JOURNAL OF AGROBIOTECHNOLOGY 2020, VOL 11(1S):46-55
e-ISSN: 2180-1983
http://dx.doi.org/10.37231/jab.2020.11.1S.233
https://journal.unisza.edu.my/agrobiotechnology/index.php/agrobiotechnology/index

# Effect of Salt Addition on Mass Transfer, Colour and Texture Characterictics of Shallow Fried Potato Strips

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*Received: 15/08/2020, Accepted: 20/10/2020, Available Online: 31/10/2020*

***ABSTRACT***

Shallow frying is widely used as one of the cooking processes because of its simplicity and ability to gives better taste of foods by adding spices, herbs and salt. Despite its widespread use, the mass transfer and product properties of shallow frying have not been studied systematically, especially after the addition of salt. This study aims to investigate the effect of adding salt to potato strips, prior to shallow frying on the mass transfer (moisture and oil contents) and physical properties (colour and texture) of products. The potato strips were cut into 9 x 9 x 50 mm and were divided into salted (1% w/w) and unsalted (as control), and then were shallow fried at 150°C and 180°C for 35 minutes. The moisture and oil contents were analysed every 5 minutes, while colour and texture were determined at the end of shallow frying (i.e. when moisture content reached ~0.82 kg $H_2O$/kg dry matter). Salted fried potato at 180°C resulted in a significantly shorter frying time of 18 minutes, compared to unsalted fried potato, which took 21 minutes. Meanwhile, at 150°C, the frying time reduced to 25 minutes for the salted product from 33 minutes under unsalted product. The oil content, colour and texture of final products were not significantly different under both treatments. Therefore, the effect of adding salt to potato strips does not influence the oil content, colour and texture of the shallow fried products, but reduces frying times by up to 24%, thereby improving energy efficiency.

**Keywords:** Shallow frying, mass transfer, salt addition

## INTRODUCTION

Frying is an oldest process and used extensively in food preparation. It essentially involves dehydration by immersing the food in oil, where the moisture content of the food is much more rapidly lowered than in conventional drying processes (Gertz, 2014). In the most commonly used frying process, known as deep fat frying, the product is generally immersed in a high amount of hot oil that maintained around 150-200°C. During frying, heat and mass transfer occur with water being lost from the product and oil being gained by the product. In addition, the texture attributes of the product also change, generally with the formation of a crunchy crust covering a soft-cooked core. Due to its rapid nature, it is widely used in domestic and industrial practices, as well as in restaurants and fast food outlets. Despite such products containing undesirably high fat contents, it continues to be popular with consumers, mainly because the products possess highly desirable flavour, colour and mouth-feel (Farinu & Baik, 2005).

Even though frying generally refers to deep fat frying, it is important to note that there are other types of frying known by terms such as shallow, pan and stir frying, which are extensively used in domestic and restaurant environments. In these frying processes, the amount of oil used is relatively low, i.e. the ratio of the oil to food is significantly lower than deep fat frying, which is good in health as well as cost points of view. In contrast to deep fat frying, shallow frying times are significantly longer and the equipment used is also different (Chiou et al., 2012). It is interesting to note that even though the frying times are shorter in deep fat frying, the same oil continues to be used for a very long period of time, which generally does not happen in shallow frying processes. As a consequence, the oil used in deep fat frying suffers significant quality deterioration by thermal degradation, hydrolysis, oxidation and polymerisation (Hosseini et al., 2016; Ahmad Tarmizi et al., 2013) which, in extreme cases, can pose cardiovascular and other health risks (Nayak et al. 2016; Dana & Saguy, 2001). Shallow frying, on the other hand, is employed in such a way that the oil quality is maintained (Rana & Raghuvanshi, 2013); the oil undergoes less oxidation (Ghosh et al. 2012) and can enhance the nutritional impact of the product (Hrncirik & Zeelenberg 2014; Hrncirik 2010).

