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Transparency phenomena of flat-rice noodles (kuew teow) at drying at soaking variation

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Abstract

This paper presents a transparency phenomenon that occurred in hot air and heat pump dried flat-rice noodles, which is explained by the higher colour changes, glassy puffing microstructures, and lower fat content in comparison to the freeze dried flat-rice noodles. Hot air drying and heat pump drying recorded the colour changes at an average of 43.87 ± 1.5 twice than colour change caused by freeze drying at 19.33 ± 1.12 to verify the transparency caused by employing high temperature to eventually increase the sample lightness. However, the microstructures study suggested that freeze drying produced distinct pores ranging from 2.05 µm to 27.68 µm whereby hot air drying and heat pump drying merely produced glossy transparent texture. Indeed, the pores disclose the fat content recorded by freeze drying in flat-rice noodles at 5.62% ± 0.2 twice than the fat content recorded by hot air and heat pump drying at 2.48% ± 0.49. Therefore, by learning the transparency phenomenon in hot air and heat pump dried noodles approves that freeze drying eventually preserves the quality attributes of flat-rice noodles as closest to the fresh flat-rice noodles in terms of colour, microstructures, and fat content.

Introduction

Food is any kind of substance consumed in order to provide nutritional support for the body. It usually comes in the form of plants or animal containing important nutrients such as vitamins, fats, proteins, or minerals. People literally eat to obtain nutritional values from the food. Even though the option of food may vary demographically as Westerners may eat hamburgers, and spaghettis as their main cuisines and the Africans may take yam and cassava and Middle Easterners go for bread by dipping it in the mutton sauce. Asians, however, do not particularly consume a specific type of food due to their wide variety, but rice and noodles are considered the mains and almost every Asian nation have at least one type of rice-based noodle as their own unique signature and many even have several (Letter H and Everything2 Media, 2004).

During the ancient days, they used to serve noodles for breakfast, dinner or even past time snacks. Even during specific occasions, noodles are presented to signify long lasting life in which the longer the noodle, the longer the life eventually is for the celebrated person (Lin and Wa, 2000). Nowadays, the savoury in flat-rice noodles for any occasion has become common across the globe. In Malaysia alone, flat-rice noodles or locally known as flat-flat-rice noodles which were previously consumed only by the Chinese can now be savoured by all. Indeed, in the sense of diversity soundness in turning basic ingredients into significant noodles themselves, nobody can deny Asians as the genuine noodle supplier to the whole world that makes pad thai as rice based noodles stood strong at number 5 in the top 50 best food in the world (CNN, 2011).

Continued soft global economic conditions, coupled with consumers' worries about the inconsistent domestic economy, are restraining consumer's spending confidence. In turns of fearing for the consumer's job security has resorted them to spend more time at work. Therefore, they are juggling into more hectic lifestyles and seeking more convenient and easy to pick and store solutions

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including meals in their daily lifestyles. This demanding situation was described through the ascending production volume of dried processed food by the increment of 3.65% and sales growth of 7.07% and noodles by the increased production volume of 4.39% and sales growth of 11.08% (Nations, Peninsula, and Independence, 2012)

Easily found in the Southeast Asia, flat-rice noodles or locally known as flat-flat-rice noodles are among the most sought after noodle varieties produced from mostly rice flour and water. Principally, rice noodle is the noodle made from rice flour and water but sometimes tapioca or starch is introduced to improve the transparency or increase the gelatinous and chewy texture of the noodles and it is white in colour with chewy and slippery texture (Fu, 2008).

The main problem faced by the industry that fresh rice noodle is very perishable and is subject to spoilage despite storage inside a freezer. It may not last longer towards storage time due to the existence of moisture inside the noodles to induce microbial growth. Therefore, eliminating moisture content from noodles by producing a dried processed noodle will definitely solve the issues addressed earlier as it preserved the mouthful feel as much as the fresh noodle before it ages by storage time.

In Malaysia alone, it is hard to find the dried flat-rice noodles in the market as at the moment, there is only one product available. This has secured an encouraging insight for the drying industry of flat-rice noodles as several drying methods may undertake to further improve the qualities of the dried rice noodle in Malaysia. By learning the transparency phenomena caused by hot air and heat pump drying, it may deduce a promising opportunity for the niche market that freeze drying may be able to offer.

