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FULL PAPER

Effects of frozen storage duration on the physicochemical and sensory properties of cassava sticks

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Abstract

Cassava sticks is a processed food made from cassava that has similar characteristics to French fries. However, cassava sticks are also classified as perishable food, so it is required to employ other processes that might increase its preservation, such as frozen storage. In this study, the cassava stick was stored at -20°C for three months to investigate its effects on the physicochemical and sensory properties of cassava sticks. The effects of frozen storage duration were monitored every month carried out in three replications. A randomized block design with a single factor was used as the experimental design. According to the results, storing cassava sticks under frozen conditions significantly increased ($P<0.05$) the oil absorption and had no effect ($P>0.05$) on the moisture content. A significant alteration ($P<0.05$) in texture was observed through the increase of cassava stick hardness from 1.11 to 2.54 N. Frozen storage duration also influenced ($P<0.05$) the lightness and yellowness, but not the redness ($P>0.05$) of cassava sticks. Fat oxidation also occurred during storage, marked by a significant increase ($P<0.05$) of free fatty acid (0.06 to 0.14%) and peroxide value (0 to 34.53 mg peroxide/kg lipid) on three months of frozen storage. Thus, this study concludes that frozen storage duration affected the physical and chemical properties of cassava sticks. Moreover, cassava sticks stored frozen for three months were acceptable for panelists with neither like nor dislike (4.30) average acceptance, and had no significant difference ($P>0.05$) with other samples.

1. Introduction

Cassava (*Manihot esculenta* Crantz) is one of the most consumed crops in the world, especially in Sub-Saharan Africa (SSA) and in developing countries of Asia such as Cambodia, Vietnam, and Laos (Benesi *et al*., 2004; International Atomic Energy Agency, 2018). Cassava is considered a substitute for rice as the primary carbohydrate source and can be consumed in various ways (fried, boiled, or steamed). Besides carbohydrates, cassava is also rich in calcium (50 mg/100 g), phosphorus (40 mg/100 g), vitamin C (25 mg/100g) and contains a significant amount of thiamine, riboflavin, and nicotinic acid (International Atomic Energy Agency, 2018). In Indonesia, cassava is generally processed into traditional food such as *tiwul, gatot, gaplek, gethuk, tapai*, and cassava chips. Furthermore, it can also be processed into a modern food such as cassava stick.

Cassava stick has similar characteristics to French fries due to its shoestring-like shape, golden brown colour, crunchy exterior, and fluffy interior. Those characteristics are obtained through several processes such as blanching, drying, frying, and each step affects the quality of the final product (Lamberg *et al*., 1990). Other processes are also required to extend shelf life since cassava sticks are classified as perishable food. Among other processes that might be employed for long-term preservation (high pressure, infrared irradiation, pulsed electric field, and ultrasound), freezing or frozen storage is still one of the most used methods (Rahman and Velez-Ruiz, 2007). Generally, frozen storage temperature is 0°F (-18°C) and even colder depending on the type of food (WFLO Commodity Storage Manual, 2008).

Several studies showed that storing food (fruit, meat, and French fries) under freezing temperatures affects the physical and chemical properties (Sattar *et al*., 2015; Celli *et al*., 2016; Medic *et al*., 2018). However, based on authors' knowledge, there is no study reported about the effect of frozen storage on the cassava sticks properties. Therefore, this study aimed to investigate the physical and chemical changes on cassava sticks during frozen storage. In addition, the sensory evaluation of

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cassava sticks during frozen storage was also studied.

2. Materials and methods

2.1 Materials

Cassava tubers (*Manihot esculenta* Crantz) used in this study were yellow cassava (Malang 2), purchased from a local market in Malang, Indonesia. The cooking oil was purchased from a market in Surabaya, Indonesia. All chemicals and other reagents used in this study were analytical grades.

