. Carbohydrates, the main source of energy for a person's daily diet, are abundant in potatoes. It also contains important phenols and antioxidants, as well as minerals (iron, potassium, phosphorus, calcium, and magnesium), vitamins B1, B3, and C, and other multinutritional components. Additionally, the resistant starch found in potatoes may have a hypoglycemic and prebiotic impact, protect against colon cancer, and prevent the accumulation of fat [8].

Global consumption of potato chips, a widely consumed potato snack, is evident. They are made by deep-frying thin potato slices in lard or oil. Compared to ware potatoes, potato tubers used in the production of chips must meet specific quality requirements. To prevent the Maillard reaction from forming melanoidins, they must have minimal levels of reducing sugars. Since sucrose is the substrate of the reducing sugars and can hydrolyze under the right conditions to produce more sugars, it is also a crucial characteristic to consider throughout the conditions of harvesting, storing, and processing [9].

Some researchers have studied and modelled the dynamics of changes in some important physical and chemical properties of potatoes during frying. Accurate measurement of the physical and chemical properties of food is critical to the food industry. In order to predict the behavior of vegetables during processing and storage, as well as the quality of processed vegetables and their acceptance by consumers, food engineers need to determine the physical and chemical properties of vegetables [10].

When it comes to the perception of food quality, color is thought to be the most significant visual quality factor. Often, consumers make their food choices only based on what they can see, and this is the only information they are given. The product's color, size, and shape are all combined to create the visual impression. First of all, color conveys vital information about the processing or manipulation used and is a quick indicator of whether a product is good or awful. The Maillard reaction, which is influenced by the surface-reducing sugar content, frying temperature, and time, is what causes color development in fried potatoes, which only starts once adequate drying has taken place. It also depends on the drying rate and heat transfer coefficient during the various stages of frying [1].

People have used potatoes as a major source of energy in their cuisine for a long time, most likely because of their high calorie content. Potato protein has a high biological quality and contains eight or nine different types of amino acids that the human body is unable to manufacture. Determining the potato's physical characteristics and how they change over time for long-term storage is crucial to producing a high-quality product that customers would accept. Following measurements of the potatoes' surface area, volume, weight, moisture content, and three main tuber diameters, other characteristics, including sphericity, roundness, geometric mean diameter, volume mean diameter, aspect ratio, effective diameter, and real density during storage, were computed [6].

Cooking is an indispensable part of daily life for many obvious reasons, including as reducing the risk of food-borne infections and enhancing flavor, texture, palatability, digestibility, and shelf life in both residential and commercial settings. According to FAO estimates, food-related energy demand is 15% for food processing and transportation, 10% for primary production, and 75% for cooking and food preparation [2].

A skillet is a physical delivery device that uses natural gas, induction, or an electrical coil to physically transmit heat to the surface of food that is intended to be cooked. The conduction of thermal energy through the food contact surface controls how food cooks. Conduction of heat is the process by which heat moves through the components of the skillet and from the heat source (the cooktop) to the base of the skillet. The materials used in the Skillet's construction primarily dictate how thermal energy is transferred from the Skillet to the meal [7].

The formation of the fried potato's desirable sensory qualities and key structural elements, such as density, porosity, and volume, is mostly due to the high heat transfer rates experienced during deep-fat frying. The thermal and physical-chemical characteristics of the food and oil, as well as the meal's shape, oil temperature, and pressure, all influence heat and mass transmission during frying. After frying, a significant amount of oil on the surface sticks to the food's surface because most of it did not enter the food's microstructure during the frying process. This happens during the post-frying or cooling phase [4].

More than 17.4 billion pounds of French fries are produced annually in the US, accounting for about 44% of all processed potato production. The two areas that make up a French fry are (1) an oil-filled, crispy, and dehydrated exterior and (2) a cooked, humid interior that is devoid of oil. The outside crust resembles the structure of a potato chip or fried potato slice quite a bit. In order to prepare raw potato strips for French fry processing, they must first be blanched in hot water and then dried in hot air until they have a moisture content of around 60% (total basis). After being cooked in hot oil (160–190C), the dry potato strips are cooled, frozen, and packaged. Fry or bake the par-fried frozen potatoes one last time to complete the preparation. French fries have a final oil and moisture level of about 15 and 38%, respectively [12].

