مجلة الإسكندرية لعلوم وتكنولوجيا الأغذية

Alexandria Journal of Food Science and Technology

Alex. J. Fd. Sci. & Technol.

Vol. 17 : No. 2 (December, 2020)

◆

Effect of Storage on Physical, Chemical, Microbial and Sensory Properties of Biscuits Prepared from Sweetpotato-Pigeonpea-Banana Flour Blend **1**

Adeola, A.A.[1], Ayansina, S.O.[2], Kayode, G.I.[3], Aderounmu, A.R.[3] & Ojo, O.G.[3]

1 Institute of Food Security, Environmental Resrources and Agricultural Research, Federal University of Agriculture, Abeokuta, P.M.B., 2240, Abeokuta, Ogun State, Nigeria.

2 Department of Agricultural Administration, Federal University of Agriculture, Abeokuta, P.M.B., 2240, Abeokuta, Nigeria.

3 Department of Food Science and Technology, Federal University of Agriculture, Abeokuta, P.M.B., 2240, Abeokuta, Nigeria.

Microwave Applications in Food Processing: An Overview **11**

Taiseer M. Abo Bakr

Food Science & Technology Dept. Fac. of Agric. Alexandria Univ. El Shatby, 21545, Alexandria, Egypt.

Milling Damaged Starch (MDS) in wheat flour: Formation, Structure, Functionality and its Effects on Baking Quality: An Article **23**

Abo-Dief , M. F.

Arabian Milling and Food Industries Company, Bourge El Arab, Alexandria, Egypt.

Effect of Storage on Physical, Chemical, Microbial and Sensory Properties of Biscuits Prepared from Sweetpotato-Pigeonpea-Banana Flour Blend

Adeola, A.A.[1], Ayansina, S.O.[2], Kayode, G.I.[3], Aderounmu, A.R.[3] & Ojo, O.G[3]

1 Institute of Food Security, Environmental Resrources and Agricultural Research, Federal University of Agriculture, Abeokuta, P.M.B., 2240, Abeokuta, Ogun State, Nigeria.

2 Department of Agricultural Administration, Federal University of Agriculture, Abeokuta, P.M.B., 2240, Abeokuta, Nigeria.

3 Department of Food Science and Technology, Federal University of Agriculture, Abeokuta, P.M.B., 2240, Abeokuta, Nigeria.

Received: 6 October, 2020 *Revised: 15 December, 2020* *Accepted: 20 December, 2020*

ABSTRACT

Biscuit is gaining increasing prominence in the diet of Nigerians since most of them have adopted the western lifestyle. It is therefore a veritable vehicle to improve the nutritional well being of Nigerians. Storage is known to affect the quality attributes of biscuit. A nutritionally improved biscuit had been formulated from optimised sweetpotato, pigeonpea and banana flour blend. This study therefore evaluated the some quality attributes of the nutritionally improved biscuit stored at room temperature of 85% relative humidity. The moisture, colour, textural properties, rancidity, microbial load and sensory properties of the biscuit packed in high density polyethylene pouches (HDPE) and low density polyethylene pouch (LDPE) were investigated at 2 weeks interval. The water vapour transmission rate of the high density polyethylene pack and low density polyethylene pack were 4.052 x 10^{-13} g/mm/day/mmHg and 6.566 x 10^{-13} g/mm/day/mmHg, respectively. The moisture content, free fatty acid and peroxide values which increased during storage varied from 6.75 to 13.2%, 1.48 to 3.77% and 1.6 to 2.43 meqO_2/kg, respectively in LDPE, while the values increased from 6.75 to 10.35%, 1.48 to 2.83% and 1.6 to 2.37 meqO_2/kg, respectively in HDPE. The L*, a*, b*, hardness, springiness, adhesiveness, cohesiveness and overall acceptability of the biscuit decreased in both LDPE and HDPE during storage. The biscuits stored in LDPE and HDPE were acceptable till 4 and 6 weeks, respectively.

Keywords: biscuit, cooking banana, microbial load, pigeonpea, storage.

INTRODUCTION

Biscuit is a popular food commodity that has gained wide acceptability among Nigerians. This may be due to the fact that biscuits fit into the daily busy schedule of both young and old in the country. Biscuits are conventionally prepared from wheat and are high in energy but low in dietary fibre. Biscuits, may thus, present likely cases of debilitating diseases, including diabetes, obesity, etc in consumers (Singh & Kumar, 2019). Preparation of non-gluten biscuit is of particular interest to both the consumers and Nigerian Government since it enables the use of indigenous crops that promote good nutrition and health. Such indigenous crops that have been successfully employed in the manufacture of biscuit include cereals, legumes, roots, tubers, etc. In an earlier study, Adeola & Ohizua (2018) reported the formulation of a biscuit from an optimised flour blend of sweetpotato, pigeonpea and unripe cooking banana using a process optimization technique. The biscuit was found to be high in dietary fibre (14.6%) and total carotenoids (151 µg/100g). However, the study did not investigate the quality of the biscuit during storage.

Storage is crucial unit operation in the food value chain of food as many changes that affect quality occur during stage. According to Smith *et al.* (2004) biscuit is mainly subjected to three changes during storage. These changes are physical, chemical and microbiological in nature. Moisture migration is a basic activity which affects the chemical and microbiological changes of biscuit during storage. Rancidity is a quality issue during storage as it affects the flavour and safety of biscuit. Microbiological changes in form of bacterial and mold attack affect the shelf stability of biscuit. These changes have been reported to depend on certain factors including packaging. Various studies on the storage of non-gluten biscuit have revealed that the physical, chemical and microbiological changes depend on packaging, temperature, light and humidity, among other important factors (Romani *et al.*, 2015, Jan *et al.*, 2017 & Duta *et al.*, 2019).

This study therefore evaluated the effect of storage on the quality attributes of biscuit formulated from sweetpotato, pigeonpea and unripe cooking banana.

MATERIALS AND METHODS

Materials

Sweetpotato (cream-fleshed), pigeonpea, mature unripe cooking banana, packaging materials and other major ingredients such as sugar, salt, milk, baking powder and butter were purchased from local markets in Abeokuta, Ogun State, Nigeria.

Preparation of Flours from Sweetpotato, Pigeonpea and Cooking Banana

The stages involved in preparing flour from sweetpotato and banana were washing, peeling, cutting, drying and milling. Pigeonpea flour was obtained by sorting, cleaning, boiling (20 min), dehulling, drying and milling the grains (Ohizua *et al.*, 2017).

Blending of Flour

The flours were blended as previously described (Adeola & Ohizua, 2018). Composite flour made up of 56.67% sweetpotato, 21.67% pigeonpea and 21.67% cooking banana were mixed with the aid of a Kenwood mixer (HM 430).

Biscuit Recipe

The biscuit recipe as previously formulated was: 250 g flour, 63 g fat, 63 g sugar, 1 g salt, 20 ml egg, 5 g milk, 1.5 g nutmeg and 1 g baking powder.

Preparation of Biscuit

Biscuit was prepared according to the method outlined in Adeola & Ohizua (2018). A fluffy mixture of fat and sugar was obtained using a Kenwood mixer (HM 430), after which eggs and milk were added, during the mixing. Other ingredients such as flour, baking powder, salt, and ground nutmeg were added to the mixture. The dough so formed was kneaded on a flat surface. Thereafter, the dough was rolled into sheets and cut into desired shape. Baking was done at 180^{o}C for 17 min.

Shelf Stability of Biscuit

Biscuits (10 g) prepared from wheat flour were individually packed in HDPE and LDPE packs, heat sealed, and put in a desiccator. This was also done for biscuits from the flour blend. Thus, four different products were stored and analysed individually. The desiccator was stored at 28^{o}C with a relative humidity of 85% in the laboratory. Strontium chloride ($SrCl_2$) was used to maintain the desired relative humidity. The biscuits were analyzed every 2 weeks for the moisture content, colour, textural profile, rancidity indices, microbial load and sensory attributes.

Determination of the Water Vapour Transmission Rate (WVTR) of Packaging Material

About 5 g of dehydrated silica gel was transferred into a cup-like glass container, sealed using the packaging materials intended for use in this study and then placed in an incubator at 28°C. The relative humidity was maintained at 80%. The weight of the cup-like glass containing the silica gel was determined at 24 hr intervals until the difference in mass was not more than 10% (Ojo *et al.*, 2017, Othman *et al.*, 2017). The WVTR of the packaging material was calculated using equation 1.

$$K = \frac{dw}{d\theta p} \times \frac{1}{ApP} \qquad [1]$$

Where d_w/ $d\theta_p$ is the slope of the linear plot between the time $d\theta_p$ (day) of incubation and cumulative moisture gain, d_w (kg) is the weight of the silica gel in the packaging material, A_p (mm) is the surface area of the packaging material and P (mmHg) is the saturation vapour pressure of water at 28^{o}C (0.378 bar).

Determination of Moisture Content

The moisture content was determined by the hot air oven method as described by the Association of Official Analytical Chemists (2010).

Determination of Colour

The colour of the biscuit sample was determined using a Konica Minolta Colour Measuring System (Chroma Meter CR-410, Minolta LTD Japan). Calibration of the instrument was done with a white tile and colour attributes [lightness (L*), redness (a*), and yellowness (b*)] were then determined.

Determination of Texture Profile

The texture profile of the biscuit sample was done as described by Da silva and Moreira (2008) by using a universal texture analyzer (TVT-300 X

PH, Perken) The measurement was taken at a test speed of 2.0 mm per second and a trigger force of 25g with the sample height being 12 mm per second. The parameters analyzed were hardness (N), springiness, adhesiveness (N. s), cohesiveness (s), gumminess (N), energy to peak (N. m) stringiness (mm) and chewiness.