2.2 Preparation of cassava stick

Cassava tubers were washed two times using tap water to remove physical contaminations. The cleaned cassava tubers were then peeled, cut into strips of 4×1×1 cm, and soaked in 0.1% (w/v) $CaCl_2$ for 15 mins to increase the crispiness of the cassava stick. Next, the soaked cassava sticks were steamed in a steamer (98°C, 15 mins) and cooled to room temperature before being pre-fried (170°C, 30 s) in cassava sticks : cooking oil ratio of 1:12 (w/v) using a deep fryer (Fritel Professional 35 SICO, Belgium). Later, the pre-fried cassava sticks were vacuum packed in a polypropylene plastic bag using a vacuum sealer (Maksindo DZ300, Indonesia) and frozen at -20°C for different storage duration (0, 1, 2, 3 months) in a chest freezer (Modena MD 45, Italy). The frozen cassava sticks were then thawed in a water bath (15 mins) and fried for 2 mins at the same condition as the pre-frying process. At the end of frying, the fryer basket was immediately shaken for 10 s and sticks were cooled to room temperature before analyzing the physicochemical properties.

2.3 Moisture content

All fried cassava stick samples were minced before immediately analyzing the moisture content. The moisture content was determined using a drying oven (Binder ED 53, Germany) with the thermogravimetric method (AOAC, 2006) for 3-5 hrs at 105±2°C.

2.4 Oil absorption analysis

The oil absorption analysis was determined according to the method by Mohamed *et al*. (1988). Approximately 5 g of minced pre-fried and fried cassava sticks were oven-dried at 105°C for 3-5 hrs and weighed until a stable weight of the sample was obtained. The oil absorption was calculated using the following equation:

$$\text{Oil absorption (\%)} = \frac{W_2 - W_1}{W_1} \times 100\%$$

where W_1 is the weight of pre-fried cassava stick (g) and W_2 is the weight of fried cassava stick (g).

2.5 Hardness

Hardness as the selected texture characteristics were determined using a TA-XT plus (Stable Micro System, UK) equipped with a three-point bend rig using compression test mode with the following conditions: pre-test speed= 2 mm/s, test speed= 0.5 mm/s, post-test speed= 10 mm/s, and distance= 10 mm. The hardness of fried cassava stick was expressed as Newton and determined as the maximum force required to compress the sample.

2.6 Free fatty acid analysis

The free fatty acid of cassava sticks was analyzed using a method by Sudarmadji *et al*. (1984). Approximately 28.2 g of fried cassava sticks were minced before adding 50 mL of neutralized alcohol and 2 mL phenolphthalein. The mixture was then titrated with 0.1 N NaOH until a stable pink colour occurred for 30 s. The percentage of free fatty acid was expressed as the percentage of palmitic acid and calculated using the following equation:

$$\text{Palmitic acid (\%)} = \frac{V_{NaOH} \times N_{NaOH} \times Mr}{W \times 1000} \times 100\%$$

where V_{NaOH} is the titre of NaOH (mL), N_{NaOH} is the concentration of NaOH (N), Mr is the molecular weight of palmitic acid (256.42 g/mol), and W is the sample weight (g).

2.7 Peroxide value

An iodometric titration method was used to analyze the peroxide value as the primary oxidation product (Sudarmadji *et al*., 1984). Briefly, 5 g of fried cassava sticks were mixed with 30 mL acetic acid – chloroform (3:2) and 0.5 mL saturated aqueous potassium iodide solution was added. Later, the mixture was shaken vigorously for 1 min before 30 mL of distilled water was added. The mixture was titrated with 0.1 M $Na_2S_2O_3$ until the yellow colour had almost disappeared. Next, 0.5 mL of 1% (w/v) starch indicator solution was added and the titration continued until the blue colour disappeared. The peroxide value was calculated using the following formula:

$$\text{Peroxide value (meq peroxide/kg oil)} = \frac{V_{thio} \times N_{thio} \times 1000}{W}$$

where V_{thio} is the titre of $Na_2S_2O_3$ (mL), N_{thio} is the concentration of $Na_2S_2O_3$, and W is the sample weight (g).