On the other hand, there are various culinary techniques to enhance food tastes. Generally, in practices, some seasonings such as salt, spices and herbs are added as food additives before fry, while others prefer to add it during or after frying (Okiy & Oke 1984). According to Cook's Illustrated (2015), by adding salt before cooking of carrot, onion and beef stew gave better taste in term of evenly seasoned, while products tasted too salty when the salt was added at the end of the process. Previous studies found that by added spices or herbs just before or during frying could inhibit oxidative degradation and extending fry-life of frying oil (Banerjee et al. 2015; Horuz & Maskan, 2015; Abriana & Johannes, 2014). Meanwhile, others demonstrated that acrylamide content could be reduced up to 40% when adding salt during frying (Kolek et al. 2007; Kolek et al. 2006). However, in general, majority of researchers focus on the benefits of spices or salt as food additives to improve the nutritional and sensory properties, but its effect on the mass transfer during frying is still unclear.

Using potato strips as illustrative product, this paper aims to exploit the mass transfer process of shallow frying, especially after the addition of salt. The final product properties such as colour and texture characteristics were also observed in detail.

## MATERIALS AND METHODS

### Raw materials

Potatoes (*Solanum tuberosum L.*), cooking oil and salt were purchased from local market in Besut, Terengganu. Analytical grade of petroleum ether and extraction thimbles were purchased from Fischer Scientific Malaysia.

### Sample preparation

Potatoes were washed, peeled and cut into rectangular slabs having dimensions of 9 x 9 x 50 mm using household French fry cutter (Kitchen Craft, Birmingham, UK). Potato samples were rinsed by using tap water for 1 minute to eliminate excess starch and the excess water was removed using tissue paper.

### Shallow frying experiment

The shallow frying experiments were carried out in a possibly same way as the actual household cooking process. A round shaped non-stick frying pan made of Teflon-coated aluminium (George Home, UK) with dimension 7 cm high and 20 cm diameter was used in this study. This frying pan was heated up by portable electrical kitchen cooker equipped with temperature control dials (Caterlite GG567) as illustrated in Fig. 1. Pan fryer was heated and maintained at desired temperature at 150°C and 180°C for 15 minutes. The frying temperature was monitored using a 3-Channel K-thermocouple temperature data logger (Extech SD200, United State). Then, about 100 g of potato strips were fried for 35 minutes in 50 g of oil to give a ratio of 1:0.5 (w/w). The potato strips were turned over at every 5 minutes to fry on the opposite side and at the end of frying, the fried strips were placed on adsorbent tissue to eliminate the excess oil and cooled at room temperature for 10 minutes before proceed for further analyses. After each frying operation, the frying pan was cleaned and used oil was removed and replaced with fresh oil for the next frying session.

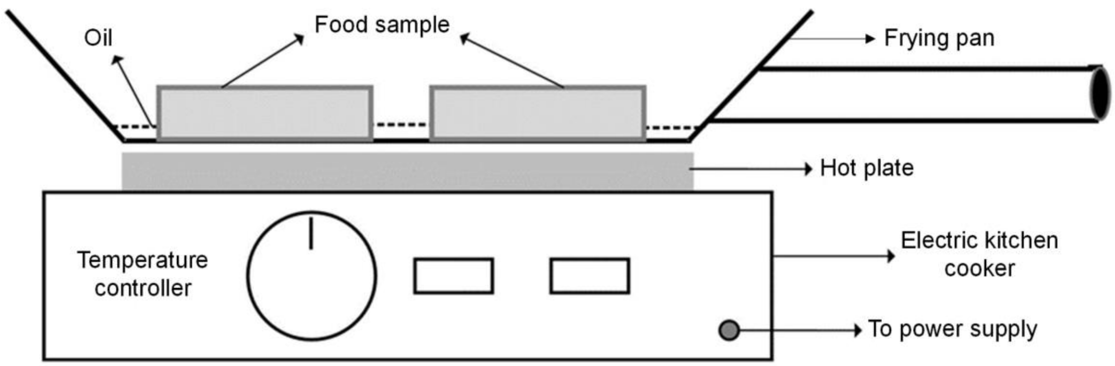


**Fig. 1.** Schematic diagram of shallow frying equipment for this study.

**Determination of moisture content and dehydration rate**

Moisture content of the fried samples were analysed every 5 minutes of frying time. Potato samples were collected, crushed in a mortar, weighed and then dried at 105°C in an oven for 24 hours until a constant weight was achieved (AOAC, 2000). The moisture content was expressed as kg $H_2O$/kg of dry matter and was calculated from:

$$MC_{\text{dry basis}} = \frac{M_{wet}-M_{dry}}{M_{dry}} \qquad \textbf{Eqn. 1}$$

$M_{wet}$ = mass of the wet sample (kg)
$M_{dry}$ = mass of the dry matter of the sample after drying (kg).

Moisture content data over the frying times were fitted with non-linear polynomial equation and the gradients of the curve were used to estimate the dehydration rate.

**Determination of oil content**

Oil content was determined by drying the samples in an oven at 105°C until a constant weight was achieved, then dried samples were ground and extracted with petroleum ether for 4 hours using Quickfit Soxhlet extraction system. The solvent was removed using a rotary evaporator and the flask containing oil was dried to constant weight in an oven at 90°C. The difference between the initial (empty) and the final weight of the flask gave the oil content (on a dry basis) (AOAC, 2000).

### Texture measurement

The hardness (a maximum breaking force) of the fried potato strips was measured using a Brookfield texture analyser fitted with 25 kg loading cell (CT3, Brookfield Engineering Laboratories, Middleborough, U.S.A.) at ambient temperature. A probe (2 mm diameter) was fitted to the instrument and a puncture test was carried out at a test speed of 1 mm/s. Each sample was punctured at the centre and penetration depth was set to 2 mm in order to study the crust formation. All data obtained were analysed by software (TexturePro CT v1.2 software) provided by the instrument supplier.

### Colour measurement

By using Konica Minolta CR-400 chromameter, colour of samples was determined and expressed in terms of L*, a* and b* values. The instrument was calibrated with white standards and the colour of fried potato strips was obtained at four different surface positions on three samples aligned to each other taken from two separate batches.

### Statistical analysis

Duplicate batches of frying experiments were performed and samples were collected in triplicates from each batch for further analysis of moisture and oil contents, texture and colour as described above. All experimental data reported in the figures and tables are the mean and standard deviation values calculated using Microsoft Office Excel 2013. A one-way analysis of variance (ANOVA) with Tukey's test was used to determine the difference between means using Minitab 17 Statistical Software at 95% confidence level.

## RESULTS AND DISCUSSION

### Moisture content and dehydration rate

Fig. 1 shows the moisture content (expressed as kg $H_2O$/kg of dry matter) of potato samples for different frying temperatures (150°C and 180°C) at 1:0.5 of the mass ratio sample-to-oil conditions until 35 minutes of frying time. As expected, the moisture content decreases significantly with time ($p < 0.05$) for all cases and this trend is similar to the deep fat and air frying, which is in agreement with previous studies (Teruel et al., 2015; Farinu & Baik, 2007). As shown in Fig. 1, the moisture content initially dropped rapidly with time and then decreased steadily at the later stage. It can be explained due to intense evaporated of surface water at the initial point, and then the water vapour releases inside the samples. Due to dehydrated continuously, the crust layer is formed at the surface product and becomes resistant to water vapour transfer from the inner.