Determination of Free Fatty Acid

The free fatty acid content of the sample was analysed according to the description of Kumar *et al.* (2016). Five grammes of ground sample was thoroughly mixed with 30 ml chloroform and then filtered through Whatman No. 1 grade filter paper. About 3 drops of 0.2 g/100 ml phenolphthalein solution were thereafter added, and titrated against alcoholic sodium hydroxide (0.1N) to the end point pink colour. The %FFA was calculated as shown in equation 2.

$$\%\text{ FFA as palmitic acid} = \frac{\text{ml of NaOH} \times \text{Molarity} \times 28.2\text{ m}}{\text{Weight of sample}} \quad [2]$$

Determination of Peroxide Value

The method described by Kumar *et al.* (2017) was used. The peroxide value (PV), expressed in milli equivalent peroxide oxygen per kg of fat ($meqO_2/kg$), was calculated as shown in equation 3.

$$PV = \frac{[(V_1 - V_2)]}{W} N \times 1000 \quad [3]$$

where, V_1 = Volume of sodium thiosulphate solution consumed for sample

V_2 = Volume of sodium thiosulphate solution consumed for blank

N = Normality of sodium thiosulphate solution

W = weight of fat content in the 20 ml of aliquot

Determination of Microbial Load

The method described by Onwuka (2018) was used. One gram of each sample was aseptically transferred into 9 ml of distilled water in a MacCartney's bottle. An appropriate serial dilution of the nutritionally improved biscuit samples was carried out and 0.1 ml of the selected dilution (10^2) was spread on duplicate plates using a sterile syringe. Bacterial load was enumerated by incubating the samples on the nutrient agar for 24 hr at 32°C and the fungal load was enumerated by incubating the samples sabaurand dextrose agar for 72 hr at 25°C. The count was expressed as colony forming units per gram of the sample.

Evaluation of Sensory Properties

The method described by Iwe (2002) was used. Biscuit samples (5 g) were served in coded disposable cups to an untrained panel of 50 people comprising of students and staff of the College of Food Science and Human Ecology, FUNAAB. The panelists were requested to rate their level of liking of biscuits' attributes (appearance, aroma, taste, texture and overall acceptance) on a 9 point Hedonic scale where 1 was 'dislike extremely and 9 was 'like extremely'. The evaluation was done on each day of observation in five sessions. Each panelist was given the coded samples and water was provided to rinse their mouths between each sample assessment.

Analysis of Data

Data were presented as mean and standard deviation using SPSS version 21. Significant differences were separated using Duncan's Multiple Range Test at 5% significant level.

RESULTS AND DISCUSION

Physicochemical Properties of Biscuit

The water vapour transmission rate (WVTR) refers to the rate at which water vapour permeates through a packaging film, and it is directly proportional to water permeability (Othman *et al.*, 2017). The WVTR of HDPE and LDPE was found to be 4.052×10^{-13}g/mm/day/mmHg and 6.566×10^{-13} g/mm/day/mmHg, respectively. Higher water vapour permeation is therefore expected to occur in LDPE. Water has effect on the storability of hygroscopic food materials as biscuit. Food packaging should therefore aim at reducing the ingression of moisture in such food materials.

Table (1) presents the effect of storage on the moisture contents of the biscuits. The moisture contents of the biscuits in both the LDPE and HDPE increased during storage, and this observation conforms to the findings of Yilmaz and Öğütcü (2015). This may have been due to the permeability of the packaging materials. The moisture content of the biscuit in LDPE was higher than the one in HDPE, due to the higher WVTR of LDPE. At the end of the storage, the moisture content of the improved biscuit was higher than the wheat biscuit, may be due to the higher initial moisture content of the former. Moisture content and water activity have effect on the qualities of food during storage (Sampaio *et al.*, 2009, Takeungwongtrakul & Benjakul, 2017, Nwosu & Akubor, 2018, Balestra *et al.*, 2019). The more available the moisture content, the higher the activity of the spoilage agents (Vaclavik & Christian, 2005). Foods such as biscuits require low moisture permeability-packaging so as to preserve their crispiness (Nwosu & Akubor, 2018, Duta *et al.*, 2019).

Table 1: Moisture content (%) of biscuit during storage

Storage period (Week)	Wheat biscuit		Improved biscuit	
	HDPE	LDPE	HDPE	LDPE
0	6.65^{a}	6.65^{a}	6.78^{a}	6.78^{a}
2	7.07^{a}	7.35^{a}	7.07^{b}	8.88^{b}
4	8.74^{b}	9.27^{b}	9.49^{c}	12.62^{c}
6	9.56^{c}	11.45^{c}	9.56^{c}	12.66^{c}
8	10.12^{d}	12.64^{d}	10.33^{d}	13.10^{d}

Mean values with different superscripts within the same column are significantly different ($p < 0.05$).

Table (2) presents the changes observed in the colour attributes of biscuit stored in HDPE and LDPE. Colour is an important attribute which arouses the appetite of an individual (Adeola & Ohizua, 2018). It is one of the important criteria used in controlling the process of baking (Pereira *et al.*, 2013). In both packaging types, the L*, a* and b* values were observed to decrease during storage for both wheat and improved biscuits. The decrease in the colour attributes may be due to the increased biochemical reactions as a result of increase in moisture during storage which may have led to a decrease in colour-imparting bioactive components of the biscuit. The a* and b* values of the improved biscuit were higher than those recorded for wheat biscuit. This may be due to the differences in the pigments contained in the flour samples. Pigmentation in yellow-fleshed potato is due to carotenoids while carotenoids (principally xanthophylls) together with flavone compounds are responsible for pigmentation in wheat flour (Val, 2000). Jan *et al.* (2017) observed increase in L* and b* values while a* values decreased during the storage of a gluten-free biscuit prepared from germinated chenopodium flour.

Textural Properties of Biscuit

There were significant (P<0.05) changes in the texture profile of biscuit during the storage period (Table 3). Textural properties of a food depend on the processing parameter, chemical composition of the ingredient and the physical properties of the food (Mesquita *et al.*, 2013, Laukova *et al.*, 2019).

Table 2: Colour attributes of biscuit during storage

Storage Period (Week)	L*	a*	b*
Wheat biscuit (HDPE)			
0	60.62^{c}	4.63^{b}	24.66^{c}
2	60.49^{bc}	4.53^{ab}	24.32^{c}
4	59.55^{abc}	4.27^{ab}	24.12^{bc}
6	59.12^{ab}	4.13^{ab}	23.66^{b}
8	58.18^{a}	3.89^{a}	20.44^{a}
Wheat biscuit (LDPE)			
0	60.62^{c}	4.63^{b}	24.66^{d}
2	59.33^{bc}	4.52^{b}	21.21^{b}
4	59.34^{bc}	4.26^{ab}	23.64^{cd}
6	58.28^{ab}	4.00^{a}	22.44^{bc}
8	57.34^{a}	3.83^{a}	19.61^{a}
Improved biscuit (HDPE)			
0	58.54^{c}	5.37^{c}	25.21^{c}
2	53.69^{a}	5.97^{d}	22.52^{ab}
4	56.15^{b}	6.14^{d}	23.41^{b}
6	61.01^{d}	3.86^{a}	22.36^{a}
8	57.74^{c}	4.48^{b}	22.36^{a}
Improved biscuit (LDPE)			
0	58.54^{b}	5.37^{b}	25.21^{c}
2	54.72^{a}	5.28^{b}	22.71^{b}
4	59.53^{b}	5.19^{b}	24.65^{c}
6	58.13^{b}	4.63^{a}	23.62^{b}
8	55.15^{a}	4.7^{a}	21.27^{a}

Mean values with different superscripts within the same column for each biscuit are significantly different ($p < 0.05$)

Hardness, which is an important textural property due to its close association with human perception of freshness, has been defined as the force required to attain a given deformation (Harahap *et al.*, 2019). The hardness of the biscuits decreased with increase in the duration of storage in both HDPE and LDPE. Pereira *et al.* (2013), Morais *et al.* (2018) and Duta *et al.* (2019) also reported a decrease in the hardness of biscuit during storage. The decrease in the hardness may be due to increase in moisture content of biscuit during storage (Qadri *et al.*, 2018). Springiness, adhesiveness, and cohesiveness also decreased during storage in both the LDPE and HDPE, may be as a result of increased moisture during storage. Harahap *et al.* (2019) also reported that hardness, adhesiveness and %deformation were positively related. Accord-

Table 3: Textural profile of biscuits during storage

Storage Period (Weeks)	Hardness (N)	Springiness	Adhesiveness (Ns)	Cohesiveness	Chewiness (N)
Wheat biscuit (HDPE)					
0	1632.95^{a}	0.93^{b}	0.98^{c}	0.67^{c}	293.57^{c}
2	2055.12^{a}	0.84^{b}	0.98^{c}	0.64^{b}	292.56^{c}
4	2066.62^{a}	0.67^{a}	0.97^{c}	0.64^{b}	288.17^{c}
6	1790.84^{a}	0.62^{a}	0.74^{b}	0.63^{ab}	271.06^{b}
8	1577.62^{a}	0.64^{a}	0.57^{a}	0.62^{a}	221.44^{a}
Wheat biscuit (LDPE)					
0	1632.95^{a}	0.93^{c}	0.98^{d}	0.67^{d}	293.57^{c}
2	2037.55^{a}	0.79^{bc}	0.90^{cd}	0.56^{c}	283.67^{c}
4	1805.10^{a}	0.63^{ab}	0.83^{c}	0.47^{b}	230.99^{b}
6	1449.10^{a}	0.57^{a}	0.64^{b}	0.40^{a}	224.14^{b}
8	1414.60^{a}	0.60^{ab}	0.40^{a}	0.37^{a}	186.80^{a}
Improved biscuit (HDPE)					
0	1442.55^{a}	0.38^{a}	0.76^{c}	0.42^{a}	222a
2	1444.1^{a}	0.44^{ab}	0.69^{bc}	0.47^{a}	294.37^{a}
4	915.75^{a}	0.5^{ab}	0.01^{a}	0.41^{a}	201.24^{a}
6	870.7^{a}	0.5^{ab}	0.04^{ab}	0.41^{a}	177.47^{a}
8	731.15^{a}	0.62^{b}	0.08^{ab}	0.48^{a}	239.76^{a}
Improved biscuit (LDPE)					
0	1442.55^{b}	0.38^{a}	0.76^{c}	0.42^{a}	222^{ab}
2	1284.95^{ab}	0.59^{b}	0.03^{a}	0.53^{ab}	402.45^{b}
4	778.55^{ab}	0.61^{b}	0.11^{b}	0.65^{b}	312.75^{ab}
6	332.41^{a}	0.72^{b}	0.01^{a}	0.63^{b}	149.73^{a}
8	303.29^{a}	0.66^{b}	-0.01a	0.62^{b}	125.62^{a}

Mean values with different superscripts within the same column are significantly different ($p < 0.05$)

ing to Hussein *et al.* (2018) springiness index is the ratio of the height a sample springs back following its deformation by the first and second chews while adhesiveness is the amount of work required to pull food away from a surface such as teeth and tongue. On the other hand, cohesiveness is a parameter that measures the sensory crumbliness and perceptions which are related to denseness of the biscuit as well as the energy needed to chew the food piece (Sanz *et al.*, 2009). The improved biscuit had lower values for hardness, springiness, adhesiveness and cohesiveness than wheat biscuit. Biscuits with lower cohesiveness values have been reported to possess greater fragility (Pereira *et al.*, 2013). For wheat biscuit, there was a decrease in chewiness during storage in the two types of the packaging materials. However, in the case of the improved biscuit, the chewiness of the biscuit stored in LDPE reduced during storage, while in HDPE, it fluctuated during storage with the final value greater than the initial. Chewiness refers to the energy needed to chew a solid food to the point that it is ready for swallowing.