2.8 Colour

The colour of fried cassava stick was identified using a colour reader (Colour Reader Minolta, CR-10). The L* value (0 = blackness, 100 = whiteness), a* value (+ = redness, - = greenness), and b* value (+ = yellowness, -

= blueness) of each sample were observed.

2.9 Sensory evaluation

In this study, the Hedonic Scale Scoring (preferred test) was used to measure the level of preference and acceptance of the product by consumers (Kusuma *et al*., 2017). The sensory evaluation was evaluated by 100 untrained panelists. The panelists were students of the Faculty of Agricultural Technology, Widya Mandala Catholic University Surabaya. The sensory attributes tested were colour, hardness, crispiness, aroma, and taste. A scoring system of 1-7 points was used to represent the sensory characteristics of each sample. On this scale, 1 was defined as dislike extremely, 2 was defined as dislike moderately, 3 was defined as dislike slightly, 4 was defined as neither like nor dislike, 5 was defined as like slightly, 6 was defined as like moderately, and 7 was defined as like extremely.

2.10 Statistical analysis

All experiments were analyzed at least three times in triplicate and represented as mean values ± SD. Statistical analyses were performed using SPSS for Windows (version 19.0, SPSS Inc., USA) and compared with Duncan Multiple Range Test (DMRT) at P<0.05.

3. Results and discussion

3.1 Moisture content and oil absorption

The moisture content of fried cassava sticks is shown in Table 1. Based on the result, different frozen storage durations have no significant difference (P>0.05) on the moisture content of cassava sticks, even though there was a downward trend in the moisture content of frozen cassava sticks for 2 and 3 months. Similar results were reported by Medic *et al.* (2018), where frozen storage duration had no significant effect on the moisture content of pork loin and belly rib. However, several researchers also found that freezing significantly (P<0.05) influenced the moisture content of the fried potato (Adedeji and Ngadi, 2017), lamb (Coombs *et al.*, 2017), and pork ham (Medic *et al*., 2018). According to Fennema (1985), water in food converts to ice crystals during freezing at -18°C and is easily removed from food when the food is dried or fried, causing the moisture content to decrease.

Oil absorption analysis was conducted to measure the ability of cassava sticks to absorb oil during frying by using a modified thermogravimetric method (Mohamed *et al*., 1988). Table 1 shows that the storage duration significantly increased (P<0.05) the oil absorption of cassava sticks. Cassava stick stored frozen for 2 months has the highest oil absorption (58.45%) but has no significant difference with cassava stick stored frozen for 3 months (57.84%). In a study conducted by Adedeji and Ngadi (2017), oil absorption also showed a significant increase in fried potato that was stored frozen. However, they also found that there was no interaction between storage duration and freezing method, which contradicts this study.

Table 1. Moisture content and oil absorption of cassava stick stored frozen in different storage duration

Frozen storage duration (months)	Moisture content (%)	Oil absorption (%)
0	45.13±7.46^{a}	20.87±15.91^{a}
1	48.83±3.27^{a}	25.66±9.51^{a}
2	28.68±7.95^{a}	58.45±2.47^{b}
3	27.75±10.13^{a}	57.94±24.71^{b}

Values are presented as mean±SD (n = 3 for each group). Values with different superscript are significantly different (P<0.05) by one-way ANOVA followed by DMRT test (α = 0.05).

According to Adedeji *et al*. (2009), moisture loss during frying affects the amount of oil absorbed in fried food. This statement is in accordance with Fellows (1990), where oil transfers into the product to replace evaporated water during frying. In addition, moisture evaporation from fried food during frying damages the cellular structure of plant tissues, resulting in an increase in porosity which contributes to oil absorption (Mellema, 2003; Rimac-Brncic *et al*., 2004; Dana and Saguy, 2006). On the other hand, during frozen storage, all water in food converts to ice crystal and causes volume expansion which is characterized by the damage to cell membranes during ice crystal formation (Fennema, 1985; Celli *et al*., 2016). This volume expansion causes the water in cassava sticks to be easier to evaporate during frying and increases oil absorption.