The measurement of fried potato color has started using digital image processing-based technologies. Browning on the surface of a fried potato is often a zero-order response at temperatures below 60°C. A brown pigment versus time plot will curve upward at increasing temperatures, just like in a first-order process. A first-order kinetics analysis of browning during frying is anticipated as deep-fat frying typically involves a brief period of time with a surface temperature below 60°C. The rate of color changes during the frying of potato strips was calculated on the assumption that the color parameters L, a, and b followed a first-order kinetics. believed that the color parameter a followed first-order kinetics to ascertain the rate at which the color of potatoes changed while they were being fried and discovered a strong relationship between the color of the chips and their acrylamide leve l[11].

Vegetable oil is necessary for many foods processing operations, including frying. The physical, chemical, nutritional, and psychological characteristics of the oil might alter during frying operations, which can impact how well it fries. French fries or potato chips are the most popular fried food item. The physical and chemical characteristics, fat content, water content, and a few other attributes are categorized as pertinent quality parameters for fried potatoes. Because of their chemical makeup, oils are susceptible to chemical alterations brought on by a variety of circumstances, which can be hazardous to one's health. Temperature, light, ventilation, metallic ions, and enzyme activity are some of these variables. They can cause oxidation, thermal polymerization, and au-toxidation in oils by acting singly or in combination. Fats may go rancid or a significant number of reaction products may arise as a result of a sequence of reactions in these occurrences [3].

Vacuum-frying improved the flavor and overall quality of potato chips while drastically lowering color and texture characteristics and increasing oil content. The physical qualities of the potato used to make the chips are one aspect influencing their quality, as not all potato varieties yield chips of a high caliber. Manufacturers of potato chips may come into significant variations in the physical attributes of the raw potatoes since they acquire their potatoes from various areas and during different seasons. These variations may have an impact on the efficiency of the manufacturing line and the quality of the finished chip [13].

The Maillard reaction that depends on the content of reducing sugars and amino acids or proteins at the surface, due to the difficulty of real-time measurements of these indicators, this research was focussed to measuring color changes with time of frying. Also measuring the differences in color properties of potato sticks and oil before and after frying by using Wock Skillet materials

MATERIALS AND METHODS

Three frying periods were performed for 10 minutes each, the initial frying (S1.), the second frying (S2.). The third frying (S3.). Potato tubers (Sponata) with a water content of 80% were used. Then slice into sticks (thickness 10 mm and diameter 59.9*10.33 mm).The skillet materials stainless steel Wock Skillet were used .The three primary colors of potato sticks and oil were measured using MATLAB software The values RGB denoted by 'R', 'G', and 'B' stand for the red, green, and blue bands, respectively. Hue, the intensity for Potato was also measured. Additionally, (La b) was measured using a digital colorimeter, and the browning index was computed as follows:

-Intensity, candela= lumen per Ste radian

$$I = \frac{1}{3}(R + G + B) \quad (1)$$

$$I2 = (R-B)/2 \quad (2)$$

-Browning Index

$$BI = \frac{100*(X-0.31)}{0.17} \quad (3)$$

$$X = \frac{a+1.75L}{5.645L+a-0.3012b} \quad (4)$$

where:

RGB Red, Green, Blue Bands

L= lightness of the colour, which range from 0 (dark) to 100 (white).

a = indicates green colour.

-b = indicates blue colour

+b = indicates yellow colour

RESULTS AND DISCUSSIONS

The optical properties, color indices, and browning index of potato sticks and oil during three separate frying wear displayed in Figures 1 through 6 and were statistically examined. The oil's color changed in the Wock Skillet at a rate of two minutes for ten minutes at each of the three frying times, according to the results.

The effect of frying periods on the color properties of oil

From Fig. 1 to 3. Showed that, the frying periods with the color properties of oil. During the initial frying time, the red band color ranged from 140 to166; Green band increased from 45to 63 the same trend with Blue band and Intensity. While Brown index decreased from 65.67 to 82.33.

In the second frying time: the red band color increased from 170to 179; G band increased from 45 to 64; the same trend with B band and Intensity. While Brown index decreased from 75.97 to 88.18.

The third frying time: the red band color increased from 175 to 185; G band increased from 50, to 65; B band and Intensity the same trend. While Brown index decreased from76.44 to 88.53.

