4. DISCUSSION

4.1. Temperature and Frying Time Determination

In the preliminary test, the experiment batch was done four times. Batch one, for vacuum frying method, was three settings with different temperature and time, Setting 1 (100°C, 600s); Setting 2 (105°C, 420s); and Setting 3 (110°C, 300s); for atmospheric fried, one temperature setting and three time-settings was used, which is 180°C with 120s; 150; and 180s. In this batch there was no blanching treatment, only rinsing PSP discs with water and drying it with a paper towel. The final product was considered a failure, there were excessive scorching/browning on atmospheric fried chips, while there were extreme shrinking and curling on chips, and the oil uptake was visibly high on vacuum fried chips.

The second attempt was done with the same settings, and blanching was implemented. Ayustaningwarno *et al*. (2018) stated blanching could prevent excessive oil uptake due to gelatinization of starch, swelled starch blocking the pores preventing too much oil absorbed, such as suggested by Moreira (2014). There was an improvement on this batch, shrinking and curling was greatly reduced for vacuum fried chips; and while there was decreasement of browning on atmospheric fried chips, heat control on conventional stove was unstable, making the heat unequally transmitted on the chip's surface. In this batch, Setting 2 on vacuum frying method was deduced to be the best setting.

In the third attempt, there was an attempt to use osmotic dehydration to increase soluble solid content to provide better texture and flavor on chips (Ayustaningwarno *et al*., 2018). Maltodextrin with DE of 30 and sugar was used, each was made into solutions with 30% concentration (Da Silva & Moreira, 2008). This attempt was considered unsuccessful. Final products of chips submerged in sugar solution were still wet, both vacuum and atmospheric fried methods. While the final product of chips submerged in maltodextrin solutions excessive darkening and the texture was too hard. This could happen because increased solid content and Maillard reaction (Ayustaningwarno *et al*., 2018).

For the fourth attempt, the temperature setting on the atmospheric fried chip was changed to 160°C, this decision was made with the expectation it was easier to stabilize and still give desired quality chips. The result of this attempt was passed as a decent sample.

4.2. Sample Preparation of Purple Sweet Potato

Purple Sweet Potato is a tuber, part of a plant that grows under soil. To process it into food, PSP needs to be prepared. The preparation needed is washing, peeling, and slicing. Washing intended to get rid of all soil and debris on the samples. The last step of preparation is blanching. The samples were blanched with boiling water for 60 seconds. Despite high temperature during blanching can destroy sensitive pigments such as anthocyanin, Fang *et al*. (2011) said processing without blanching could increase losses. But the advantages of blanching are many; including limiting oil uptake due to starch gelatinization swells the starch and preventing oil from entering the samples (Ayustaningwarno *et al*., 2018). Mariscal & Bouchon (2008) also added blanching could improve color and texture of said products. Ayustaningwarno *et al*. (2018) said more than 5 minutes blanching could result in color loss, even before the next heat included processing. Which is why the blanching time was set below 5 minutes.

4.3. Frying Process of Purple Sweet Potato Chips

The high temperature in frying induces physical and chemical changes, causing obvious micro and macro structural changes to chips' surface. As Oke *et al*. (2017) mentioned, transfer heat by convection by oil to food and core by conduction makes moisture escape through food's crevices and forcefully dug pores created by pressured moisture trapped inside. This moisture loss subsequently raises the surface temperature close to the oil's, hence the crust formation. For the same reason, high heat has a preserving effect on food, because of thermal destruction of microorganisms and enzymes, also reduction of water activity from surface area (Mariscal & Bouchon, 2003; Moreira, 2014; Oke *et al*., 2017).

As many stated, deep fat frying is a popular processing method, both in industrial world or household use. Oke *et al*. (2017) stated that the popularity could be attributed to the fast speed of cooking, the efficiency for energy and economical aspect, the consistency of the final product, and add flavor, color, and desirable texture to food. But aside from many advantages deep fat frying brings, the condition that requires high heat processing in atmospheric pressure also brings many disadvantages. Tagalpallewar *et al*. (2015) and Moreira (2014) both stated that the surface excessive darkening or scorching are the most usual disadvantage deep frying have, Moreira (2014) added that oil decomposition brought many adverse health effects, as supported by Oke *et al*. (2017), that the longer oil used, the greater the degradation. Moreira (2014) explained the cause of oil degradation is continuous exposure to high temperature and atmospheric air, inducing production of highly oxidized, and potentially toxic products.

Compared to atmospheric deep frying, vacuum frying has more advantages such as reduction of oil content in fried snacks, preservation of natural color and flavor of product, reducing the adverse effect of oil deterioration, higher retention of nutritional quality, also reduction of toxic molecules in food (e.g acrylamide), all the while maintaining necessary degree of dehydration without too much darkening or scorching. All the benefits of vacuum frying could be attributed to lower temperature and lower oxygen exposure compared to atmospheric frying (Garayo & Moreira, 2002; Da Silva & Moreira, 2008; Mariscal & Bouchon, 2008; Zhu *et al*., 2015; Tagalpallewar *et al*., 2015). Tagalpallewar *et al*. (2015) has elaborated more on the reduced oxygen presence during frying could exhibit lipid oxidation and enzymatic browning, causing the color and nutrients of food could be preserved more.