Indeed, dehydration is a mass transfer process to remove water or another solvent from a solid, semi-solid or liquid through evaporation which shall cater as a final step before packaging. The process usually involved a source of heat or a medium in a way to remove the vapour produced since the absence of water inhibit bacterial growth that generally spoils the food.

There are many types of drying available whereby most of them use the hot source as the medium. Being the most traditional preservation method was sun drying and still common in many developing countries. Due to the difficulty of sun drying, hot air drying was introduced. Being a complex operation, hot air drying however usually introduces disturbance in product quality comprising shrinkage, puffing, crystallization, and glass transitions. It may lead to necessary or unnecessary chemical or biochemical fluctuations of colour, odour, texture, or other properties of the solid product mostly due to the utilization of hot air (Ratti, 2001).

In specific, air drying can be either classified as hot-air drying (more than 70˚C) and non-hot air drying (less than 50˚C) subjected to the maximum temperature employed in such drying process. Hot-air drying is usually used in the manufacture of steamed and hot-air dried instant noodles and non-hot air drying is normally practised for the production of plain dry noodles. Nonetheless, it is inevitable that drying is vital to increase product’s shelf life, cut down packaging rate in regards to shipping load and perhaps to appreciate physical outlook, encapsulate original essence and possibly maintain enriching values (Fu, 2008).

In the meantime, by optimizing the design as well as its operating conditions at a minimum expense and maximum output towards the production of a dehydrated item of preferred quality, heat pump drying may be able to help in improving drying quality by utilizing gentler temperature. Since drying is an energy intensive process which is accounting to 15% of overall energy usage in most industries (Chua *et al*., 2001) resulting in a large segment of energy is inutile (Ogura *et al*., 2005). Taking an average of 9 to 25% of overall domestic energy consumption in developed countries (Goh *et al*., 2011), thus to reduce energy consumption per unit of product moisture, it is paramount to learn other techniques to perk up the energy productivity of the drying facilities by introducing heat pump drying (Mujumdar, 1987).

In the meantime, freeze drying or lyophilisation is a drying method often credited for its excellent stability and minimal loss in product quality specifically in removing water moisture. Structural integrity and the preservation of volatile component results in the significant quality of the freeze dried products. It is a method of removing moisture through sublimation. This is achieved by keeping the conditions of water below that of triple point through a combination of temperature and pressure (Arun, 2007).

Therefore, the aim of the research is to justify the motivation of the transparency phenomena that occurred in the hot air and heat pump drying of flat-rice noodles. The phenomenon is well described by rationalizing the food quality attributes by hot air drying and heat pump drying to the freeze drying process.

Materials and Methods

Soaking

Before dehydration process, soaking is performed on fresh noodles. Soaking is the rinsing of fresh noodles for a short time with plain water, and is an essential step before canning, drying or freezing of food. The presence of heat in soaking is not necessarily to cook the food but to inactivate substances that would otherwise adversely affect the nutrient content, colour, flavour or texture during further processing and storage that is usually termed as soaking (Briggs and Wahlqvist, 1988).

Hot air drying

A packet of fresh rice noodle (400 grams) was separated and half of them was soaked with water and filtered to create two types of sample namely soaked rice noodle and non-soaked rice noodle. The rice noodle was placed in a layer to promote direct drying on two similar meshed-surface tares (0.8 m × 0.8 m each) inside the drying chamber of oven dryer. Meanwhile, the remaining noodles were arranged in a manner of free air circulating for the purpose of quality analysis.

Fresh flat-rice noodles were dried in a laboratory-scale hot air circulation oven (range 20–250°C, Memmert, Schwabach, Germany) with an accuracy of ±0.5°C at air temperatures of 30°C with air circulation. The air circulation was set at a velocity of 1.401ms^{-1}. Prior to drying experiments, the oven was turned on at the selected operating conditions for 30 minutes to achieve steady-state conditions. As drying has started, current mass is measured on the shorter interval at 10 minutes during the initial process and it spanned longer towards completion up to 30 minutes per interval. The total drying times for hot air drying with air circulation were determined once the noodles reached equilibrium moisture content (EMC) by prolonging the drying process until the constant mass of drying sample was observed. The previous study of Thailand rice noodles utilized the drying temperature ranging from 55 to 85˚C (Kongkiattisak and Songsermpong, 2012). Such drying at high temperature may only induce the product quality, the bigger drying range was chosen for the sample. A similar experiment was then repeated for the temperature of 60°C and 90°C (Memmert, 2010).