In Fig. 4 The Brown index of oil decreases sequentially from 67.81 to 72.24, then to 75.18, then to 82.35, then to 84.49 until it reaches 87.75 at the end of the initial frying time. In the second frying time it decreases from 75.97 to 77.15, then to 78.92, then to 83.52, then to 86.93 until it reaches 88.18 at the end. The same trend with Brown index in the third frying time.

In Fig. 5 The Intensity increased sequentially from 65.67 to 67, then to 71.33, then to 75.33, then to 78.33 until it reaches 82.33 at the end of the initial frying time. In the second frying time it increased from 77 to 79, then to 80.67, then to 85.33, then to 86.67 until it reaches 89 at the end. The same trend with Intensity in the third frying time.

The effect of frying periods on the color properties of potato sticks

From Fig. 6 to 8. Showed that, the frying periods with the color propertieschanged of potato sticks.

The potatoes were placed into the Skillet after fourth minute of the frying stage, and the values are estimated at a rate of two minutes until ten minutes at each of the three frying times, according to the results.

During the initial frying time, the red band color ranged from 28 to 155; G band increased from38to58 the same trend with Brown index and Intensity. While B band decreased from 141 to 32.

In the second frying time: the red band color increased from30to157; G band increased from 40to 60; the same trend with Brown index and Intensity. While B band decreased from 143to34.

The third frying time: the red band color increased from34, to161; G band increased from 44to 64; the same trend with Brown index and Intensity. While B band decreased from 147to38.

In Fig. 9 The Brown index of potato sticks decreases sequentially from 48.11 to 54.23, then to 61.83 until it reaches 69.5 at the end of the initial frying time. In the second frying time it decreases from 50.83 to 58.26, then to 64.67 until it reaches 72.39 at the end. The same trend with Brown index in the third frying time

In Fig. 10 The Intensity increased sequentially from 51.38 to 58.26, then to 64.67 until it reaches 72.39 at the end of the initial frying time. In the second frying time it increased from 51.38 to 60.25, then to 66.11 until it reaches 73.39 at the end. The same trend with Intensity in the third frying time.

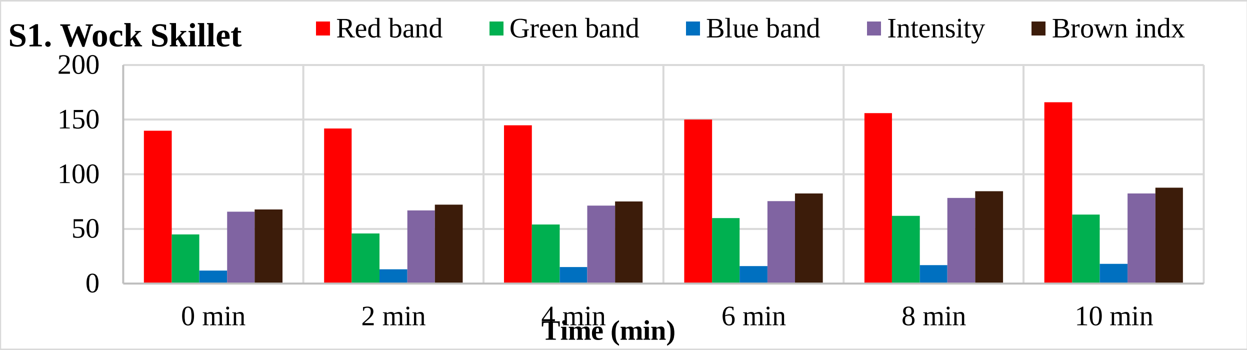

Fig. 1. The relationship between RGB bands, intensity, browning index and oil in (Wock Skillet) during the first frying time
Source: Authors' determination.