3.2 Hardness

In this study, hardness was chosen as the analyzed texture attribute to evaluate the impact of frozen storage duration on the texture of cassava sticks. According to Szczesniak (2002), hardness is the force required to change the shape of material due to its resistance to resist deformation. The effect of frozen storage duration on the hardness of cassava sticks is presented in Figure 1. As shown in that figure, frozen storage duration significantly affected (P<0.05) the hardness of the cassava sticks. Cassava stick that was stored frozen for 3 months has the highest force (2.54 N) among other samples (0.63 – 1.41 N). These results were in accordance to Adedeji and Ngadi (2017). They found a marginal increase in the hardness of fried potatoes as the frozen storage duration increased. Therefore, the increase in fried cassava stick hardness might be due to the retrogradation of cassava starch during frozen storage. This statement was supported by a similar study by Yu *et*

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al. (2010), where the hardness of cooked rice increased continually with the amylopectin retrogradation during frozen storage. Based on those findings, amylopectin retrogradation contributed to the hardness increase during storage on the high starch food products.

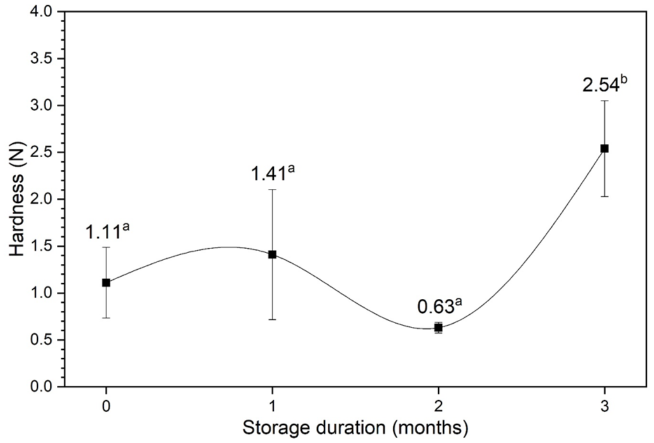

Figure 1. Hardness of cassava stick stored frozen in different storage duration. Values are presented as mean±SD (n = 3 for each group). Values with different superscript are significantly different (P<0.05) by one-way ANOVA followed by DMRT test (α = 0.05).

3.3 Free fatty acid and peroxide value

This study assessed the percentage of free fatty acid and peroxide values to monitor the fat oxidation in cassava sticks during frozen storage. The increase of free fatty acid and peroxide value indicates the rancidity of food products that produce off-flavors (Maity *et al*., 2012) and might reduce consumers' preferences. The free fatty acid of cassava stick was expressed as the percentage of palmitic acid since the cooking oil used to fry was palm oil. Meanwhile, the peroxide value as the primary oxidation product of fat oxidation was expressed as meq peroxide/kg fat. The percentage of free fatty acid and peroxide value of fried cassava sticks is shown in Figure 2. A significant increased (P<0.05) of free fatty acid was recorded during 2 months of frozen storage (0.13 %) and had no significant difference (P>0.05) with cassava sticks stored frozen for 3 months (0.14%). On the other hand, the peroxide value of cassava stick was also significantly increased (P<0.05) as the frozen storage duration increased (0 – 34.53 meq peroxide/ kg fat). Similar results were also reported by some studies where frozen storage duration increased the free fatty acid and peroxide value of potato strips (Kizito *et al*., 2017), pork meat (Medic *et al*., 2018), and ready-to-fry vegetable snacks (Maity *et al*., 2012).