It may be noted that higher frying temperature and salted products resulted in shorter frying time. For example, the shortest of frying time, which is the time required to drop the initial moisture content from 4.5 ± 0.61 kg $H_2O$/kg of dry matter to the 0.082 kg $H_2O$/kg dry matter was 18 minutes under 180°C/salted, followed by 21 minutes (in 180°C/unsalted), 25 minutes (150°C/salted) and 33 minutes (in 150°C/unsalted). The 0.082 kg $H_2O$/kg dry matter was chosen as moisture content of the final product of the potato strip that fulfils the criteria set by industry (Matthaus et al., 2004). The more significant water loss of salted products might be due to osmotic dehydration occurs before and during the frying process (Barat et al., 2006). It can be observed that salted products had lower initial moisture content (4.11 ± 0.19 kg $H_2O$/kg of dry matter) than unsalted products (4.50 ± 0.61 kg $H_2O$/kg of dry matter). These results also revealed that high frying temperature causes more energy to heat the sample, thus, of course, increases the dehydration rate.

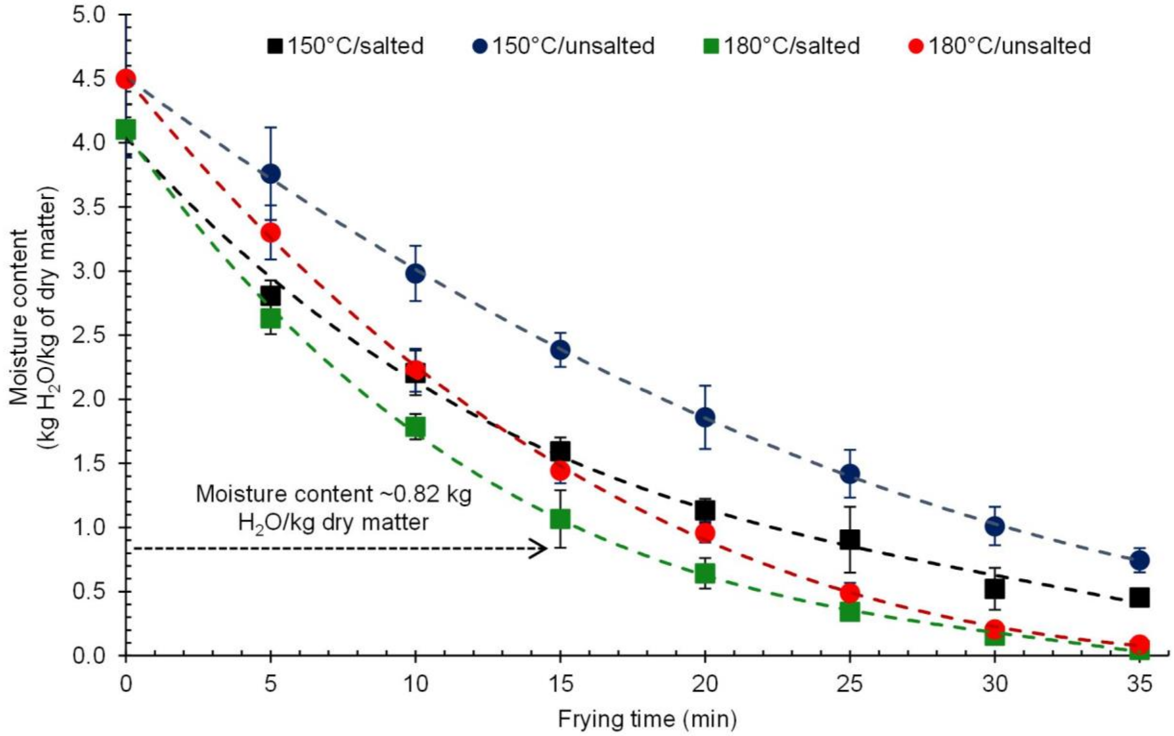


**Fig. 1.** Transient moisture content in unsalted and salted potato samples fried using shallow frying at 150°C and 180°C.