Heat pump drying

A packet of fresh rice noodle (400 grams) was arranged horizontally in a way to allow air circulation on the wire screen tray with a size of 0.27 m x 0.23 m inside a drying chamber of a heat pump dryer, perpendicular to the air flow. The dryer as in Figure 1(a) consists of two drying chambers measuring 0.95 m x 0.33 m x 0.33 m and the samples were put inside chamber A only. As the heater turned on, the drying chamber operated at drying temperature of 51°C whereas the drying temperature is 38°C when the heater was off. The temperature differs mainly according to ambient conditions. Air velocity was measured at 4.6 ms^{-1} ± 0.5 and relative humidity at 14.6% to 26.7% ± 1.0.

The dryer can be operated in two modes, continuous mode, and intermittent mode however for this research, the dryer was performed continuously. Moreover, the UV light was turned on. The current mass of sample was measured using an electronic balance (model GF-3000, range 0.5 g–3100 g, with an accuracy of 0.01 g, San Jose, CA) at certain intervals until EMC is again achieved.

Freeze drying

Before being freeze dried in a laboratory freeze dryer as in Figure 1(b) at different drying times, fresh flat-rice noodles were kept inside an FZ-220 deep freezer supplied by Mistral, Khind (M) Sdn Bhd. overnight at -18°C. The frozen noodles should be inserted into the drying chamber immediately as any thawing should not be tolerated for the optimum drying efficiency. Before starting up with the experiment, the vacuum pump is turned on for 30 minutes to create a vacuum inside the chamber. After that, the operating conditions were set to run for 24 hours under two different parameters which are -10°C (259.90 Pa) and -40°C (12.84 Pa) for the main drying at the range of noodle collapse temperature (-30 ˚C) (Chen, 2008).

(a) (b)

Figure 1. System set-up of (a) heat pump and (b) freeze drying

Colour change

The colour of fresh and dried flat-rice noodles was measured using a handheld colorimeter (Lovibond, LC100/SV100 Integrated Package, England). As outlined by the International Color Standardization body, colour parameters were characterized into three groups viz. The colour of the sample was measured in terms of L* (light–dark spectrum, range from 0 to 100), a* (green–red spectrum, range from -60 to +60), and b*(blue–yellow spectrum, range from -60 to +60), respectively. The dried sample was scanned at three anonymous measurements to eventually define the average values (n=3) by taking fresh noodles as the reference value. Total colour change (ΔE) and chroma value (ΔC) were calculated using Equation 1 and 2 (Wyszecki and Stiles, 2000):

$$\Delta E = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2} \quad (1)$$

$$Chroma\ (\Delta C) = \sqrt{(a\square)^2 + (b\square)^2} \quad (2)$$

ΔL, Δa, and Δb represented (Lo-L*), (ao-a*) and (bo-b*) where Lo, ao, bo are the initial colour measurements of fresh samples and L*, a* and b* are the colour measurements of the dried samples.

Microstructural analysis

Available samples were cut approximately of the scanning area at the dimension of 0.4 cm x 0.2 cm. The conductive adhesive (carbon tape) was attached to the specimen holder (aluminium stub) and the observation was done through Scanning Electron Microscope (SEM) at different magnifications of 80, 500, 2000, and 5000 (Kongkiattisak and Songsermpong, 2012; Li *et al*., 2016).

Oil content analysis

A Soxhlet extractor is an extraction set of laboratory apparatus which was originally designed for the extraction of a lipid from a solid material. A known weight of particularly dried food was placed in a porous thimble and inserted in Soxhlet reflux apparatus and the extracting solvent (petroleum ether) was placed in a dried, weighed distillation flask. As soon as the solvent volatilizes, it was heated, and collected, after condensing in a container of the porous thimble. The solvent then mixed with the food, dissolves out the fat and eventually siphons back into the original distillation flask. The water content of the water bath should be ensured sufficient and add if necessary in order to control the temperature of the heater. Extra caution in making sure that the solvent is not evaporated or dry during refluxing should be taken. If so, more petroleum ether should be added.