According to Crosa *et al*. (2014), free fatty acids are formed through the nucleophilic attack at triacylglycerol's ester bond and have been associated with the undesirable odors and taste of food products. Furthermore, the formation of hydroperoxides during storage generally occurred during the early stage of oxidation (Fennema, 1985) and later decomposed to other secondary oxidation products such as pentanal, hexanal, 4-hydroxynonenal and malondialdehyde (Kizito *et al*., 2017; Medic *et al*., 2018). Another factor that might increase the formation of hydroperoxides was the contact of cassava stick with oxygen before and after storage; since oxygen is one of the reactants that caused fat oxidation (Giri and Mangaraj, 2012).

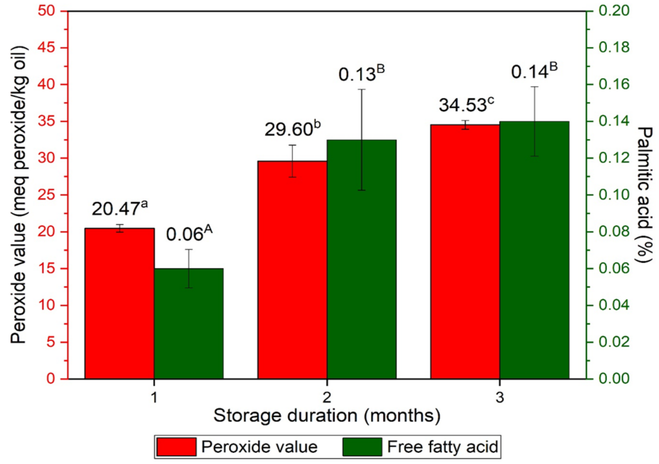

Figure 2. Free fatty acid and peroxide value of cassava stick stored frozen in different storage duration. Values are presented as mean±SD (n = 3 for each group). Values with different superscript are significantly different (P<0.05) by one-way ANOVA followed by DMRT test (α = 0.05).

3.4 Colour properties

Colour is generally considered an important attribute that significantly affects the physical properties of food, the perception of consumers, and determines the nutritional quality of food products (Hutchings, 2002; Patras *et al*., 2011). In this study, the colour of cassava sticks is shown in Table 2 and was measured using Hunter's L*, a*, and b* colour attributes. The L* value expressed the degree of lightness, where the highest value was measured in the cassava stick stored frozen for 3 months (75.20). However, the results were not significantly different (P>0.05) with cassava stick that was not stored frozen (71.55) and significantly different (P<0.05) with other samples (66.52 – 67.98). The different results were shown on the a* value, which expressed the degree of redness (+a*) and greenness (-a*) of cassava sticks. All samples had no significant difference (P>0.05) on the degree of redness (2.94 – 4.62). Meanwhile, the b* value expressed the degree of yellowness (+b*) and blueness (-b*). The results show that the b* values of cassava stick (25.77) that stored frozen for 2 months was significantly lower (P<0.05) than other samples (30.79 – 32.08).

Research by Oner and Wall (2012) also found that frozen storage significantly influenced (P<0.05) the colour of French fries. The colour change of fried cassava sticks during frozen storage duration might be due to the surface moisture desiccation (Maity *et al*., 2012). The amount of moisture loss during the frying process also influence the colour of fried cassava stick since moisture loss is associated with crust formation and accelerates the Maillard browning (Sahin, 2000). The Maillard browning occurs due to the reaction between amino acid and reducing sugar during frying and results in the increase in coloration of yellow, red, and brown in fried food (Pedreschi *et al*., 2005). Another factor that might influence the crust colour of cassava sticks was the heat transfer rate in the cassava sticks during frying (Maity *et al*., 2012).

Table 2. Colour of cassava stick stored frozen in different storage duration

Frozen storage duration (months)	Colour		
	L*	*a**	*b**
0	71.55±4.08[ab]	2.95±0.78[a]	32.08±3.02[b]
1	67.98±2.78[a]	4.62±1.93[a]	30.79±1.87[b]
2	66.52±1.15[a]	3.21±0.37[a]	25.77±0.98[a]
3	75.20±1.80[b]	4.01±0.30[a]	31.40±1.66[b]

Values are presented as mean±SD (n = 3 for each group). Values with different superscript are significantly different (P<0.05) by one-way ANOVA followed by DMRT test (α = 0.05).