Rancidity Indices of Biscuit

Fat is a major ingredient of biscuit and its decomposition (oxidation) during storage leads to loss of quality such as losses in flavour, nutritional value and safety (Daglioglu *et al.*, 2004, Bialek *et al.*, 2016). Table (4) presents the free fatty acid (FFA) and peroxide values (PV) of biscuits increased during storage. PV is used to determine the hydroperoxides formed during the initial stages of the oxidation (Bialek *et al.*, 2016). Hydroperoxides often lead to the production of many secondary lipid oxidation products that are detrimental to

Table 4: Rancidity indices of biscuit during storage

Storage Period (Week)	**Wheat Biscuit**				**Improved Biscuit**			
	HDPE		**LDPE**		**HDPE**		**LDPE**	
	FFA (%)	**PV (meqO_2/kg)**	**FFA (%)**	**PV (meqO_2/kg)**	**FFA (%)**	**PV (meqO_2/kg)**	**FFA (%)**	**PV (meqO_2/kg)**
0	3.00^{a}	1.97^{a}	3.0^{a}	1.97^{a}	1.48^{a}	1.60^{a}	1.48^{a}	1.60^{a}
2	4.14^{b}	2.06^{a}	4.79^{b}	2.49^{b}	1.92^{b}	1.86^{b}	2.50^{b}	1.83^{b}
4	4.26^{b}	2.25^{b}	4.95^{b}	2.78^{c}	2.48^{c}	2.03^{c}	2.83^{c}	2.14^{c}
6	4.60^{c}	2.60^{c}	5.27^{c}	3.08^{d}	2.67^{d}	2.17^{d}	3.38^{d}	2.17^{c}
8	4.87^{c}	2.80^{d}	5.68^{d}	3.39^{e}	2.83^{e}	2.37^{e}	3.77^{e}	2.43^{d}

Mean values with different superscripts within the same column are significantly different ($p < 0.05$)

human health (Bialek *et al.*, 2017). For wheat biscuit, FFA values ranged from 3.0 to 4.87% and 3.0 to 5.68% for HDPE and LDPE, respectively while the PV also ranged from 1.97 to 2.8 milliequivalent peroxide oxygen per kg oil (meqO2/kg) and 1.97 to 3.39 meqO2/kg for HDPE and LDPE materials, respectively. For the improved biscuit, FFA values varied from 1.48 to 2.83% and 1.48 to 3.77% for HDPE and LDPE packages, respectively while those of PV 1.6 to 2.37 meqO2/kg and 1.6 to 2.43 meqO2/kg for HDPE and LDPE materials, respectively. Swapna & Rao (2016) stated that increase in FFA during biscuit storage may be due to the hydrolysis of fat. The increase observed in the rancidity indices during storage was in accordance with the findings of Bashir *et al.* (2015), Yilmaz & Öğütcü (2015) and Bialek *et al.* (2016). There are differences in the acceptable level of FFA and PV in literature. Yilmaz & Öğütcü (2015) reported that the level of PV of shortening for baked foods must not be more than 1 meqO2/kg. On the other hand, Bialek *et al.* (2016) stated that 3 meqO2/kg is the safe level of PV for bakery fats. Daglioglu *et al.* (2004) further stated that 10 meqO2/kg is acceptable maximum limit for biscuits and similar products. The safe limit of FFA for biscuit has been reported to be 1.5% (Daglioglu *et al.*, 2004). The ranges of FFA of both the wheat and improved biscuits were therefore higher than the recommended levels while the PV of the biscuits is within the safe limit of 10 meqO2/kg. The FFA and PV values of wheat biscuit were higher than those of the improved biscuit for both the HDPE and LDPE. This may be due to the difference in the composition of the biscuits (Romani *et al.*, 2015).

Microbial Load of Biscuit

Table (5) reveals that the microbial load of the biscuit samples increased during storage. This conforms to the report of Jan *et al.* (2017). Significant ($P < 0.05$) differences were observed in the microbial loads. The bacterial count of wheat biscuit stored in HDPE and LDPE ranged from 5.50 to 63 ×102 cfu/g and 5.50 to 90.5 ×102 cfu/g, respectively. The improved biscuit had bacterial count of 11.0 to 72.0 ×102 cfu/g and 11.0 to 103 ×102 cfu/g for HDPE and LDPE, respectively. It was also observed that the bacterial count of the improved biscuit was higher than wheat biscuit, may be as a result of differences in composition and the higher moisture content of the former. The fungal count of

Table 5: Microbial load of biscuit during storage

Storage Period (Week)	**Wheat biscuit**		**Improved biscuit**	
	HDPE ($\times 10^2$ cfu/g)	**LDPE ($\times 10^2$cfu/g)**	**HDPE ($\times 10^2$ cfu/g)**	**LDPE ($\times 10^2$ cfu/g)**
Bacterial count				
0	5.50^{a}	5.50^{a}	11.0^{a}	11.0^{a}
2	24.5^{b}	35.5^{b}	35.5^{b}	54.5^{b}
4	37.0^{c}	59.5^{c}	50.5^{c}	71.5^{c}
6	47.5^{d}	78.0^{d}	62.0^{d}	92.0^{d}
8	63.0^{e}	90.5^{e}	72.0^{d}	103.0^{e}
Fungal count				
0	0.5^{a}	0.5^{a}	2.0^{a}	2.0^{a}
2	5.0^{b}	23.5^{b}	9.5^{ab}	20.0^{b}
4	16.0^{c}	26.0^{b}	15.5^{b}	32.5^{c}
6	24.0^{d}	41.5^{c}	26.0^{c}	52.0^{d}
8	30.5^{e}	54.5^{d}	32.0^{d}	63.0^{e}

Mean values with different superscripts within the same column for each organism group are significantly different ($p < 0.05$)

wheat biscuit stored in HDPE and LDPE ranged from 0.50 to 30.5 ×102 cfu/g and 0.50 to 54 ×102 cfu/g, respectively. The fungal count of the improved biscuit stored in HDPE and LDPE ranged from 2.0 to 32 ×102 cfu/g and 2.0 to 63 ×102 cfu/g. It was also observed that the fungal count of the improved biscuit was higher than wheat biscuit. The higher microbial load of the improved biscuit when compared with wheat biscuit may be due to the fact that dried sweetpotato products have been reported to be high in sugar, which encourage the growth of microorganisms (Hal, 2000). There are public health concerns about molds because of their association with mycotoxins. In previous studies, Agu & Okoli (2014) reported that the microbial load of biscuits produced from the composite flour of wheat, beniseed and plantain was found to increase during storage. They reported a bacterial load of 4.0 x 103 cfu/g and a mold count of 5.0 x 104 cfu/g for the most acceptable biscuit sample. The microbial load observed for the biscuit samples during the storage period was within the recommended limit of 104 to 106 cfu/g (Centre for Food safety, 2014, Khanom *et al.*, 2016).

Table 6: Sensory properties of biscuit during storage

Storage Period (Weeks)	Appearance	Aroma	Taste	Texture	Overall Acceptability
Wheat biscuit (HDPE)					
0	7.03^{b}	7.58^{c}	7.61^{c}	7.10^{c}	7.74^{d}
2	7.43^{b}	7.60^{c}	7.50^{c}	7.10^{c}	7.27^{c}
4	6.32^{a}	6.39^{b}	6.68^{b}	6.23^{b}	6.55^{b}
6	6.03^{a}	5.71^{a}	5.81^{a}	5.48^{a}	5.55^{a}
Wheat biscuit (LDPE)					
0	7.03^{b}	7.58^{c}	7.61^{b}	7.10^{b}	7.74^{b}
2	7.40^{b}	7.20^{b}	7.57^{b}	7.20^{b}	7.50^{b}
4	5.45^{a}	5.42^{a}	5.52^{a}	5.45^{a}	5.45^{a}
6	5.42^{a}	5.35^{a}	5.71^{a}	5.23^{a}	5.29^{a}
Improved biscuit (HDPE)					
0	7.35^{c}	6.74^{b}	6.97^{c}	6.32^{b}	7.06^{b}
2	6.5^{b}	6.53^{b}	6.43^{b}	6.73^{b}	6.57^{b}
4	5.77^{a}	5.58^{a}	5.52^{a}	5.45^{a}	5.71^{a}
6	5.45^{a}	5.48^{a}	5.58^{a}	5.65^{a}	5.55^{a}
Improved biscuit (LDPE)					
0	7.35^{c}	6.74^{b}	7.0^{c}	6.29^{b}	7.06^{c}
2	6.37^{b}	6.33^{b}	6.17^{b}	6.1^{b}	6.33^{b}
4	4.81^{a}	4.58^{a}	4.77^{a}	4.58^{a}	4.45^{a}
6	4.94^{a}	5.0^{a}	4.9^{a}	4.94^{a}	4.74^{a}

Mean values with different superscripts within the same column for each biscuit treatment are significantly different ($P < 0.05$). Scale 1 -'Extremely dislike, Scale 9 – 'Extremely like'

Sensory Attributes of Biscuit during Storage

Table (6) shows that the mean values of the sensory attributes of the wheat and improved biscuits reduced as the storage period increased, although higher scores were given to those stored in HDPE than those in LDPE packages. Kumar *et al.* (2017) also reported a decreasing trend in the sensory attributes of biscuit during storage. Significant ($P < 0.05$) differences were observed in the sensory attributes of the samples. Averagely, the overall scores of wheat biscuit were higher than the improved biscuit. This may be due to the fact that the panelists were used to wheat biscuit. Furthermore, Hal (2000) stated that sweetpotato-based ingredients imparted distinct taste, smell and texture to products which tended to make them to be marketed as different products. This is has been attributed to the fact that sweetpotato flour possess distinct flavour component and that the free sugar in sweetpotato flour caramelizes during baking (Laukova *et al.*, 2019). The wheat and improved biscuits stored in HDPE were acceptable (based on the overall acceptability scores) to the panelists till 6 weeks while the acceptability of those stored LDPE was 4 weeks.