The process was then repeated continuously for a period of 8 hours, after which it is assumed that all the fat has been extracted from the food and present in solution in the distillation flask. Removal of the solvent by rotary evaporator from the round bottom flask leaves the fat as a residue. Round bottom flask was placed into the oven at 105oC for 15 minutes. The round bottom flask was then cooled in desiccators. The round bottom flask was reweighed and the increase in flask weight taken as the weight of fat present in the original food. The latter steps were repeated until constant weight is achieved (Yu, 2003). By taking W as the weight of sample in grams and weight of oil as M in grams the percentage of oil in a sample is determined by calculating

$$W = \frac{M}{W} x\ 100 \quad (3)$$

Statistical analysis

Statistical analysis was conducted by analysis of variance (ANOVA) using the general linear model (Minitab 16.0). The data were analyzed using the ANOVA module and Tukey's by assuming equal variances to detect the differences among treatments. Comparisons between the indices relative to different treatments were conducted using ANOVA, and significance of difference was defined at $p < 0.05$ in the colour evaluation, textural determination, and fat content.

Results and Discussion

Colour analysis

Table 1 shows the colour parameters of flat-rice noodles at different drying and soaking variation. As the temperature increases, the average colour changes are getting distinct. This could be due to the higher temperature that may lead to apparent changes due to heating effect in the reference to the fresh noodles. Total colour change of hot air drying at 30°C for soaked noodles is 28.37 ± 3.092 and for non-soaked noodles is 35.100 ± 2.307. In the meantime, hot air drying at 60°C produces a total colour change of 35.90 ± 5.242 for soaked noodles and 36.76 ± 5.91 for non-soaked noodles. Finally, the total colour change is vivid at 43.03 ± 2.30 for soaked noodles and 43.86 ± 1.49 for non-soaked noodles under hot drying at 90°C.

As the temperature of both drying methods increases, the colour changes are more deteriorating (Hu *et al*., 2006). The higher temperature of drying process will only introduce burning colour to the products and therefore a very high colour change can be seen for the hot air drying at 90°C that is not recommended. However, oxidative reactions and enzymatic browning were more likely to cause the brown stain of the products during both drying processes, which made the products brown more easily (Zhu *et al*., 2010).

Colour changes of noodles due to heat pump drying are obvious for soaked and non-soaked samples at the temperatures of 38°C and 51°C.

Table 1 Colour parameters of flat-rice noodles at drying and soaking variation

Treatment	Parameter[1]			
	ΔL	Δb*	ΔC*	ΔE*
Soaked Hot Air Drying at 30°C	-27.57 ± 3.35b	4.47 ± 3.89 [a]	3.50 ± 3.20 [a]	28.37 ± 3.09 [cd]
Non-Soaked Hot Air Drying at 30°C	-34.43 ± 2.97[bc]	4.73 ± 3.15 [a]	3.43 ± 3.30 [a]	35.10 ± 2.30 [bc]
Soaked Hot Air Drying at 60°C	-36.03 ± 5.12[bc]	1.40 ± 4.12 [ab]	1.30 ±2.26 [a]	35.90 ± 5.24 [abc]
Non-Soaked Hot Air Drying at 60°C	-36.40 ± 5.97[bc]	1.63 ± 0.31 [ab]	1.10 ± 0.50 [a]	36.76 ± 5.91 [abc]
Soaked Hot Air Drying at 90°C	-42.90 ± 2.19[c]	-2.07 ± 2.26 [ab]	-0.76 ± 0.95 [a]	43.03 ± 2.30 [ab]
Non-Soaked Hot Air Drying at 90°C	-44.50 ± 6.14[c]	-2.13 ± 3.05 [ab]	-1.10 ±1.51 [a]	43.86 ± 1.49 [ab]
Soaked Heat Pump Drying at 38°C	-41.03 ± 4.20[c]	-1.47 ± 3.05 [ab]	-0.73 1.61[a]	41.23 ± 4.30 [ab]
Non-Soaked Heat Pump Drying at 38°C	-42.00 ± 4.50[c]	-3.40 ± 3.14 [b]	-0.30 ± 3.16[a]	42.26 ± 4.91 [ab]
Soaked Heat Pump Drying at 51°C	-42.86 ± 2.87[c]	0.03 ± 2.15 [ab]	-1.03 ±2.11 [a]	43.00 ± 2.82 [ab]
Non-Soaked Heat Pump Drying 51°C	-45.50 ± 3.39[c]	-1.10 ± 3.16 [ab]	-0.36± 0.80 [a]	45.66 ± 3.51 [a]
Soaked Freeze Drying at -10°C	22.73 ± 1.30[a]	2.83 ± 1.30 [ab]	1.43 ± 1.30 [a]	23.03 ± 1.29 [de]
Non-Soaked Freeze Drying at -10°C	17.43 ± 3.28[a]	4.00 ± 0.56 [ab]	2.66 ± 0.51 [a]	18.03 ± 3.09 [e]
Soaked Freeze Drying at -40°C	18.93 ± 1.22[a]	3.23 ± 0.35 [ab]	1.83± 0.35 [a]	19.33 ± 1.12 [de]
Non-Soaked Freeze Drying at -40°C	17.70 ± 1.67[a]	4.47 ± 0.50 [a]	3.06 ± 0.50 [a]	18.40 ± 1.47 [de]