3.5 Sensory evaluation

The sensory evaluation results of cassava sticks stored frozen in different storage durations are shown as a spider plot in Figure 3. According to the results, the highest score for the colour attribute was the 0-month storage cassava sticks (5.60) and significantly different (P<0.05) with other samples (3.20 – 4.96). The decrease in panelists' colour preference was due to the colour changes in cassava sticks that tend to be darker and brownish than the regular cassava sticks. Meanwhile, on the hardness attribute, the panelists' preference significantly decreased (P<0.05) as the frozen storage duration increased (5.30 – 4.20). This result was in accordance with the objective analysis on hardness, where frozen storage duration significantly increased the hardness of cassava sticks due to the starch retrogradation. The next sensory attribute tested was the crispiness and the results were quite varied. Cassava sticks stored frozen for 0 months (4.88) had no significant difference (P>0.05) compared to 2 months stored cassava stick (4.66) but showed a significant difference (P<0.05) with cassava sticks stored frozen for 1 month (3.86) and 3 months (3.68). This result indicated that panelists perceived that frozen storage duration influenced the crispiness of fried cassava sticks. Furthermore, the frozen storage duration significantly influenced (P<0.05) the panelists' preferences on the aroma of cassava sticks. The aroma of cassava sticks tended to be different for each treatment and might be influenced by the formation of hydroperoxides and free fatty acids. The last sensory attribute evaluated was the taste of cassava sticks. According to the result, the frozen storage duration had no significant difference (P>0.05) on the panelists' perception of the taste of cassava sticks (4.16 – 4.88). Overall, the average score of panelists' preference showed that frozen storage duration did not significantly affect (P>0.05) panelists' acceptance of the cassava stick.

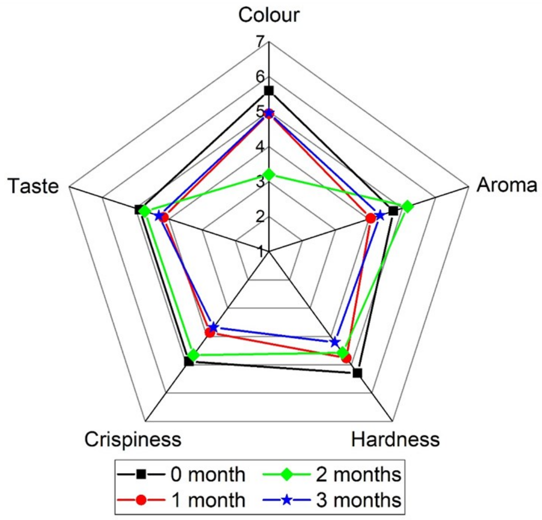

Figure 3. Sensory evaluation of cassava stick stored frozen in different storage duration. Values are presented as mean±SD (n = 3 for each group). Values with different superscript are significantly different (P<0.05) by one-way ANOVA followed by DMRT test (α = 0.05).

4. Conclusion

Frozen storage can be used to extend the shelf life of food products. However, the use of frozen storage on cassava sticks affects its physical and chemical properties. Different frozen storage duration influenced the oil absorption of cassava sticks, though the moisture content showed no significant change. The effect of frozen storage duration was also significant on the texture of cassava sticks, especially on hardness. Another studied quality characteristic, such as cassava stick surface colour, substantially declined during the frozen storage. The free fatty acid and peroxide value of cassava sticks was gradually increased with the elongation of frozen storage duration. According to the sensory evaluation results, frozen storage duration influenced all of the sensory attributes besides the taste of cassava sticks. Cassava sticks stored frozen for 3 months were still acceptable by the panelists and the acceptance was defined as neither like nor dislike.