CONCLUSION

The quality attributes of a nutritionally improved biscuit during storage have been investigated. The water vapour transmission rate of the high density polyethylene pack and low density polyethylene pack were 4.052×10^{-13} g/mm/day/mmHg and 6.566 x 10^{-13} g/mm/day/mmHg, respectively. There was a reduction in the L*, a*, b*, hardness, springiness, adhesiveness and sensory attributes while the moisture, free fatty acid, peroxide value and microbial load increased during storage. Changes in the quality attributes of the biscuit were more pronounced in low density polyethylene packs than high density polyethylene packs. The improved biscuits packed in high density polyethylene pack and low density polyethylene pack at 28 ^{o}C with a relative humidity of 85% were acceptable to panelists till 6 and 4 weeks, respectively.

ACKNOWLEDGEMENT

The authors acknowledge TetFund, Nigeria for providing the grant (TetFund IBR 2015/2016 Merged), through the Federal University of Agriculture, Abeokuta, Nigeria, (FUNAAB) to support this study. The monitoring and evaluation role of the Directorate of Research, Innovation and Partnership, FUNAAB, is also acknowledged.

REFERENCES

Adeola, A. A. & Ohizua, E. R. **2018.** Physical, chemical and sensory properties of biscuits prepared from flour blends of unripe cooking banana, pigeon pea and sweet potato. Food Science and Nutrition, **6:** 532-540.

Agu, H. O. & Okoli, N. A. **2014.** Physicochemical, sensory and microbiological assessments of wheat-based biscuit improved with beniseed and unripe plantain. Food Science & Nutrition, **2:** 464-469.

Association of Official Analytical Chemists. **2010.** Official Methods of Analysis (18thed.). Association of Official Analytical Chemists, Washington, United States of America.

Bashir, A., Ashraf, S. A., Khan, M. A. & Azad, Z. R.A.A. **2015.** Development and compositional analysis of protein enriched soybean-pea-wheat flour blended cookies. Asian Journal Clinical Nutrition, **7:** 76-83.

Balestra, F., Verardo, V., Tappi, S., Caboni, M. F., Rosa, M. D. & Romani, S. **2019.** Chemical and physical changes during storage of differently packed biscuits formulated with sunflower oil. Journal of Food Science and Technology, **56**: 4714–4721.

Bialek, A., Bialek, M., Jelinska, M., & Tokarz, A. **2017.** Fatty acid composition and oxidative characteristics of novel edible oils in Poland. CyTA - Journal of Food, **15**: 1-8.

Bialek, M., Rutkowska, J., Bialek, A. & Adamska, A. **2016.** Oxidative stability of lipid fraction of cookies enriched with chokeberry polyphenols extract. Polish Journal of Food and Nutrition Science, **66:** 77–84.

Centre for Food Safety. **2014.** Microbiological guidelines for food. The Centre for Food Safety, Food and Environmental Hygiene, Queensway, Hongkong. cfs.gov.hk/English/food_leg/files/food_leg_Microbiological_Guidelines_for_Food_e.pdf.

Daglioglu, O., Tasan, M., Gecgel, M. & Daglioglu, F. **2004.** Changes in oxidative stability of selected bakery products during shelf life. Food Science and Technology Research, **10:** 464-468.

Da silva, P. & Moreira, R. **2008.** Vacuum frying of high-quality fruit and vegetable based snacks. LWT- Food Science and Technology, **41:** 1758-1767.

Duta, D. E., Culetu, A. & Mohan, G. **2019.** Sensory and physicochemical changes in gluten- free oat biscuits stored under different packaging and light conditions. Journal of Food Science and Technology, **56:** 3823–3835.

Hal, V. **2000.** Quality of sweetpotato flour during processing and storage. Food Reviews International, **16**: 1- 37.

Harahap, E.S., Julianti, E. & Sinaga, H. **2019.** Utilization of orange fleshed sweet potato flour, starch and residual flour in biscuits making. IOP Conf. Series: Earth and Environmental Science.

Hussein, A. M. S., Hegazy, N. A., Kamel, M. M. & Mohamed, O. S. S. **2018.** Physicochemical study on lactose-free biscuits and brownness cakes. Journal of Biological Sciences, **18:** 434-440.

Iwe, M. O. **2002.** Handbook of Sensory Method and Analysis. Rejoint Communication Service Ltd, Enugu, Nigeria.

Jan, R., Saxena, D. C. & Singh, S. **2017.** Effect of storage conditions and packaging materials on the quality attributes of gluten-free extrudates and cookies made from germinated chenopodium (Chenopodium album) flour. Journal of Food Measure and Characterisation, **11:** 1071-1080.

Khanom, A., Shammi, T. and Kabir, M. S. **2016.** Determination of microbiological quality of packed and unpacked bread. Stamford Journal of Microbiology, **6:** 24-29.

Kumar, C. T. M., Raju, P. N. & Singh, A. K. **2017.** Effect of packaging materials and storage temperatures on shelf life of micronutrient fortified milk-cereal based complementary food. Journal of Packaging Technology and Research, **1:** 135–148.

Kumar, P., Chatli, M. K., Mehta, N., Malav, O. P., Verma, A. K. & Kumar. D. **2016.** Quality attributes and storage stability of chicken meat biscuits incorporated with wheat and oat bran. Journal of Food Quality, **39:** 649–657.

Laukova, M., Minarovicova, L., Karovicova, J. & Kohajdova, Z. **2019**. Quality evaluation of sweet potato powder-enriched cereal products. Food Science and Technology International, **25**: 523-532

Mesquita, C. D. B., Leonel, M. & Mischan, M. M. **2013.** Effect of processing on physical properties of extruded snacks with blends of sour cassava starch and flaxseed flour. Journal of Food Science and Technology (Campinas), **33:** 404-410.

Morais, M. P., Caliari, M., Nabeshima, E. H., Batista, J. E. R., Campos, M. R. H. & Soares, M. S. **2018.** Storage stability of sweet biscuit elaborated with recovered potato starch from effluent of fries industry. Food Science and Technology (Campinas), **38:** 216-222.

Nwosu, A. N. & Akubor, P. I. **2018.** Acceptability and storage stability of biscuits produced with orange peel and pulp flours. IOSR Journal of Environmental Science, Toxicology and Food Technology, **12**: 8-15.

Ohizua, E. R., Adeola, A. A., Idowu, M. A., Sobukola, O. P., Afolabi, T. A., Ishola, R. O. & Falomo, A. **2017.** Nutrient composition, functional and pasting properties of unripe cooking banana, pigeon pea and sweet potato flour blends. Food Science and Nutrition, **5:** 750-762.

Ojo, O. G., Akintayo, R. O., Falaye, A., Shittu, T. A. and Adeola, A. A. **2017**. Moisture -based shelf life estimation of ambient-stored grain flours. FUTA Journal of Research in Science, **13:** 473-482.

Onwuka, G. I. **2018.** Food Analysis and Instrumentation: Theory and Practice (2nd ed.). Naphthali Prints, Lagos, Nigeria. p. 488.

Othman, S. H., Edwal, S. A. M., Risyon, N. P., Basha, R. K. & Talib, R. A. **2017.** Water sorption and water permeability properties of edible film made from potato peel waste. Food Science and Technology (Campinas), **37:** 63-70.

Pereira, D., Paula, M. R., Correia, P. M. R. & Guiné, R. P. F. **2013.** Analysis of the physical-chemical and sensorial properties of Maria type cookies. Acta Chimica Slovaca, **6:** 269-280.

Qadri, T., Hussain, S. Z., Rather, A. H., Amin, T. & Naseer, B. **2018.** Nutritional and storage stability of wheat-based crackers incorporated with brown rice flour and carboxymethyl cellulose (CMC). International Journal of Food Properties, **21:** 1117-1128.

Romani, S., Tappi, S., Balestra, F., Estrada, M. T. R., Siracusa, V., Rocculia, P. & Rosaa, M. D. **2015.** Effect of different new packaging materials on biscuit quality during accelerated storage. Journal of the Science of Food and Agriculture, **95:** 1736-1746.

Sanz, T., Salvador, A., Baixauli, R. & Fiszman, S. M. **2009.** Evaluation of four types of resistance starch in muffins. II. Effects in texture, colour and consumer response. European Food Research and Technology, **229:** 197-204.

Sampaio, R. M., Marcos, S. K., Moraes, I. C. F. & Perez, V. H. **2009.** Moisture adsorption behavior of biscuits formulated using wheat, oatmeal and passion fruit flour. Journal of Food Processing and Preservation, **33**: 105–113.

Singh, A. & Kumar, P. **2019.** Storage stability determination of calorie deficit gluten-free biscuit: Taguchi concern. Journal of Food Processing and Preservation, **43**: e13927.