Aside from the much advantageous effect, Tagalpallewar *et al*. (2015) express that in economical aspects, the investment of vacuum frying is much higher than conventional method of frying. This is because this method is designed more specifically for industrial use, and lack of consideration for small-scale production makes it hard for small enterprises to afford the machines and equipment without any outside financial aid. Bhattacharya (2015) also said that vacuum fried practice in few Asian countries died out because of improving raw material and blanching techniques.

4.4. Color of Purple Sweet Potato Chips

The first aspect of food that would be judged by potential consumers is its appearance. While appearance consists of many things, color was the first thing that enters human eyes. Color has an unmistakable correlation with flavor and pigment contents, making it used as an indirect measurement of said aspects. Which is why color is one of the most measured aspects of food quality attributes (Pathare *et al.*, 2012).

This analysis was done by using spectrophotometer on Lab basis (Konica Minolta CM-5), and the test results are presented in L*, a*, b* value. L* value represents lightness level, whereas the scale ranges from positive (lighter) to negative (darker). a* value is a red-green indicator, whereas the scale ranges from positive (redness) and negative (greenness). As for b* value, it's a yellow-blue indicator, with positive means yellowness, and negative means blueness.

As the result seen in Table 1, we can see that L* (lightness) value from atmospheric fried chips is significantly higher than vacuum fried chips. It means that more monomeric anthocyanin that brings the dark purple color was broken down due to high temperature used in atmospheric deep fried method. Anthocyanin contained in purple sweet potato is high enough to be considered as an antioxidant (Elvana *et al.*, 2016). It was confirmed as it was mentioned by (Patras *et al.*, 2010) that antioxidant is significantly impacted by the use of heat in food processing.

Meanwhile, the a* and b* value for the atmospheric fried chips was higher and lower, respectively, compared to vacuum fried chips. It is in accordance with the result from Da Silva & Moreira (2008), in which researchers use blue potato chips as the sample. It means that vacuum fried chips are less red, and bluer or we could say purple, compared to atmospheric fried chips. The result of red color comes from the Maillard reaction, which could form acrylamide (Mottram *et al.*, 2002).

The result is in accordance with theory from Moreira (2014), which said that the vacuum frying method is more able to retain the natural color and flavors of fried product compared to conventional frying.

4.5. Texture of Purple Sweet Potato Chips

Oyedeji *et al*. (2017) stated that texture is an important quality attribute in determining the level of product acceptance, the texture depends on raw product attributes such as starch content, starch granule size, and also process conditions which include frying time and temperature.

Crispy texture from chips is one of the important quality attributes of chips. Crispy texture in chips could be described in terms like crispness, hardness, and crunchiness. When the surface moisture is lost and dehydrated, the surface temperature is rising close to the hot oil temperature, causing a crust to form. Temperature elevation also instigates chemical and physical changes such as starch gelatinization, protein denaturation, and pore formation, making it a major factor to determine textural attributes on chips (Adedeji & Ngadi, 2011).

The result of texture analysis could be seen in Table 2, we could see the bioyield point (N), which is an indication of initial cell rupture. Vacuum frying has a bigger bioyield point or hardness, which means that the crust surface is harder to rupture than atmospheric deep-fried chips, which means it is crispier. However, it is not significantly higher, which is in accordance with research from Garayo & Moreira (2002) in which reported that the final hardness value between vacuum fried and atmospheric fried chips were not significantly different ($p<0.05$).

4.6. Moisture Content of Purple Sweet Potato Chips

Changes of moisture content in fried products were one of the main mechanisms of frying process. Heat will cause the product to lose moisture and in exchange, gain fat from oil. The amount of moisture could impact the production and quality of chips, such as perishability because moisture has an impact in chemical stability and microbial contamination in chips (Caetano *et al*., 2018), hence the need to monitor moisture content in the product.

The result of this analysis could be seen from Table 3, both the fried chips moisture content was much lowered compared to the raw product. Sandhu (2015) said that this occurrence is due to heat transferred into the product from hot oil. The heat will cause moisture loss and thermal degradation, which lead to softening of food material, and as the frying process progresses, the product will lose more moisture and take up oil. However, the rate of oil uptake is less than moisture loss due to moisture has a higher rate of transport.

Da Silva & Moreira (2008) in their journal have varying results, some of their vacuum fried products have lower moisture loss compared to atmospheric fried, but in the discussion they express that the amount of moisture removed from all products are similar, meaning that structure and composition of product is more important. In this research, the moisture content between vacuum fried chips and atmospheric fried chips are significantly lower. In Marischal & Bouchon (2008), they also found that atmospheric fried products have higher moisture loss compared to vacuum fried products, even though the initial rate of loss are the same. They stated that differences might occur because of microstructural changes during initial depressurization that might affect water escape.