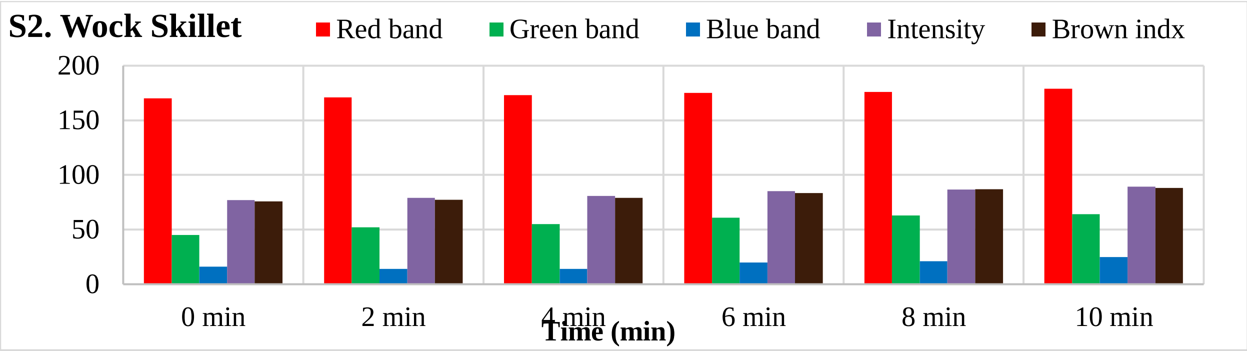

Fig. 2. The relationship between RGB bands, intensity, browning index and oil in (Wock Skillet) during the second frying time
Source: Authors' determination.

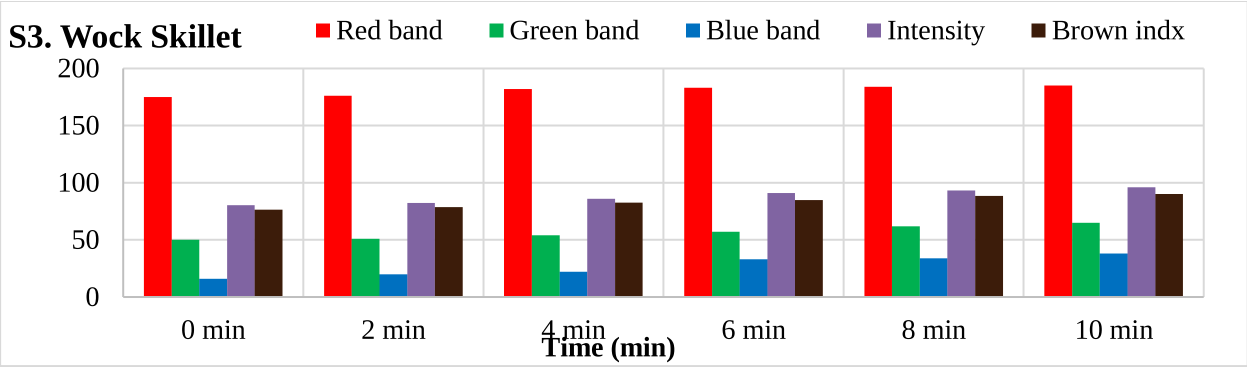

Fig. 3. The relationship between RGB bands, intensity, browning index and oil in (Wock Skillet) during the third frying time
Source: Authors' determination.

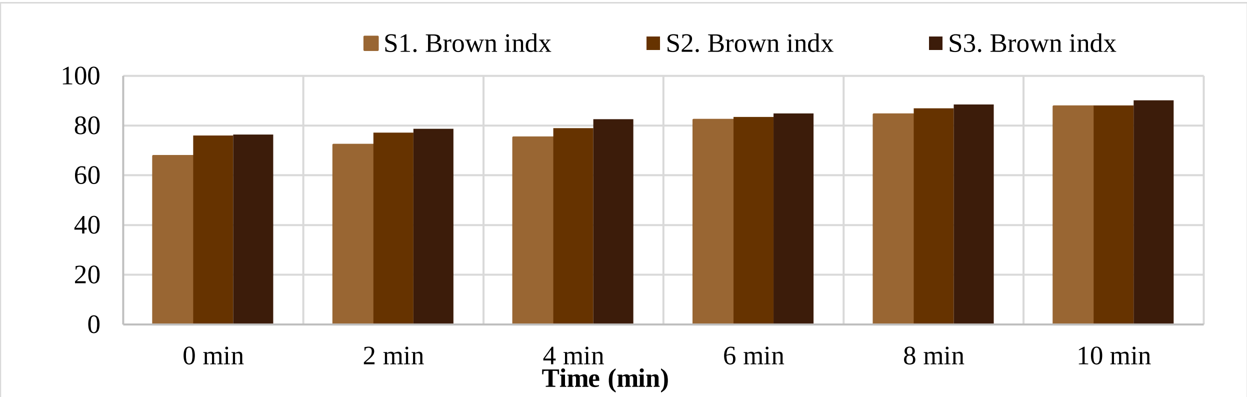

Fig. 4. The relationship between browning index and oil in (Wock Skillet) during the three frying times
Source: Authors' determination.