The colour changes of soaked noodles and non-soaked noodles at 38°C are recorded at 41.23 ± 4.30 and 42.26 ± 4.91 respectively. Meanwhile, colour changes of soaked noodles and non-soaked noodles undergoing heat pump drying at 51 °C are 43.00 ± 2.82 and 45.66 ± 3.51 from the fresh noodles. Both methods produced significant changes that verify the transparency phenomenon caused by employing high temperature to eventually increase the sample lightness

Furthermore, lesser colour changes can be seen in freeze dried noodles in comparison to the hot air and heat pump drying to describe the colour's close marginal to the fresh noodles. However, higher colour change for soaked noodles undergoing freeze drying was recorded at 23.03 ± 1.29 at -10°C and 19.33 ± 1.12 at -40°C compared to the non-soaked noodles at 18.03 ± 3.09 at -10°C and 18.40 ± 1.47 at -40°C.

From the significant analysis, the colour changes of soaked and non-soaked freeze dried noodles at the temperatures of -10°C and -40°C was found to be significantly higher ($p < 0.05$) than other drying variation. This is due to the slight colour changes occurred in those samples in comparison to the other drying variation. It can be concluded that freeze drying produced a lower value of the colour change in flat-rice noodles due to the drying process itself. Being established in most quality attributes' retention, freeze drying eventually causes fewer changes in colour as it preserved the colour to the fresh one. Therefore, distinct relatively smaller changes can be seen from the colour difference in freeze drying compared to the hot air and heat pump drying that generally removed moisture as well as the colour to eventually cause the higher value of colour changes from fresh noodles (Van Mana *et al*., 2012).

The common factors of colour changes prior to processing are pigment degradation, particularly carotenoids and chlorophyll), browning reactions, change of ingredient structure and oxidation of ascorbic acid. Apart from that, processing temperature and time, cultivars and heavy metal contamination primarily affect the average colour changes. By introducing soaking process to the sample, it removes the sample contamination to eventually cause higher lightness explained by the leaching occurrence of yellow color pigments and vitamins in soaked noodles. (Bayram, Kaya, and Oner, 2003). Therefore, the soaking process itself explained a higher intensity and saturation inside a sample since soaking produce a brighter colour which leads to lower colour change and higher lightness value (Nour *et al*., 2011).

Microstructural analysis

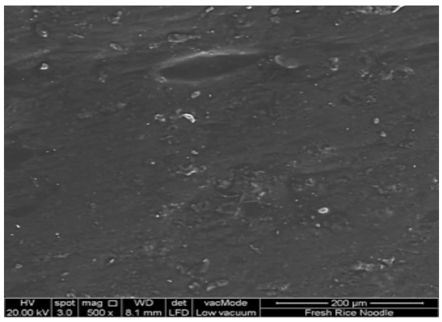

Figure 2. Microstructures of fresh flat-rice noodles

The microstructures of fresh flat-rice noodles at 500 magnifications are presented as in Figure 2. The microstructures of soaked and non-soaked noodles undergoing drying variation were shown under Scanning Electron Microscope (SEM) observance at 200 μm respectively. Figure 3 shows the microstructures of hot air dried noodle strand which produced the consistent disruption of declining intercellular connection. The falling of cell structure was observed through the bits and pieces on the surface in a constant and stable manner through gentler drying at such low temperature.

As reported by Fang *et al*. (2011) that decreased drying temperature governed to relatively even size and shape with solid particle surface. It had a more uniform pore size and distribution in comparison to the noodles undergoing hot air drying at 60°C and 90°C. Therefore, firmness and durability can be deduced in such homogenous compact texture manner. This glass and a smooth transition will, therefore, increase the fatigue strength of the structure to further explain the higher breakability in such samples by continuous crack growth. A number of glossy oily dots may be observed through higher magnifications, particularly in the non-soaked noodle as in Figure 3.