Frying is a simultaneous heat and mass transfer between food samples and oil medium. The data of moisture content in Fig. 1 were fitted with a polynomial model to obtain the dehydration rate. It is clearly showing that moisture content data fitted well under third-degree polynomial equation with $R^2 \geq 0.9959$ as shown in Table 1. Dehydration rate was calculated by taken gradient of the polynomial equation that listed in Table 1 and the data were plotted over frying time as illustrated in Fig. 2

It is obviously shown that dehydration rate falls over frying time and is commonly known as falling drying rate period. Dehydration rate was high at the beginning of frying and then reduces steadily as frying progresses in all cases. This is because, at the initial frying, the heat was transferred from oil to potato surface by natural convection and thus, the high amount of free water on the surface products were evaporated rapidly due to high temperature of the oil. Then, the water of products was diffused out in water vapour form due to heat conduction inside the products. The reduction of dehydration rate over the time was due to crust formation at the potato surfaces, which pose a high resistance for water vapour escapes from the products and lower moisture content of samples throughout frying time (as shown in Fig. 1) also contributed to the reduction of dehydration rate. Previous findings also reported the similar principles that applied in deep fat frying and air frying (Isik et al. 2016; Farinu & Baik, 2007). Fig. 2 reveals that the rate of moisture loss was higher for salted potato samples and at higher oil temperature and thus reduces the total frying time.

**Table 1.** The polynomial equation used in the determination of dehydration rate

| Condition | Polynomial equation | $R^2$ |
|---|---|---|
| 150°C/salted | $y = -7E\text{-}05x^3 + 0.0068x^2 - 0.2512x + 4.0465$ | 0.9959 |
| 150°C/unsalted | $y = -5E\text{-}07x^3 + 0.0017x^2 - 0.1668x + 4.512$ | 0.9997 |
| 180°C/salted | $y = -9E\text{-}05x^3 + 0.009x^2 - 0.3143x + 4.0735$ | 0.9992 |
| 180°C/unsalted | $y = -4E\text{-}05x^3 + 0.0056x^2 - 0.2776x + 4.5119$ | 0.9996 |