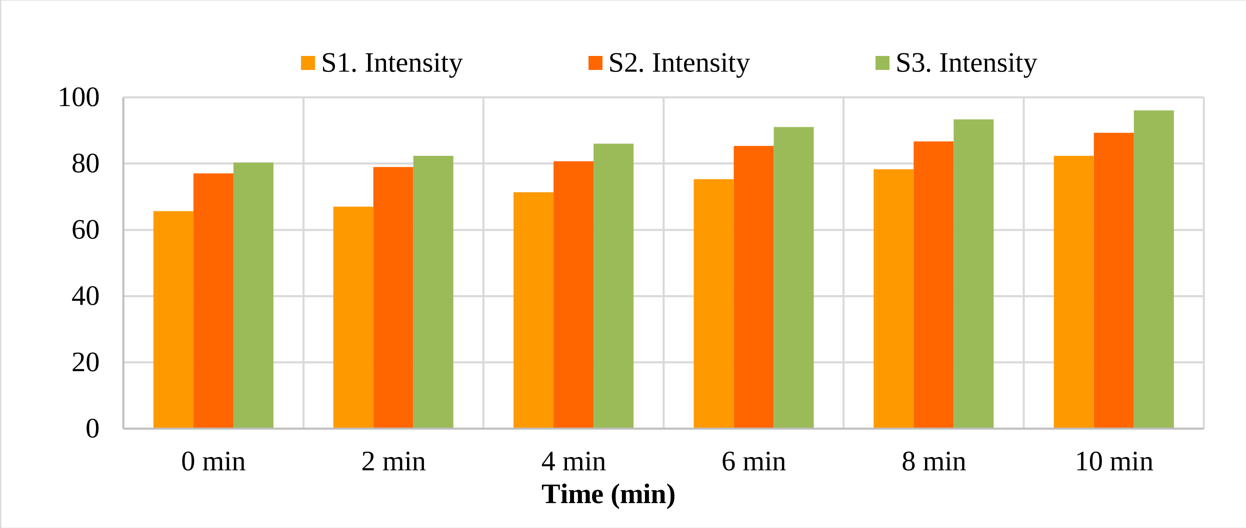

Fig. 5. The relationship between intensity and oil in (Wock Skillet) during the three frying times
Source: Authors' determination.

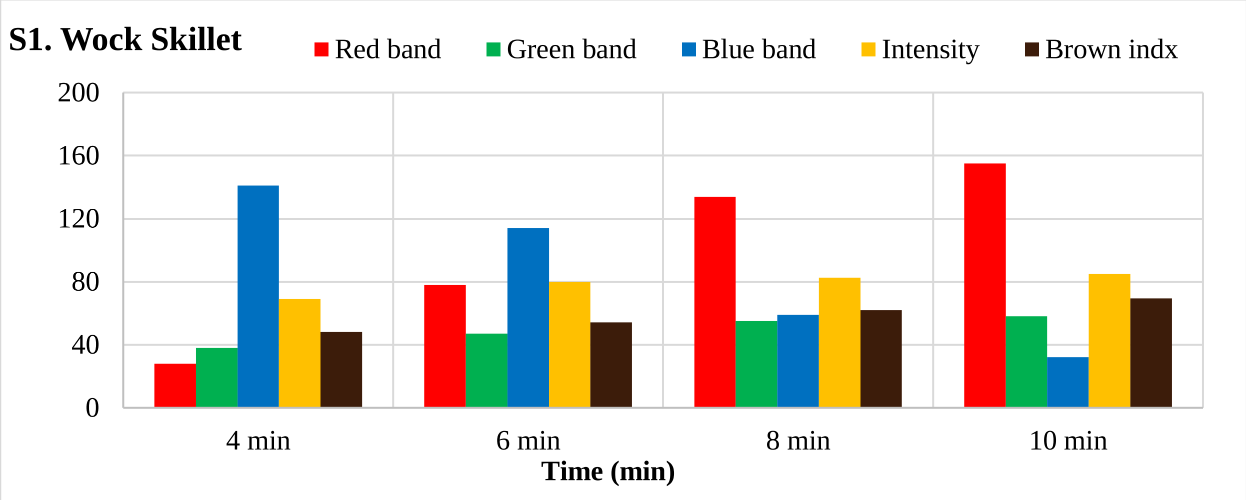

Fig. 6. The relationship between RGB bands, intensity, browning index and potatoesSticks in (Wock Skillet) during the first frying time
Source: Authors' determination.