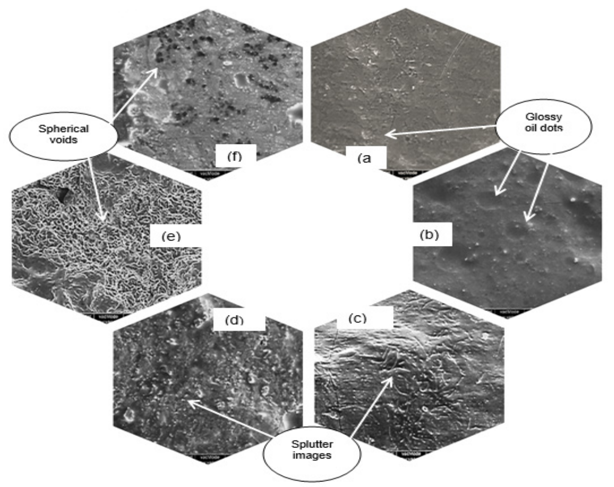

Figure 3. Microstructures of the (a) hot air drying of soaked noodles and (b) non-soaked noodles, follows by (c) heat pump drying of soaked noodles and (d) non-soaked noodles, and (e) freeze drying of soaked noodles and (f) non-soaked noodles

It is agreed that the intensity of soaked sample as in Figure 3 is higher with a lesser degree of glass uniformity compared to non-soaked noodles. The intensity was contributed mostly by the hydrophobic behaviour of oil towards soaking prior to drying. The lesser glass texture in all soaked noodles was due to the removal of oil during soaking as oil in noodle merely created such transparency. Soaking will only disturb the noodle texture. Thus, it can be observed that more extensive surface shrinkage was found in the samples compared to the hot air dried noodles at 30°C with shrinking cell walls. The non-soaking noodles were covered with minimal undistinguished dotted oily cells.

From Figure 3, splutter images can be spotted through higher magnifications for both soaked and non-soaked noodle strand undergoing heat pump drying. This can be due to the inconsistent heat being pumped into the drying system to cause the inconsistency. However, the non-soaked noodles are rustic texture and seem more reticulated as it went by higher magnifications. During heat pump drying, internal cracks are formed and shrinkage stresses pull the tissue apart.

Performing heat pump drying on flat-rice noodles produced SEM images as in Figure 3 of a glassy transparent feature due to shorter drying period and under such a high temperature. Seamless texture can be seen for both types of noodle variation at this temperature. Generally, soaked noodles of heat pump drying at both temperatures are smoother than the non-soaked noodles due to the addition of water into the sample, especially during the soaking process. On top of that, high temperature drying could not produce significant microstructures at different drying temperatures (Kongkiattisak and Songsermpong, 2012)

The general microstructures of freeze dried noodles respectively at -10°C and -40°C were shown via SEM observance for soaked and non-soaked noodles strand. Such textural behaviour shown is largely due to the fact that oil content inside noodle escapes in a way more random in due to hydrophobicity prior to the soaking process. In Figure 3, there are some large spherical voids in the noodle which may have been formed by the ice crystals during freezing. The SEM images of freeze dried soaked noodles at -10°C produced a more uniform small pores ranging from 2.04 μm to 7.00 μm. whereby firmness and durability can be deduced in such texture observance. On the contrary, non-soaked noodles merely created more continuous structure by showing smaller air cells.

The perforated cell walls of flat-rice noodles under freeze drying are well notable for soaked noodle strand as in Figure 3. The microstructures of soaked sample under such temperature are described to the pore sizes ranging from 7.67 μm to 27.68 μm. This is largely due to the fact that oil content inside noodle escapes in a way more random in due to hydrophobicity prior to soaking. This is reflected by the most consistent structure with fewer voids that can be observed for this temperature in comparison to the freeze drying under -10°C that is mostly contributed by introducing gentler drying at a lower temperature. However, non-soaked noodle produced smoother microstructures since oil inside a sample is not affected by a soaking process which causes oil hydrophobicity.