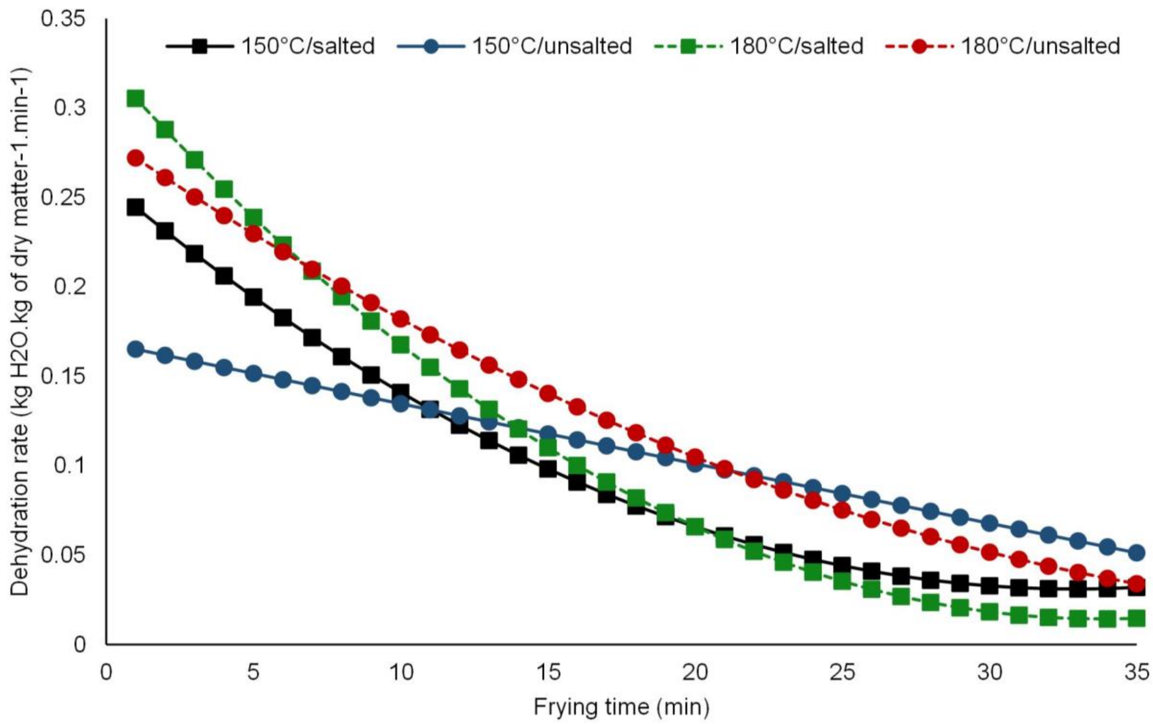


**Fig. 2.** Dehydration rate curve of fried potato samples under different frying conditions.

**Oil content**

The oil content is one of the important parameters determining the good quality of fried products. Fig. 3 illustrates the oil content of fried potato strips under salted and unsalted treatments as a function of frying times for both frying temperatures. It is obviously showing that the trend of oil content was similar for all frying conditions, which significantly ($p<0.05$) increased over frying progresses and then, become consistent at the end of frying time, which is around 0.18 to 0.22 kg oil/kg dry matter. This observation is in agreement with most previous researches on the other frying processes such as deep fat frying (Teruel et al., 2015; Bingol et al., 2012) and vacuum frying (Su et al., 2018; Yagua & Moreira, 2011).

This trend can be explained due to the development of crust during frying process, which is accounts for the crispy texture of fried products. When the foods loaded into the pan, a sharp temperature gradient between hot oil and foods, caused moisture at the food surface became evaporated as a steam form and thus, resulted in cracks, voids and defects in the cellular structures that generally referred as the crust formation. Due to the porous medium of the crust is developed during frying, it allows oil to be absorbed and remain trapped within the pores, especially as the products cool after frying (Ziaiifar et al., 2008). Ziaiifar et al. (2010) also noted that the thickness of the crust increased with frying time and facilitated oil absorption due to its highly porous structure.

It can be noticed that fried potato strips at lower temperature absorbed more oil than higher temperature when comparing at similar moisture content value. For instance, the oil content at 0.82 kg $H_2O$/kg dry matter, which at final moisture content was lower in case of 180°C/salted (0.13 kg oil/kg dry matter) than in case of 150°C/salted (0.165 kg oil/kg dry matter). This value was estimated by interpolating its value in Fig. 3 at desired frying time to reach at the final moisture content at 18 minutes and 25 minutes in the case of 180°C/salted and 150°C/salted, respectively. On the other hand, statistical analysis showed that there was no significant difference ($p>0.05$) between the oil content of samples at the same final moisture content of both salted and unsalted treatments.