Smith, J. P., Daifas, D. P., El-Khoury, W., Koukoutsis, J. & El-Khoury, A. **2004.** Shelf life and safety concerns of bakery products - A review. Critical Reviews in Food Science and Nutrition, **44:** 19-55.

Swapna, K. S. & Rao, K. J. **2016.** Studies on effect of oat and cheese incorporation on sensory and textural quality of short-dough type biscuit. Journal of Food Science & Technology, **53:** 1505–1514.

Takeungwongtrakul, S. & Benjakul, S. **2017.** Biscuits fortified with micro-encapsulated shrimp oil: characteristics and storage stability. Journal of Food Science and Technology, **54:** 1126-1136.

Vaclavik, V. A. & Christian, E. W. **2005.** Essentials of Food Science (2nd ed.). Springer (India) Private Limited, New Delhi, India.

Yilmaz, E. & Öğütcü, M. **2015.** The texture, sensory properties and stability of cookies prepared with wax oleogels. Food and Function, **6:** 1194-1204.

تأثير التخزين على الصفات الفيزيفية والكيماوية والميكروبية والحسية للبسكويت المعد من مخلوط دقيق البطاطا و البسلة الهندية (بسلة الجرام) والموز

أديولا، أ.أ.[١]، أيانسينا، س.و.[٢]، كايود، ج.ي.[٣]، أديرويونيما، أ.ر.[٣]

١- معهد الأمن الغذائي، بحوث المصادر البيئية والزراعية، الجامعة الفيدرالية الزراعية، أبيكوتا، نيجيريا.

٢- قسم الإدارة الزراعية، الجامعة الفيدرالية الزراعية، أبيكوتا، نيجيريا.

٣- قسم علوم تكنولوجيا الأغذية، الجامعة الفيدرالية الزراعية، أبيكوتا، نيجيريا.

زاد استهلاك البسكويت في وجبات النيجيريين بسبب اتباعهم لنمط الحياة الغربي، لذا فإن البسكويت يعتبر من الأغذية التي يمكن عن طريقها تحسين المستوى الغذائي في نيجيريا. ومن المعروف أن للتخزين تأثيراً على محددات جودة البسكويت.

في هذه الدراسة تم تقييم بعض محددات جودة البسكويت المصنع من غير دقيق القمح عند التخزين على درجة حرارة ٢٨°م ورطوبة نسبية ٨٥٪، واستخدام البسكويت المصنع من دقيق القمح كعينة ضابطة (كونترول). وقد تم تقدير المستوى الرطوبي، اللون، القوام، التزنخ، الحمل الميكروبي والخواص العضوية الحسية للبسكويت المعبأ في عبوات مصنعة من كل من البولي إثيلين عالي الكثافة (HDPE) ومنخفض الكثافة (LDPE)، وذلك كل أسبوعين. وجد أن قيم معامل نفاذية بخار الماء اختلفت معنوياً (P≥٠,٥) وكانت ٢,٩٣٣ ×١٠-١٥±١,٨٥×١٠-٣١ للعينات المعبأة في LDPE. وأوضحت النتائج وجود اختلافات معنوية (P≥٠,٥) بين البسكويت المصنع من غير دقيق القمح مع نظيره المصنع من دقيق القمح، وذلك في المحتوى الرطوبي ، قيمتاً *L*, a للون ، الصلابة المرونة، التماسك، والأحماض الدهنية الحرة، قيمة البيروكسيد للبسكويت، وكان لنوع العبوة تأثير معنوي على الخواص الحسية للبسكويت.

تبين ارتفاع المحتوى الرطوبي، الأحماض الدهنية الحرة، قيمة البيروكسيد خلال التخزين واختلفت القيم على النحو التالي: من ٦,٧٥ إلى ١٣,٢٪، من ١,٤٨ إلى ٣,٧٧٪، ومن ١,٦ إلى ٢,٤٣ ملليمكافئ /كجم، على الترتيب لعينات البسكويت المعبأة في LDPE بينما ارتفعت هذه القيم من ٦,٧٥ إلى ١٠,٣٥٪، من ١,٤٨ إلى ٢,٨٣٪ ومن ١,٦ إلى ٢,٣٧ ملليمكافئ/ كجم على الترتيب لعينات البسكويت المعبأ في HDPE.

تبين انخفاض قيم *L*, a*, b، الصلابة ، المرونة ، التماسك والتقبل العام لعينات البسكويت المعبأة في كل من نوعي البولي اثيلين خلال التخزين. وكان البسكويت المخزن في عبوات البولي اثيلين منخفضة الكثافة وتلك المعبأة في عبوات بولي ايثيلين مرتفعة الكثافة متقبلاً حتى أربعة وستة أسابيع من التخزين على الترتيب.

Microwave Applications in Food Processing: An Overview

Taiseer M. Abo Bakr

Food Science & Technology Dept. Fac. of Agric. Alexandria Univ. El Shatby, 21545, Alexandria, Egypt.

Received: 29 November, 2020 *Revised: 16 December, 2020* *Accepted: 22 December, 2020*

ABSTRACT

In the recent years, the industrial applications of microwaves have been popular all over the world. Microwave heating has been applied in a wide range in the food processing such as cooking, blanching, drying, thawing, tempering, baking, pasteurization and sterilization. Microwave energy has many advantages than conventional heating. The present review aimed to investigate the heating of microwave and its applications in the field of food processing. Furthermore, focus on the advantages and disadvantages of microwave heating and comparison between the traditional heating methods and the heating using the microwave energy on the quality of the food products will be also highlighted. The advantages of pasteurization and sterilization of fresh juices,food fluids and other food products and their ability to exhibit inhibition for the most microorganisms at lower temperatures than the usual heating methods have been discussed. Also, using the microwave heat in drying food products suchas microwave assisted air drying,freeze drying followed by microwave, vacuum drying combined by microwave and using drying by microwave combined with the conventional drying methods were reviewed.

Keywords: Microwave, drying, cooking, blanching, baking, thawing, and pasteurization.

INTRODUCTION

Microwave was principally used for communication during the Second World War with the development of radar. Presently, the microwave heating had become so accepted all over the world. Microwave oven has become one of the common household appliances which is used for food preheating, cooking, and tempering of frozen foods. The microwave is the novel tool to attain consumer demands for food and more easier in use and saving time in its preparation. Recently, most food industries use microwave to heat, dry and sterilize many food products. Microwaves have been used successfully in many foods processing such as cooking, blanching, drying, thawing, tempering, baking, pasteurization and sterilization. Microwave heating has many benefits as compared to the conventional heating methods. These advantages are;speed of heating, saving energy, short times for start-up and shut down to reach the desired temperatures. The heat is generated throughout the food and has greater penetration depth. Also, about 80% or higher heating efficiency can be obtained. Moreover, the heating is clean,noiseless and no burned out gas is generated. It is suitable for heat- sensitive food products and multiphase fluids. Other advantages include products of good quality in terms of flavour, taste, texture, colour and nutritional contents (Ahmed & Ramaswamy, 2007, Tewari, 2007,Chavan & Chavan, 2010, Kalla & Devaraju, 2017).

The principle of microwave heating:

Microwave is one of the electromagnetic radio wave. The radio wave which has a frequency band ranging from 300 MHz to 300 GHz is known as microwave. Two frequencies (915 and 2450 MHz) are used for microwave processing. The Microwave heating is given by the interaction between dipolar water molecules orcharged ions and electromagnetic field. When food is placed in a microwave oven, the behavior of food contents is different. The water is the principle component that absorbs heat and make food to be heated. The food which has a high level of moisture being the faster in heating. Water acts like a magnet. It has two ends opposite in charge, 2 hydrogen atoms (positive charge) and oxygen molecule (negative charge). So, water in food behaves as a magnet. Therefore, when microwave oscillate the water molecule, it will rotate due to its different poles. This because the positively charged end of water will attracts to the negative end of microwave. Meanwhile, the end of water which has a negative charge will attracts to the microwave positive end. Heat will generate as a result of molecular friction due to the rotation of dipolar molecule. Due to the strong dipole rotation of water, it is the first component which reacts with microwaves and produce heat. The microwaves rotate at very high speed of 2450 time / sec. So, the water molecules will rotate 2450 time/ sec. The water molecules will crash each other very fast to produce heat as the result of the rotation. This heat flows by convection, conduction or radiation through the food to warm it up (Fig. 1) (Kalla & Devaraju, 2017).

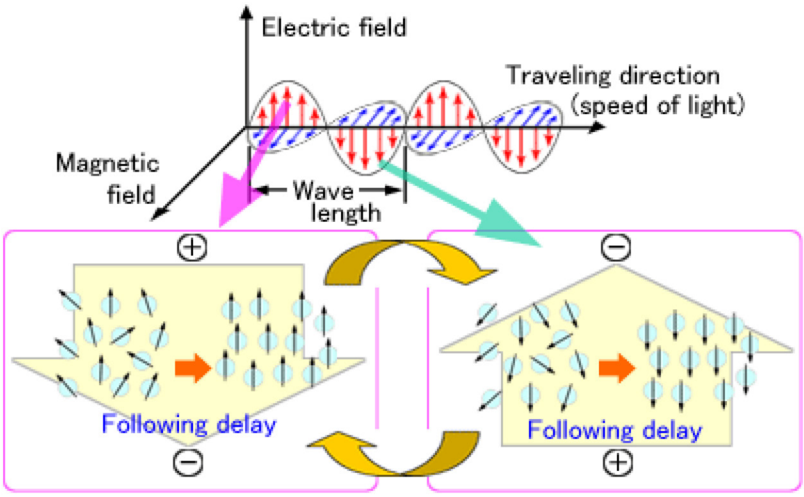

Fig. 1: Microwave heating formula and the dielectric properties of materials (Lehpamer, 2010)

Microwave travel similar to light waves. Microwave heating has some characteristics which are not found in the other conventional heating methods. These are: 1- internal heating. 2- select and rapid heating 3- clean energy and uniformity 4- rapid response and easy to control. (Figs. 2 & 3). (Oliveira &Franca, 2002, Ahmed & Ramaswamy 2007, Marra, *et al*, 2009, 2010).