Fat content analysis

Table 2 Fat content of flat-rice noodles at drying and soaking variation

Treatment	Fat Content[1] (%)
Soaked Hot Air Dried Noodles at 30°C	0.980 ± 0.199 [f]
Non-Soaked Hot Air Dried Noodles at 30°C	2.780 ± 1.009[bcde]
Soaked Hot Air Dried Noodles at 60°C	1.883 ± 0.371[ef]
Non-Soaked Hot Air Dried Noodles at 60°C	3.230 ± 0.208[bcd]
Soaked Hot Air Dried Noodles at 90°C	2.480 ± 0.490[bcde]
Non-Soaked Hot Air Dried Noodles at 90°C	3.700 ± 0.174 [b]
Soaked Heat Pump Dried Noodles at 38°C	1.980 ± 0.138[def]
Non-Soaked Heat Pump Dried Noodles at 38°C	3.130 ± 0.186bcde
Soaked Heat Pump Dried Noodles at 51°C	2.230 ± 0.174[cdef]
Non-Soaked Heat Pump Dried Noodles 51°C	3.340 ± 0.447[bc]
Soaked Freeze Dried Noodles at -10°C	2.310 ± 0.203[cde]
Non-Soaked Freeze Dried Noodles at -10°C	5.620 ± 0.199[a]
Soaked Freeze Dried Noodles at -40°C	2.650 ± 0.767[bcde]
Non-Soaked Freeze Dried Noodles at -40°C	6.620 ± 0.530[a]

[1] Means that do not share a letter are significantly different.

In Table 2, soaked noodles recorded low-fat value of 0.980% ± 0.199, 1.883% ± 0.371, and 2.480% ± 0.490 at 30°C, 60°C, and 90°C respectively. Meanwhile, non-soaked noodles resided a higher amount of fats with the percentage of 2.780% ± 1.009, 3.23% ± 0.208 and 3.700% ± 0.174 at the respective 30°C, 60°C, and 90°C. In general, hot air drying produced a higher content of fat for the non-soaked samples to the soaked noodles. The sharp drop in the percentage of fat content upon soaking may be as a result of the breakdown of complex compounds into a simpler state during such pre-treatment.

Fresh foods are generally low in fats and these values are slightly raised by drying process itself (Islam, Alam, Amin, and Roy, 2010). In this study, hot air drying at a higher temperature of 90°C produced a higher amount of fats in a sample for soaked and non-soaked noodles in comparison to the 30°C samples. Indeed, the addition of fats of increasing drying temperature indicates a higher degree of gelatinization as can be seen from the noodle microstructures shown earlier whereby a higher degree of drying depicts a more transparent texture (Sakiyan *et al.*, 2011). This is contributed by the fact that oil behaving at high temperature tends to lead to crust formation thus favouring the oil absorption that may eventually prevent oil to escape during drying (Heldman, 2003). However, the low increase in fats contents could be described by possible losses during various heat treatments. Furthermore, studies revealed that lipid contents fluctuate notably with storage time, raw materials and storage cycle of specific consumables (Ali *et al.*, 2011).

Furthermore, soaked noodles under heat pump drying recorded low fat percentage of 1.980% ± 0.138 and 2.230% ± 0.1744 respectively at 38°C and 51°C meanwhile non-soaked noodles recorded a higher amount of fats with the percentage of 3.130% ± 0.186 and 3.34% ± 0.447 at 38°C and 51°C. Non-soaked samples during heat pump drying produced a higher content of fat to the soaked noodles as certain fats were removed mostly during the soaking process together with the oil.

As previous, noodles undergoing freeze drying also produced a higher content of fat for the non-soaked samples to the soaked noodles as certain fats were removed mostly during soaking. Soaked noodles recorded low fat percentage of 2.310% ± 0.203 and 2.650% ± 0.767 respectively at -10°C and -40°C meanwhile non-soaked noodles extracted a higher amount of fats with the percentage of 5.620% ± 0.199 and 6.620% ± 0.530 at -10°C, and -40°C. The high content of fat was contributed by the fact that freeze drying preserved most nutrients including fats during the process (Ratti, 2001).

Conclusion

It can be concluded that the nature of freeze drying in nutrient retention has closely preserved the qualities of flat-rice noodles. The quality attributes in terms of colour, microstructures and fat content to the fresh flat-rice noodles which have on the contrary further explained the transparency phenomena that occurred in hot air and heat pump dried flat-rice noodles than the freeze dried noodles. Thus, the starch gelatinization effect is in the account for further studies.

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