4.7. Oil Content of Purple Sweet Potato Chips

The major event on frying process is the exchange of moisture and oil, when the oil temperature increase, water escape from the sweet potato chips, and in the process the cells are damaged and causing the surface area to become hydrophobic, hence the oil are absorbed into the damaged sites (Ayustaningwarno *et al*., 2018). Mariscal & Bouchon (2008) also mentioned that the amount of water loss during frying affected the extent of forming the crust, as supported by Oke *et al*. (2017) which stated that during frying water in the crust are evaporated and move out of the food, which makes voids to fat to enter, hence the reason why moisture or water loss is largely affecting the fat uptake of the food.

The result of this analysis could be seen that vacuum fried chips have significantly lower oil content compared to atmospheric fried chips. This result is in accordance with Mariscal & Bouchon (2008) in which said that from visual observation, vacuum fried chips have less volume expansion compared to those fried under atmospheric pressure. They elaborate that these could occur because of the direct impact from lower pressure of water in vacuum frying, and also, higher temperature in atmospheric deep frying contribute to structural changes which enhance the oil absorption.

On the other hand, on research by Yagua & Moreira (2011) about properties of potato chips during vacuum frying they expressed IOC (Internal Oil Content) i.e. the oil content of the chips after the de-oiling process is only a small part of TOC (Total Oil Content) of chips. IOC was found to be easily removed by the de-oiling system (centrifuge) of vacuum fryer, and was inversely proportional to frying temperature. This could occur because high temperature reduced oil viscosity, hence easier removal of oil during the centrifuge process. The de-oiling process itself has obvious benefit for vacuum fried chips compared to atmospheric fried chips that were only placed on a mesh for the oil to drip. There has been some suggestion that the oil content for vacuum fried foods was lower compared to conventional frying method is because of the de-oiling process, that the factor affecting the oil content is the de-oiling method, in addition to lower temperature and pressure. But until now there has not been any study discussing this topic.

4.8. Monomeric Anthocyanin Content of Purple Sweet Potato Chips

Anthocyanin contained in purple sweet potatoes generally exists in the form of acetylation, which means there are advantages in pH and heat resistance, sensitivity to light, and overall stability (Xu et al., 2015). Xu et al. (2015) stated that generally purple sweet potatoes are processed into additive products so that a process that involves heat and oxygen exposure is needed, resulting in the degradation of anthocyanin pigments. Therefore, anthocyanin stability was assessed as an attribute that had an impact on overall quality.

Despite the heat resistant advantages of anthocyanin, Husna *et al*. (2013) stated that anthocyanin content would decrease after processing because heat usage will affect volatile compounds such as ascorbic acid, beta-carotene, and also anthocyanin. The stability and endurance of anthocyanin will change when placed at high temperature, causing it to degrade. This analysis was using a pH differential method by AOAC, which determines anthocyanin as cyanidin-3-glucosides equivalent.

The result could be seen in table 5. While it shows that vacuum-fried chips have higher monomeric anthocyanin contents, it is not significantly higher compared to atmospheric fried chips. While in accordance with results from Da Silva & Moreira (2008) and Yang *et al*. (2012) that vacuum-fried chips have higher retention of anthocyanin, the result is not as dramatically higher as the previous research.

This could happen because anthocyanin is a volatile/unstable compound; hence oxygen, temperature, light, enzyme, and pH could affect anthocyanin's chemistry, and further affecting their stability and color (Martin *et al.,* 2017). Lee & Wrolstad (2009) found that total anthocyanins were greater in amount if expressed as malvidin-3-glucosides rather than cyanidin-3-glucosides.

4.9. Sensory Analysis of Purple Sweet Potato Chips

In this research, we conducted a sensory analysis with the parameters of color, flavor, crispiness, oiliness after chewing, and overall acceptability. Results from various researchers show that the sensory analysis between atmospheric fried food and vacuum fried food is significantly higher for vacuum fried food. Moreira (2014) mentioned that in a conducted study that most of their sensory panelists chose vacuum frying over atmospheric fried food for color, texture, taste, and the overall quality. Ayustaningwarno *et al*. (2018) also stated that vacuum fried chips' scores are significantly higher compared to atmospheric fried chips. The same thing is also expressed by the research result from Esan *et al*. (2015) and Da Silva & Moreira (2008) that the scores from the panelists are significantly higher for vacuum fried food, compared to conventional fried food. Moreira (2014) expressed that because vacuum fried foods are more able to retain or highlight the natural color of food. Despite all the findings, in a study conducted by Yang *et al*. (2012) while there was higher acceptability for vacuum fried chips in color and flavor aspects, but the score for texture or crispiness are higher on atmospheric fried chips.

In this sensory analysis, the result is not in accordance with other research. This could happen because the control that was used is not quite appropriate. Hence, could affect the whole sensory analysis result. Sidel *et al*. (1981) said that misuse in sensory analysis could happen from earlier stages until the reporting stage. In this case, in my opinion, the misuse happened in the planning and execution stage. Miscommunication and lack of time are the primary cause the result is not suitable. Ideally, there would be selection and training of subjects before conducting the real sensory test, but in this case, there are no training sessions. And these reasons could cause the result of the analysis is unsuitable