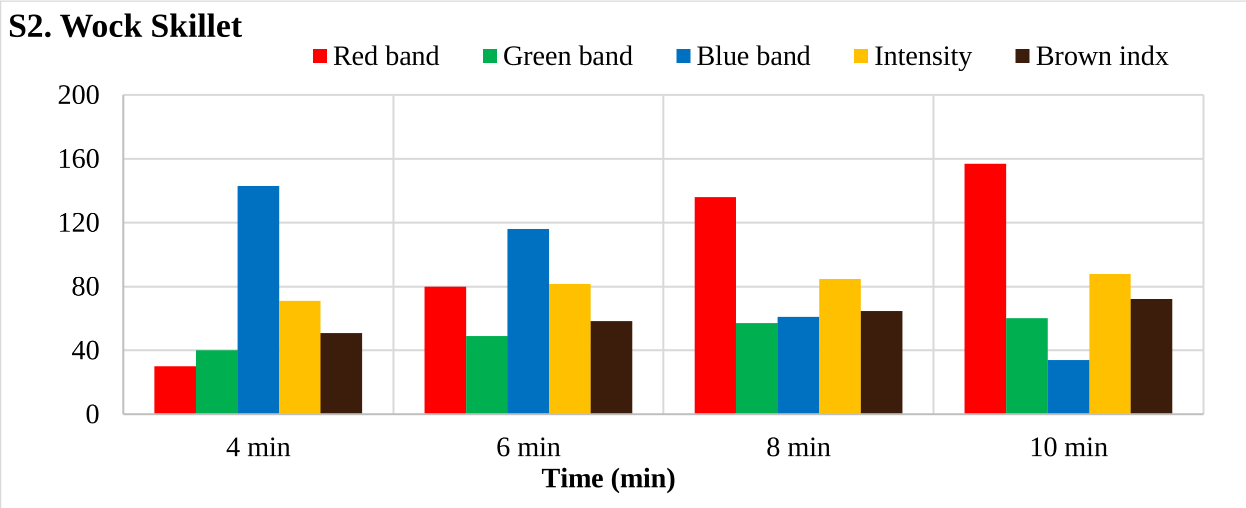

Fig. 7. The relationship between RGB bands, intensity, browning index and potatoesSticks in (Wock Skillet) during the second frying time
Source: Authors' determination.

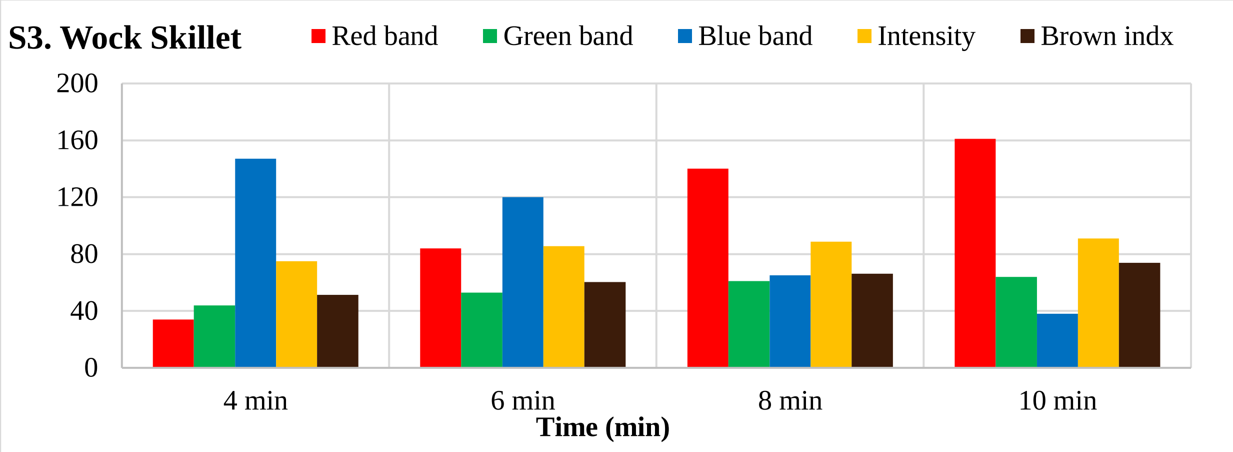

Fig. 8. The relationship between RGB bands, intensity, browning index and potatoesSticks in (Wock Skillet) during the third frying time
Source: Authors' determination.