Conflict of interest

The authors declare no conflict of interest.

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References

Adedeji, A.A., Ngadi, M.O. and Raghavan, G.S.V. (2009). Kinetics of mass transfer in microwave precooked and deep-fat fried chicken nuggets. *Journal of Food Engineering*, 91(1), 146-153. https://doi.org/10.1016/j.jfoodeng.2008.08.018

Adedeji, A.A. and Ngadi, M. (2017) Impact of freezing method, frying and storage on fat absorption kinetics and structural changes of parfried potato. *Journal of Food Engineering*, 218, 24-32. https://doi.org/10.1016/j.jfoodeng.2017.08.024

AOAC (Association of Analytical Communities). (2006). Official Methods of Analysis of AOAC International. 18th ed. Gaithersburg, USA: AOAC International.

Benesi, I.R.M., Labuschagne, M.T., Dixon, A.G.O. and Mahungu, N.M. (2004). Genotype X environment interaction effects on native cassava starch quality and potential for starch use in the commercial sector. *African Journal of Crop Science*, 12(3), 205-216. https://doi.org/10.4314/acsj.v12i3.27880

Celli, G.B., Ghanem, A. and Brooks, M.S. (2016) Influence of freezing process and frozen storage on the quality of fruits and fruit products. *Food Reviews International*, 32(3), 280-304. https://doi.org/10.1080/87559129.2015.1075212

Coombs, C.E.O. Holman, B.W.B., Collins, D., Friend, M.A. and Hopkins, D.L. (2017). Effects of chilled-then-frozen storage (up to 52 weeks) on lamb *M. longissimus lumborum* quality and safety parameters. *Meat Science*, 134, 86–97. https://doi.org/10.1016/j.meatsci.2017.07.017

Crosa, M.J., Skerl, V., Cadenazzi, M., Olazabal, L., Silva, R., Suburu, G. and Torres, M. (2014). Changes produced in oil during vacuum and traditional frying of potato strips. *Food Chemistry*, 146, 603-607. https://doi.org/10.1016/j.foodchem.2013.08.132

Dana, D. and Saguy, I.S. (2006). Review: Mechanism of oil uptake during deep fat frying and surfactant effect-theory and myth. *Advances in Colloid and Interface Science*, 128-130, 267-272. https://doi.org/10.1016/j.cis.2006.11.013

Fellows, P.J. (1990). Food Processing Technology Principles and Practice. London, United Kingdom: Ellis Horwood

Fennema, G.R. (1985). Principles of Food Science. New York, USA: Marcell Dekter Inc.

Giri, S.K. and Mangaraj, S. (2012). Processing Influences on Composition and Quality Attributes of Soymilk and its Powder. *Food Engineering Reviews*, 4, 149-164. https://doi.org/10.1007/s12393-012-9053-0

Hutchings, J.B. (2002). The Perception and Sensory Assessment of Colour. Cambridge, United Kingdom: Woodhead Publishing Limited. https://doi.org/10.1201/9781439823194.pt1

International Atomic Energy Agency. (2018). Cassava production guidelines for food security and adaptation to climate change in Asia and Africa. Retrieved on October 21, 2021 from website: https://www.iaea.org/publications/12311/cassava-production-guidelines-for-food-security-and-adaptation-to-climate-change-in-asia-and-africa

Kizito, K.F., Abdel-Aal, M.H., Ragab, M.H. and Youssef, M.M. (2017). Quality attributes of French fries as affected by different coatings, frozen storage and frying conditions. *Journal of Agricultural Science and Botany*, 1(1), 18-24.

Kusuma, S.T., Kurniawati, A.D., Rahmi, Y., Rusdan, I.H. and Widyanto, R.M. (2017). Pengawasan Mutu Makanan. Malang, Indonesia: UB Press. [In Bahasa Indonesia].