Microwave applications in food processing:

Cooking

Cooking with microwave is the most familiar application of microwave at the entire world. Microwave heating is very rapid and the food products reach the desired temperature in a short time. Cooking using microwave heating is suitable for the small amounts of foods(Sukhwant, *et al.*, 1992).

The physical and chemical properties of vegetables are changed as a result of cooking in boiling water. Also, some reduction in dietary components were observed in cooked vegetables by microwave heating(Sukhwant, *et al*, 1992, Zia-ur-rehman, *et al*, 2003, Zhang & Hamauzu, 2004).The advantages of cooking by microwave are less loss of moisture content and minimal loss of nutrients of foods. Also, its speed, saving in energy and uniform heating through the food products.Because microwave heating penetrates inside the food materials, so, cooking occurred internally and rapidly through the whole volume of the food, which reduces the cooking time and energy. Moreover, because the transfer of heat is fast, flavour, colour, vitamins and most the food nutrients will be well preserved (Puligundla, *et al.*, 2013).

Many studies on the effect of cooking using microwave heating on the food ingredients were investigated. A reduction in energy consumption was noted due to the benefits of cooking using microwave oven for raw and soaked rice comparing to the cooking in boiling water. The brown rice cooked by microwave retained higher levels of protein, fat, and ash contents as compared to steaming and conventional boiling methods (Lakshmi *et al*, 2007). When the legumes such as common beans and chickpeas

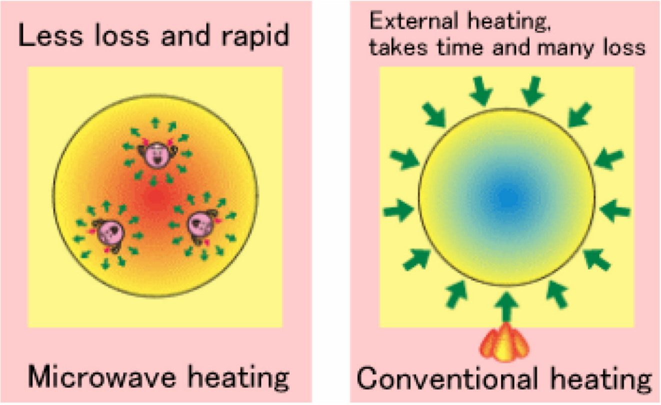

Fig. 2: Microwave heats object internally (Lehpamer, 2010)

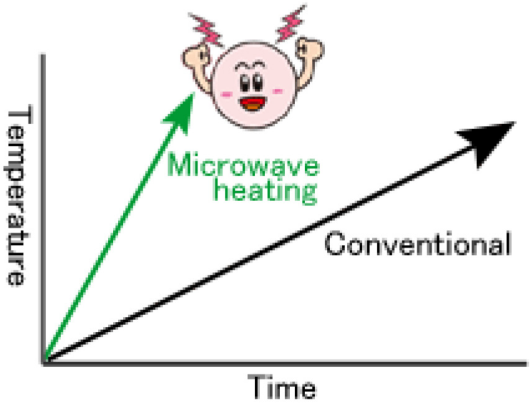

Fig. 3: Microwave heating is fast (Lehpamer, 2010)

were cooked by microwave, the time for cooking was short and they retained higher levels of the major minerals (Ca, Na, K, and Mg) and the minor ones (Fe, Cu, and Zn) comparing with the traditional cooking methods (Marconi, *et al*, 2000, Arab, *et al*, 2010).

Baking

The baking process is the first commercial application of microwave energy. At 2450 MHz, the first bread baking was reported by Ahmed& Ramaswamy(2007). Baking is an important process in bakery industry. The dough expand during the baking process and have high volume, losses in moisture and at the final stage the moisture loss decrease as a result of the falling down of air cells in the dough due to the increased vapor pressure (Mondal, & Datta, 2008).

Many advantages are found for using microwave in baking industry such as short time, small-space, preserves nutrients and save energy as compared to conventional baking. Some problems are noted when baking is carried out using microwave heatingonly such as tough and quite hard texture, dry and loss of flavour and colour. Also, many studies reported that there were some problems related to the microwave bread baking such as the lack of crust formation, surface browning, less firm texture, low volume, lack of colour and rapid staling. Also, some defects were found in cakes baked by microwave such as low volumes, tough textures, lack of colour, high weight loss (Scanlon & Zghal, 2001, Sumnu,2001).

Therefore, recently the combination of microwave with thermal energy (conventional or infrared baking)is investigated by many researchers to produce crust loaf in short time to avoid the absence of crust formation and the brown colour of loaf surface. The combination of traditional heat source with microwave energy succeeded to decrease the baking time by 50 % (Sumnu, 2001, Sumnu, *et al*, 2005,Yolacaner, *et al*, 2017)

The European soft wheat with high ἀ- amylase can be used with the combined process. This because the microwave heating was uniform to rise in the whole product. Therefore, the inhibition of ἀ-amylase is fast enough to prevent extensive damaged starch (Tewari, 2007).

Goedeken, *et al* (1997) reported that the power of microwave oven should be adjusted to avoid the water loss during bread baking. Sumnu, *et al*, (2005) reported that doughnut proofing by microwave heating can be completed in 4 min only comparing with 40-60 min by traditional heating methods. Also, using microwave heating in baking cookies at the final stages resulted in producing products without cracking andhave good properties.

During the conventional baking, the conductive and radiant heat heated the products from outer surface. This causes some structural changes in the ingredients of the dough such as the gelatinization of starch, denaturation of protein, increase in the volume and crust formation. While, microwave radiation interacts with water molecules, that results in the structure changes and water movement (Therdthai & Zhou, 2003). The heating mechanism in the microwave differs from the conventional methods. In the microwave the energy absorption results in internal heating and generates internal vapor pressure (Yolacaner, *et al*, 2017).

Ahmad, *et al*. (2001) studied the radiation of high- frequency and their effect on the quality of biscuits which baked in a convection oven, followed by baking immediately in microwave oven for 30 sec. Baking by microwave reduced checking in biscuits to 5 % as compared with 61% in conventional baking and less affected to checking when exposure to high humidity.

Microwave baking do not have the ability to form browning as the conventional methods in baked products (Chavan&Chavan, 2010). Durairaj, *et al*.(2009) reported that ceramic layer is useful in decrease the thermal runaway and enhance the power absorption in food samples by the ceramic layers in the microwave oven.

Some studiesfound that using microwave ovens provide with infrared heating will enhance the quality of the baked products (Datta & Ni, 2002, Sevimli, *et al*., 2005). Today the most important use of microwave heating is in the final stages of the baking industry, when the conventional processes lead to longer baking times (Kumar, 2015).

Drying:

The food preservation by drying process is used for many products, especially fruits and vegetables to extend self-life (Doymaz, 2006). So, new methods are used to shorten the drying time and decrease of the consumption of energy. The benefits of microwave heating are its penetration depth and the uniform heating. Microwave drying is used to shorten drying time to an extent of about 90-95%and saving energy consumption as compared with the conventional air drying. Also, only 20-35% of the floor is needed for microwave system (Maskan, 2000, Ahmed &Ramaswamy, 2007).

Microwave drying of food is used in the final stage (falling period) of drying food products because the migration of water from the center of the products is decreased. The mechanism of drying with microwave is different from the traditional hot air drying method. Drying food using microwave heating, the heat is generated through the product causing higher heat transfer. Also, the temperature rises more faster than in conventional drying (Gowen, *et al*, 2008, Chandrasekaran, *et al*, 2013,Gaukel, *et al*, 2017).

The microwave drying cause too much high temperature at the edges of the food products during the final stages of drying which results in production off flavours. So, the use of microwave drying in food processing at a commercially industry was for drying products in the final stage of drying. In the food industry it could be used two – stage drying process involving conventional drying at the initial stage using forced air followed by microwave drying (Ahmed& Ramaswamy, 2007). It was found that the drying time of banana slices reduced by 64% when hot air drying combined with microwave (at 350 W), as compared to the air drying method (at 60°C). The banana samples took place a longest time in the falling rate period by air drying. Meanwhile, the samples were lighter in colour and, the product had excellent taste, no shrinkage and good flavour (Maskan, 2000, Chandrasekaran *et, al*, 2013, Kumar, 2015).

Bouraoui, *et al*,(2007) studied three different methods for drying potato slices (microwave heating, convective drying and combined microwave and convective drying). The results showed that the drying by microwave heating producing dried potato slices of better quality and reducing drying time. Microwave drying at low power have a good effect on the quality of dried apple slices. The coating material affects the textural quality of the slices such as texture strength(Askari, *et al*., 2006).

Pasta is made from semolina by steps include, hydration, mixing, kneading and extruding to obtain the different shapes then drying. The drying step is the difficult and critical to obtain pasta of high quality. It is difficult because the moisture migrates slowly to the surface when hot air is used. Using microwave heating will provide a positive moisture flow to the surface. In many countries, pasta products and noodles are dried successfully by microwave at 915 MHz at a commercial scale (Goksu *et al*., 2005).

Szadzińska, *et al*.(2019) investigated the microstructural alteration, and rehydration properties of the dried raspberry using drying with the application of microwaves (MW) and ultrasound (US) and convective drying (CV) as a reference method. The results showed significantly shorter drying time by 54–64% for CV followed by US and 69% for CV combined by MW comparing to CV. Also, and a lower energy consumption resulting in energy saving of 14to 23% for CV followed by US and 54% for CV combined with MW, as compared to CV.

Ultrasound and microwaves were applied in drying red beetroot using convective drying continuously (hybrid processes) or periodically (hybrid intermittent processes). The drying processes were evaluated in terms of drying time, drying rate, and energy consumption. Furthermore, the total colour change, retention of natural dye (betanin), water activity, texture, and microstructure of dry product were examined. It was found that hybrid intermittent drying reduces the total drying time and energy consumption, enhances both the drying rate and product quality, it was demonstrated that the hybrid intermittent drying can serve as an alternative to conventional hot air drying that could produce a more porous, nice colour, and crispy vegetable products (Szadzińska, *et. al*.,2020).