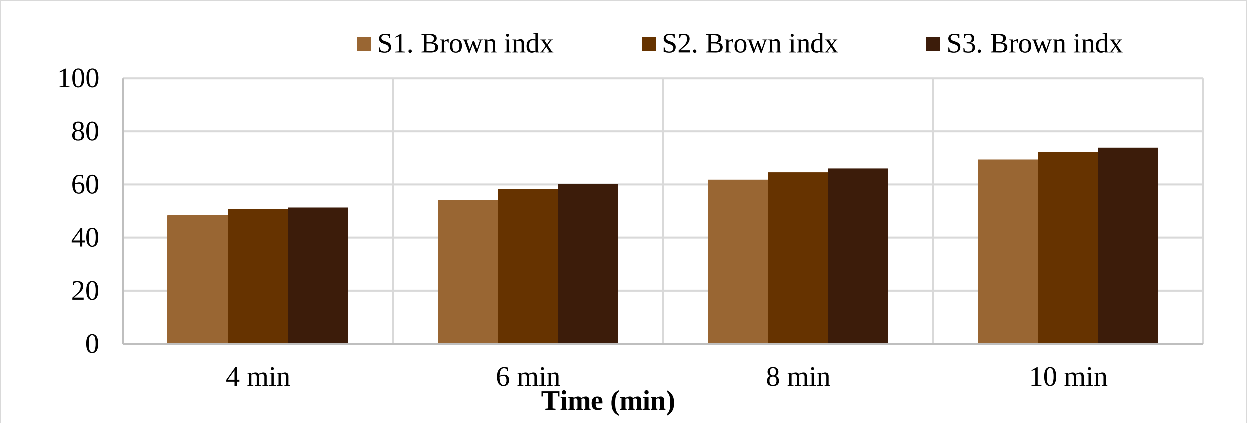

Fig. 9. The relationship between browning index and potatoesSticks in (Wock Skillet) during the three frying times
Source: Authors' determination.

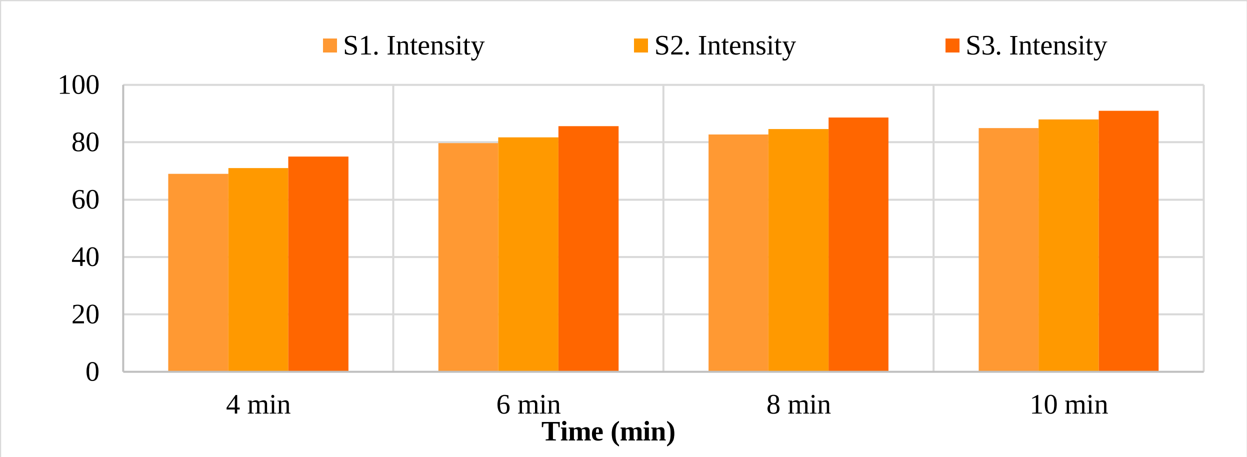

Fig. 10. The relationship between intensity and potatoesSticks in (Wock Skillet) during the three frying times
Source: Authors' determination.