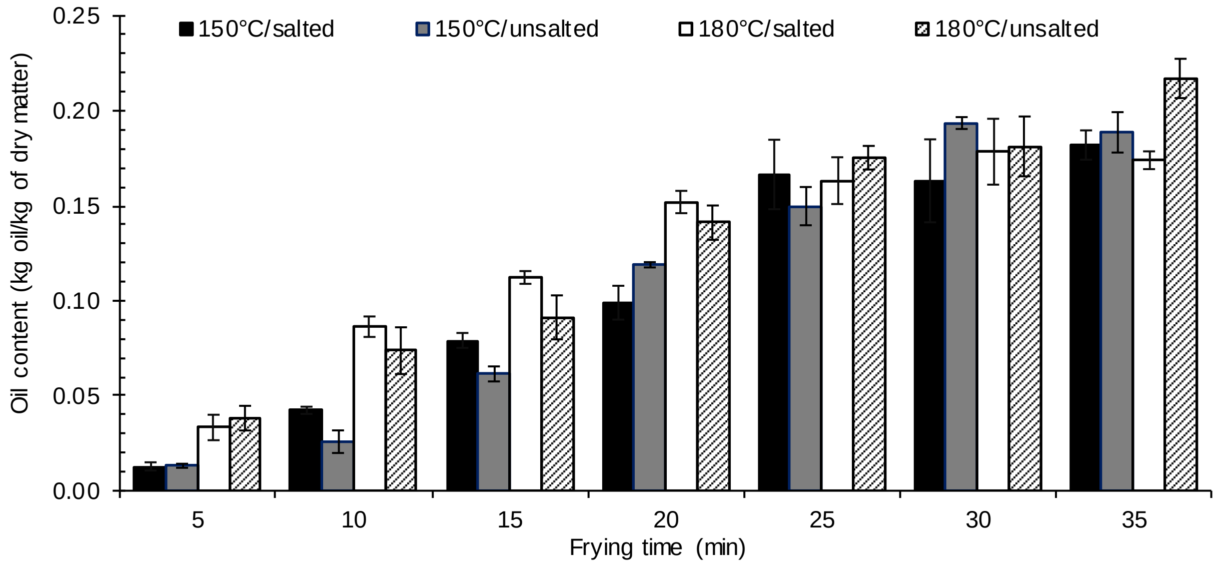


**Fig. 3.** Transient oil content in shallow fried of unsalted and salted of potato strips at 150$^{o}$C and 180$^{o}$C.

## Texture and colour analysis

The texture and colour are the most important criteria determining consumer acceptability and it accounts for the crispiness and appearance of products, respectively. Miranda and Aguilera (2006) reported that the moisture adsorption from humid air tends to soften the texture of fried products during the cooling period after frying. Hence, in this study, the fried potato strips cooled to room temperature after frying and immediately packaged in PE bags in order to ensure no moisture uptake occurs during storage, which then contributes to texture softening.

As discussed in the previous section, fried potato strips at a higher temperature (180°C) gave a better performance to minimize the total frying time and oil content for both salted and unsalted samples. Therefore, only samples that fried at 180°C were chosen to observe the effect of salt addition on the analysis of product quality i.e. texture and colour parameters.

Table 2 shows the hardness and colour parameters values of shallow fried potato strips at the final moisture content in the case of salted and unsalted at 180°C. Hardness value is referring to the maximum force needed to break the surface crust by probe penetration and it indicates the crispiness of the fried potato strips, while the parameters of L*, a*and b* are associated with lightness, redness and yellowness of samples. Based on the statistical analysis, there is no significant difference ($p>0.05$) between hardness value and all colour parameters for salted and unsalted potato strips. Thus, the salting process gave no effect towards the quality of the final shallow fried potato strips.

**Table 2.** Hardness and colour analysis of final shallow fried of potato strips (~0.82 kg $H_2O$/kg of dry matter) at 180$^{o}$C

| Parameter | Salted | Unsalted |
|---|---|---|
| Hardness (g) | 251 ± 33 | 246 ± 13 |
| L* | 38.82 ± 4.00 | 41.31 ± 3.57 |
| a* | 9.82 ± 2.55 | 11.81 ± 2.27 |
| b* | 6.97 ± 3.10 | 9.97 ± 2.69 |

## CONCLUSION

This study explores the effect of salting of potato strips prior to shallow frying at 150°C and 180°C on the mass transfer and physical properties of fried products. Addition of salt to potato strips during shallow frying increases water loss rate and thus reduces frying times by up to 24% thereby improving energy efficiency during the frying process. The enhancement in water loss rates may be attributed to local osmotic dehydration induced by salt. Meanwhile, the higher oil temperature resulted in a significant decrease in the moisture content of both the products. Both salted and unsalted products had slightly similar in term of oil content, texture and colour characteristics.

## ACKNOWLEDGEMENTS

We would like to thank the laboratory staffs of Faculty of Bioresources and Food Industry UniSZA for their guidance and assistance throughout this study.

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**How to cite this paper:**
Fathullah, R., Mat Rashid, N.H., Wan Mokhtar, W.M.F. &, Wan Mohammad, W.A.F. (2020). Effect of salt addition on mass transfer, colour and texture characteristics of shallow fried potato strips. Journal of Agrobiotechnology, *11*(1s), 46-55.