Microwave assisted vacuum drying, Zhang *et al*. (2006) reported that the thermal efficiency has been improved when microwave was combined with vacuum drying. Microwave vacuum drying was used for various cereal grains, concentration of citrus juice and for production of grape puffs. Many studies reported that microwave applications were used for drying fruits and vegetables (Marra, *et al*, 2010)

Zielinska *et. al.* (2019) investigated hot air convective drying (HACD) and microwave vacuum drying (MWVD) on the drying kinetics and quality of whole cranberries in terms of texture. It was found that drying times were shorter for the samples dried by MWVD as compared to the samples dried by HACD. Moreover, cranberries processed by MWVD were significantly had greater hardness, gumminess, and chewiness as compared to HACD samples. Also, the texture was hard and crispy and resistance to stress associated with manufacturing, packaging and storage. Meanwhile, HACD produced brittle fruits that were difficult to store and transport and were not fully suitable for direct consumption. Furthermore, when freezing was followed by MWVD the overall appearance of cranberries was improved.

Freeze drying is the method used to preserve the sensitive food products in good quality. It needs a long processing period and consumed great amount of energy. So, microwave can help the freeze drying to produce food products of high quality similar to that of vacuum freeze drying and can shorten the drying period effectively .The drying rate in microwave freeze drying of cabbage was more effective than that of vacuum freeze drying (Kalla&Devavju, 2017)

The falling rate period in the fluidized bed dryers is long drying time. However, using microwave heating combined with fluidized bed dryers can overcome this disadvantage (Chen, 2001, Puligundla*et al*, 2013, Kumar, 2015)

Using vacuum drying can produce a more porous dehydrated products compared by air dried products. Drying by hot air had many disadvantages such as lengthy time and low energy efficiency. This is due to the rapid reduction of surface moisture transfer. This resulted in reducing the quality of food. So, to overcome these disadvantages microwave was combined with hot air drying (Masken, 2001, Sharma & Prasad, 2001).

Botha *et al*, (2012) found that when using osmotic dehydration for drying pre- heated samples of pineapple, they were dried quickly by using microwave at different power conditions and had a good quality.

Carrot slices dried with microwave vacuum drying contained high content of ά - carotene and vitamin C, also had soft texture and good colour than that of air drying. Also, carrot slices dried at 400 W power by microwave retained about 88% of its ß - carotene (Mayer-Miebach, *et al*, 2005).The kinetics and drying properties of potato slices were studied using different microwave powers and vacuum pressure by Song, *et al*, (2009).

Blanching

In the blanching process the food products are exposure to boiling water, steam or boiling solutions containing salts or acids to inactivate the enzymes which catalyze the oxidation of food products and cause undesirable changes in texture, colour and flavour of the food products. This process is an essential step in food processing such as canning, drying and freezing. Also, blanching serves to decrease the microbial load of the food products and eliminate dissolved oxygen from the food (Maskan, 2000, Ahmed & Ramaswamy, 2007).

In general, hot water or steam is commonly used in the blanching step in the food industry. The traditional blanching method is associated with a reduction in weight and leaching some nutritive components such as sugars, water soluble vitamins and minerals (Maskan, 2000, Ramesh, *et al*, 2002).

To keep the nutritional quality of food products, microwave blanching can be used to reduce the leaching of nutrients in water, since it requires little amount of water for efficient heat transfer in food products (Ponne, *et al*, 1994, Ramesh, *et al*, 2002, Lin & Brewer, 2005,Puligundla, *et al*, 2013).

The advantages of blanching using microwave compared with traditional methods include saving consumed energy, speed of operation, no additional water requirement, precise process and faster times for start - up and shut down. The combination of microwave heating with initial hot water or steam could provide an excellent economic benefit. Steam or low cost hot water were used first to raise the temperature, then microwave heating does the more difficult and the high cost of internally blanching stage of food products. Furthermore, blanching by microwave will finish the blanching of the centers quickly regardless to the thick or non-uniform sections (Shaheen, *et al*, 2012).

Also, when using microwave to inactivate enzymes (peroxidase, catalase, polyphenol oxidase and pectinase), a reduction in time and energy were achieved as compared with the traditional methods. Furthermore, the bioactive compounds were enhanced and avoid the leaching effect of water blanching for the phytochemicals due to the short time required by microwave blanching. The food materials blanched with microwave include vegetables, fruits, leaves, tubers, and mushrooms (Dorantes- -Alvares *et al*, 2017, Kalla & Devaraju, 2017).

Using microwave heating in blanching process was preferred than using hot water or steam in blanching step because leafy vegetables can retain its maximum green colour, vitamin C (ascorbic acid) and chlorophyll contents. Also, it is more effective in retaining water-soluble vitamins and other nutrients as compared to the traditional blanching methods. Microwave heating were carried out for blanching many vegetables like, carrots, mushroom, sweet potato, peas, pepper, beet and green beans. Furthermore, maximum retention of red pigments and total antioxidant activity were found in all the treatments (Severini, *et al*,2016,Wang *et al*, 2017).

However, using the microwave heating can lead to some problems such as non-uniform for heating and distribution of the energy which causes hot and cold points in the product (Chandrasekaran, 2013, Xiao, *et al* , 2017).

Pasteurization and sterilization:

Pasteurization is the process that uses relatively mild heat treatment on foods. The main goals of pasteurization are to destroy pathogenic microorganisms and inactivate some enzymes in foods. It is usual method used to extend the storage period and shelf-life of food products to make food safe for consumption like milk and fruit juices, where minimum process is necessary to minimize health-associated. The absorbed energy from microwave causes a rise in the temperature of the food to be high enough to destroy the pathogenic microorganisms such as bacteria by thermal treatment and to inactivate the undesirable enzymes in foods (Nott & Hall, 1999, Tewari, 2007, Guo, *et al*,2017).

Pasteurization can be achieved by many methods such as ohmic heating, non-thermal technologies (UV light, high hydrostatic pressure, high intensity ultrasound, pulsed electric field and ionizing radiation)(Pereira& Vincente, 2010).

Microwave destroys the microorganisms at sublethal temperatures can be explained by different theories:1-The theory of selective different heating: the microorganisms are selectively heated to higher temperature than the fluid surrounding it and killed very quickly. 2- Electroporation theory: the cell membrane had pores as a result of electrical potential, which causes the drainage of cellular materials. 3- Cell membrane method: the voltage applied causes rupture in the cell membrane. 4- Magnetic field theory: the coupling electromagnetic energy causes disrupted of some components of the cell like protein of the DNA. Also, the polar and / or charged moieties of proteins (COO^-, and NH_4) are affected by the electrical component of the microwaves and the disruption of non- covalent bonds by microwaves cause of speedy microorganisms' death (Kozempel, *et al*, 1998, Koulchma, *et al*.2001).

Salazer-Gonzalez, *et al*, (2012) reviewed the using of microwave pasteurization of many liquid foods such as different fruit juices, milk, coconut milk and sweet potato puree and they reported that desired lethality could be obtained. Microwave pasteurization of ready-to-eat meals has also been found to be a commercial success in European countries although US industries are still reluctant to use this technology. Moreover, microwave pasteurization of packaged products is possible for different packaging materials (plastic, paper, and glass).

It was found that pasteurization of eggs shell by microwave can be achieved without losing the shell integrity. Also, the inhibition of Salmonella in the yolk of eggs can be obtained by microwave pasteurization. About 22% reduction of microbes was attained for microwave heating for 15 sec. Whereas, about 36% reduction was obtained using moist heat treatment for 15 min (Dev, *et al*., 2008,Shenga, *et al*., 2010).

Sterilization is a more severe thermal treatment of foods. The process is designed to achieve commercial sterility of the food products, giving it long-term shelf foods. The traditional heat sterilization is mainly carried out by heating and is characterized by slow heat transfer and long sterilization time, which seriously affects the quality of food products. Therefore, microwave heating has the advantage of overcoming the limitation imposed by slow thermal diffusion of conventional heating. Some researchers have claimed non-thermal or enhanced thermal effects, to be associated with microwave heating on the destruction of microorganisms and inactivation of enzymes (Ahmed, & Ramaswamy, 2007, Kalla, & Devaraju, 2017). To preserve fluid foods, the process of high – temperature short- time (HTST) has been used to avoid the thermal degradation in food quality. But for solid foods, the HTST is not suitable due to the slow penetration of heat and overheating of the solid surface during the time of heating. Meanwhile, heating by microwave will overcome the slow heat penetration of traditional heating methods. The heat produced by microwave will shorten the time of heating as compared to the commercial sterilization (Ahmed& Ramaswamy, 2007, Vadivambal & Jayas, 2010).

Sterilization of food products packed in different materials can be achieved by using new techniques like microwave irradiation, Ultra Violet light (UV), cold plasma and ozone. Some packaging materials may migrate into food materials. Benzene may be produce as a result of the high temperature of microwave heating due to the leaking of some polymers or adhesive components of packaging materials. So, paper, glass and ceramics were preferred for using in microwave packaging (Guilard, *et al.*, 2010, Chandrasekaran, 2013). When macaroni packed in pouches with cheese were preserved by sterilization using heat of microwave at 950 MHz, no changes in the taste, texture or flavour of the products were observed (Esteve, *et al.*, 1998). According to U.S. Food and Drug Administration (FDA) (2019) the non-thermal inactivation effect of microwave process on the destruction of microorganisms and inactivation of enzymes is not sufficient to use in sterilization of all types of food. It is recommended to include only thermal effects in the models. The sterilization of potatoes and fish fillet using in pouches was approved recently by the FDA. The process was carried out by dipping the food package in boiling or hot water and usingthe heat of microwave at a frequency of 950 MHz. The food pathogens and spoilage bacteria will be eliminated in 5 to 8 min and the products were safe and have good quality (Brody, 2012).