CONCLUSIONS

Impact of frying time on color properties for fried potato chipsshowed with Wock Skillet recorded a clear color change appeared in the potato slices with frying time and successive periods of boiling the oil. There isrelationship between the oil browning index and the frying duration, as the longer the frying period, the greater the value of the oil browning index, and also a direct relationship between the oil browning index andpotato browning index with the number of frying times, where the values of the oil browning indexes in the third frying time are less than the oil browning indexes in the first frying time.

REFERENCES

[1]Abdullah, M.Z., Guan, L.C., Lim, K.C., Karim, A.A., 2004, The applications of computer vision systems and tomographic radar imaging for assessing physical properties of food. Journal of Food Engineering 2004, 61, 125–135. Accessed on 24 April 2024.

[2]Bulut, M., Boga, M., 2021, Effects of climate change on agriculture and food security. Sustainable agriculture and livestock for food security under the changing climate, 339. Accessed on 24 April 2024.

[3]Diop, A., Sarr, S.O., Ndao, S., Cissé, M., Baldé, M., Ndiaye, B., Diop, Y.M., 2014, Effect of deep-fat frying on chemical properties of edible vegetable oils used by Senegalese households. Afr. J. Food Agric. Nutr. Dev. 14, 2218-2238. Accessed on 24 April 2024.

[4]Dura´n, M., Pedreschi, F., Moyano, P., Troncoso, E., 2007, Oil partition in pre-treated potato slices during frying and cooling. Journal of Food Engineering 2007, 81, 257–265. Accessed on 24 April 2024.

[5]FAO, 2021, FAOStat: Crops Production. http://www.fao.org/faostat/en/#data/QCL. Page ID=157#ancor. Accessed on 24 April 2024.

[6]Golmohammadi, A., Afkari-Sayyah, A.H., 2013, Long term storage effects on the physical properties of the potato. International Journal of Food Properties, 16:104–113. Accessed on 24 April 2024.

[7]Karunanithy, C., Shafer, K., 2016, Heat transfer characteristics and cooking efficiency of different sauce pans on various cooktops. Applied Thermal Engineering, 93, 1202-1215. Accessed on 24 April 2024.

[8]Mowafy, S., Liu, Y., 2024, High-humidity hot-air impingement blanching conditions for the inhibition of potato-browning enzymes and for quality retention. Journal of the Science of Food and Agriculture, 104(5), 2679–2691. https://doi.org/10.1002/ jsfa.13153. Accessed on 24 April 2024.

[9]Nawaz, A., Danish, A., Waseem, A.S., Shahbaz, H.M.; Khalifa, I.; Ahmed, A.; Irshad, S., Ahmad, S., Ahmed, W., 2021, Evaluation and storage stability of potato chips made from different varieties of potatoes cultivated in Pakistan. J. Food Process. Preserv. 2021, 45, e15437. Accessed on 24 April 2024.

[10]Pedreschi, F., Aguilera, J.M., Pyle, L., 2001, Textural characterization and kinetics of potato strips during frying. Journal of Food Science 2001, 66, 314–318. Accessed on 24 April 2024.

[11]Pedreschi, F., Leo´n, J., Mery, D., Moyano, P., 2006, Implementation of a computer vision system to measure the color of potato chips. Food Research International 2006, 39, 1092–1098. Accessed on 24 April 2024.

[12]Saguy, I., Dana, D., 2003, Integrated approach to deep fat frying: Engineering, nutrition, health and consumer aspects. Journal of Food Engineering 2003, 56, 143–152. Accessed on 24 April 2024.

[13]Troncoso, E., Pedreschi, F., 2009, Modeling water loss and oil uptake during vacuum frying of pre-treated potato slices. LWT-Food Science and Technology, 42, 1164-1173. Accessed on 24 April 2024.

[14]Yang, Z., Xie, C., Bao, Y., Liu, F., Wang, H., Wang, Y., 2023, Oat: Current state and challenges in plant-based food applications. Trends in Food Science & Technology, 134, 56–71. https://doi.org/10.1016/j.tifs.2023.02.017, Accessed on 24 April 2024.