Lamberg, I., Hallstrom, B. and Olsson, H. (1990). Fat uptake in a potato drying/frying process. *Lebensmittel-Wissenschaft und –Technologie*, 23(4), 295–300

Maity, T., Shah, A., Raju, P.S. and Bawa, A.S. (2012). Development of ready-to-fry frozen vegetable snack and its quality evaluation. *Journal of Food Science and Technology*, 49(1), 42–49. https://doi.org/10.1007/s13197-011-0257-8

Medić, H., Kušec, I.D., Pleadin, J., Kozačinski, L., Njari, B., Hengl, B. and Kušec, G. (2018). The impact of frozen storage duration on physical, chemical and microbiological properties of pork. *Meat Science*, 140, 119-127. https://doi.org/10.1016/j.meatsci.2018.03.006

Mellema, M. (2003). Mechanism and reduction of fat uptake in deep-fat fried foods. *Trends in Food Science and Technology*, 14(9), 364-373. https://doi.org/10.1016/S0924-2244(03)00050-5

Mohamed, S., Abdullah, N. and Muthu, M.K. (1988). Expansion, oil absorption, elasticity, and crunchiness of keropok (fried chips) in relation to the physicochemical nature starch flours. *Proceeding of the Food Conference,* 88, 108-113.

Oner, M.E. and Wall, M.M. (2012). Processing conditions for producing french fries from purple-fleshed sweet potatoes. *American Society of Agricultural and Biological Engineers*, 55(6), 2285-2291. https://doi.org/10.13031/2013.42486

Patras, A., Brunton, N.P., Tiwari, B.K. and Butler, F. (2011). Stability and degradation kinetics of bioactive compounds and colour in strawberry jam during storage. *Food Bioprocess Technology*, 4, 1245–1252. https://doi.org/10.1007/s11947-009-0226-7

Pedreschi, F., Moyano, P., Kaack, K. and Granby, K. (2005). Colour changes and acrylamide formation in fried potato slices. *Food Research International*, 38 (1), 1-9. https://doi.org/10.1016/j.foodres.2004.07.002

Rahman, M.S. and Velez-Ruiz, J.F. (2007). Food preservation by Freezing. In Handbook of Food Preservation. 2nd ed. USA: CRC Press. https://doi.org/10.1201/9781420017373-41

Rimac-Brncic, S., Lelas, V., Rade, D. and Simundic, B. (2004). Decreasing oil absorption in potato strips during deep fat frying. *Journal of Food Engineering*, 64(2), 237-241. https://doi.org/10.1016/j.jfoodeng.2003.10.006

Sahin, S. (2000). Effect of frying parameters on the colour development of fried potatoes. *European Food and Research Technology*, 211, 165-168. https://doi.org/10.1007/s002170050017

Sattar, S., Sarower, K., Uddin, M.B. and Jubayer, M.F. (2015). Impacts of varieties and freezing storage condition on the quality of French fried potatoes (*Solanum tuberosum* L.). *Food Science and Technology: An International Journal*, 1(1), 9-19

Sudarmadji, S., Haryono, B. and Suhardi. (1984). Prosedur Analisa untuk Bahan Makanan dan Pertanian. Yogyakarta, Indonesia: Liberty. [In Bahasa Indonesia]

Szczesniak, A.S. (2002). Texture is a Sensory Property. *Food Quality and Preference*, 13(4), 215–225. https://doi.org/10.1016/S0950-3293(01)00039-8

WFLO Commodity Storage Manual. (2008). Frozen Foods Handling and Storage. Retrieved on October 25, 2021, from website: http://www.cold.org.gr/library/downloads/docs/frozenfoodshandling.pdf

Yu, S.F., Ma, Y. and Sun, D.W. (2010). Effects of freezing rates on starch retrogradation and textural properties of cooked rice during storage. *LWT - Food Science and Technology*, 43(7), 1138-1143. https://doi.org/10.1016/j.lwt.2010.03.004

https://doi.org/10.26656/fr.2017.7(S1).5