Several studies demonstrated that the application of microwaves in the sterilization of foods is limited due to the uneven heating of the product during sterilization. Also, the temperature of the product at some locations does not reach the real temperature distribution during microwave heating. Other researchers reported that replacement of the conventional heating by microwave energy as only heating source is impossible without understanding the real heating and inactivation mechanisms, temperature distribution in all layers of foods and other critical factors. To distinguish between thermal and no thermal effects on destroying microorganisms, most studies used the experiments under identical heating conditions to evaluate the inactivation effects of conventional and microwave heating. The major drawback in the microwave sterilization is the lack of availability of actual temperature profiles. Measurement of temperatures at some locations does not guarantee the real temperature distribution in the food product during heating by microwave (Nguyen, *et al* 2013, Peng, *et al*, 2017 Michalak, *et al*, 2020).

Thawing and tempering;

Thawing of frozen food products is the reversal process of freezing. Thawing is the process used for change the frozen products from frozen state to reach temperature of $0^{O}C$ and be free from ice (unfrozen state) or defrosting. Before cooking the frozen foods should be thawed, to be sure that the food during cooking is sufficiently heated to destroy the spoilage microorganisms. When conventional thawing methods are used, it will take a long time, the outer surface of food product will be the first area which rise in the temperature and results in bacteriological and chemical deterioration. Thawing using hot air or water will subject the outer surfaces of frozen meat blocks to high temperatures for a long time. Microwave heating is usually used for thawing food products because its heat is generated from the center to the surface and the process will be more faster than the conventional thawing (Shaheen, *et al*., 2012, Kalla & Devaraju, 2017).

The heating of microwave is usually used for thawing frozen bread. It was reported that some bakery products thawed or heated by microwave have low quality, due to presence of some bad properties such as lack of browning, low volume, flavour changes, tough, difficult to chew crumb and bread staling after short time of heating (Sumnu, 2001).

The disadvantagesof using microwave in thawing process are the phenomenon of runaway heating due to the unbalance in heating and the higher amount of power absorption in liquid parts of the materials. So, it is important to adjust the heat produced by the microwave ovens. At commercial practice few quantities of frozen products such as frozen meat, vegetables, fish, fruits and juice concentrates are thawed by microwave heating (Kalla & Devaraju, 2017).

The tempering process is usually carried out at temperature below freezing point (generally bellow- $18^{o}C$) and ranged between -5 to $-2^{o}C$, where the water in the food product is turned to ice but not all the quantity of water changed to ice. At this temperature the product will be strict but not hard. Many studies reported that complete thawing the frozen foods completely by microwave is not practical. Therefore, tempering by microwave showed great benefits and can be used instead or alternative to thawing. At the tempering temperature, the texture and the product firmness are intact and permits further processing without causing harm. Tempering is more commonly used in the technique for the products that are subsequently required size reduction, and it is quicker than the thawing. Tempering also reduces problems such as drip in the frozen products and bacterial growth that are associated with the thawing. Furthermore, it can handle large amounts of frozen product at small cost, has a high yield, and is accomplished in small spaces with no bacterial growth compared to traditional tempering techniques either with water or air (Chizoba *et al*., 2017).

In many times it is not important to complete the thawing to save energy, the time will be shorter and obtain products of good quality. The frozen meat is usually found in large pieces. So, in order to cut and slice the frozen meat, it should be tempered firstly. Therefore, the pieces will be tempered from the hard state to a temperature to be easier for cutting without damage the product. The temperature used for tempering will be according to the shapes of pieces, the method used for cutting, slicing and the composition of food product such as moisture, fats, and proteins. Traditional tempering methods usually use hot air and water; in this case the meat surfaces from outside will subject to high temperatures for long periods until the heat reaches the center of the product. Tempering microwave has been carried out for frozen foods such as fish, meat and poultry either in different methods such as batch or continuous systems.

The advantages of microwave tempering are handling large quantities of frozen products, low cost, occupy tempering of bulky products due to its deeper penetration in the product as compared to the frequency of (2450 MHz) (high band) microwave(Ahmed& Ramaswamy 2007, Shahen,*et al*., 2012, Kalla. & Devaraju, 2017).

The main advantages and disadvantages of microwave heating:

In conclusion, microwave heating presents some advantages and disadvantages in comparison to the conventional techniques as reported by some researchers (Salazar-Gonzaler, *et al*., 2012,Chandrasekaran, *et. al*., 2013, Kumar, 2015, Kalla & Devaraju, 2017, *Szadzińska, et al., 2019*).

The advantages:

1- Faster heating: the microwave heat generates with high heating efficiency (80% or more achieved).
2- The heat is generated throughout the food and has greater penetration depth.
3- Shorter processing time: it uses about a quarter of the time used in the conventional heating and requires short times for start-up and shut down to reach the desired temperatures.
4- Better quality of processed food products: the target temperature reached quickly due to the high heating rate, thus reducing the harmful effects of thermal heating on the food and it is more effective in retaining the nutrients components of the food products.
5- It is suitable for the sensitive, high viscosity, and multiphase fluids.
6- It is safe to handle the packed foods after microwave pasteurization.
7- Ease of operation, small space requirement, and low energy consumption (high efficiency), reduction of noise levels, and low maintenance cost.
8- Environmentally it is clean energy, and does not produce toxics gases or any pollutants wastes.

The disadvantages:

1- The microwave ovens usually use electricity, which is high in costs.
2- It is much expensive to build long towers.
3- To obtain high quality food products, it needs qualified engineers who have experience to develop this novel technology for using at industrial scale.
4- Microwave heating is not suitable for bread baking because bread staling may occur quicker as compared with the conventional baked methods.
5- Microwave drying usually is used only in the falling period of drying many products.
6- Applying microwave heating in drying of some food products may cause too much heating at the edges and corner of the products resulted in off-flavours and unacceptable taste.
7- In order to use microwave heating in the drying of food products, it should combine the drying by microwave with the traditional drying methods to achieve products of high quality.
8- The non uniform temperature distribution, resulting in hot and cold spots mainly in solid and semi-solid products.

REFERENCES

Ahmed, J. & Ramaswamy, H. S. **2007**. Microwave pasteurization and sterilization of foods. In: Handbook of Food Preservation, 2nd Ed, (Rahman, S. M. (Ed), CRC Press, Taylor and Francis Group, New York. pp: 691-709.

Ahmed, S. S., Morgan, M. T. & Okos, M. R. **2001**. Effects of microwave on the drying, checking and mechanical strength of backed biscuits. Journal of Food Engineering, **50:** 63-75.

Arab, E. A.A., Helm, I. M. F. & Bareh, G. F. **2010.** Nutritional evaluation and functional properties of chickpea (Cicerarietinum L.) flour and the improvement of spaghetti produced from it. Journal of American Society, **66:** 1055-1072.

Askari, G. R., Emmam-Djomeh, Z., & Mousavi, S.M. **2006**. Effect of combined coating and microwave assisted hot- air on the texture, microstructure and rehydration characteristics of apple slices. Food Science and Technology, **12:** 39-46.

Botha, G. E., Oliveira, J. C. & Ahrne, L. **2012**. Microwave assisted air drying of osmotically treated pineapple with variable power programmers. Journal of Food Engineering, **108:** 304-312.

Bouraoui, M., Richard, P. & Durance, T. **2007**. Microwave and convective drying of potato slices. Journal of Food Process Engineering, **17:** 353-363.

Brody, A. I., **2012**. The coming wave of microwave sterilization and pasteurization. Food Technology Magazine, **66:** 78- 80.

Chandrasekaran, S., Ramanathan, S., & Basak, T. **2013**. Microwave Food Processing – A review. Food Research International, **52:** 243-261.

Chavan, R.S.& Chavan, S.R., **2010**. Microwave baking in food industry. A review. International Journal of Dairy Science, **5:** 113-127.

Chen, G., Wang, W. & Mujumdar, S. **2001**. Throretical study of microwave heating patterns on batch fluidized bed drying of porous material. Chemical Engineering Science, **56:** 6823-6835.

Chizoba, E. F. G., Sun, D. W., Han, Z., & Cheng, J. H. **2017**. Microwave-assisted food processing technologies for enhancing product quality and process efficiency: A review of recent developments. Trends in Food Science and Technology, **67:** 58–69.

Datta, A. K., & Ni, H. **2002**. Infrared and hot –air assisted microwave heating of foods for control of surface moisture. Journal of Food Engineering, **51:** 355-364.

Dev, S. R. S., Raghavan, G. S. V. & Gariepy, Y. **2008**. Dielectric properties of egg components and microwave heating for in- shell pasteurization eggs. Journal of Food Engineering, **86:** 207- 214.

Dorantes-Alvares, L., Ortiz-Moreno, A., Guzman-Geronimo, R., & Parada- Dorantes. **2017**. Microwave- assisted blanching. In: The Microwave Processing of Foods. (Schubert, H. &Regier, M. (Eds). Cambridge CRC press, pp: 179-199.

Doymaz, L. **2006**. Drying kinetics of black grapes treated with different solutions. Journal of Food Engineering,**76:** 212-217.

Durairaj, S., Chaudhary, A. & Basak, T., **2009**. Efficient microwave heating of discrete food samples layered with ceramic composites. Journal of Food Engineering, **95:** 62-75.

Esteve, M. J., Frigola, A., Martorwll, L., & Rodrigo, C. **1998**. Kinetics of ascorbic acid degradation in green asparagus during heat processing. Journal of Food Protection, **61:** 1518- 1521.

Food and Drug Administration. **2019**. Kinetics of microbial inactivation for alternative food processing technologies – microwave and radio frequency processing. Available online: http://www.fda.gov/Food/ScienceResearch/ResearchAreas/SafePracticesforFood-Processes/ucm100250.htm (accessed on 18 April 2019).

Gaukel, V., Siebert, T., & Erle, U. **2017**. Microwave-assisted drying. In: The Microwave Processing of Foods (Schubert,H.&Regier,M.(Eds). Cambridge CRC press, pp: 152-178.

Goedeken, D. L., Tong, C. H. & Virtanen, A.J. **1997**. Dielectric properties of a pregelatinized bread system at 2450 MHz as a function of temperature, moisture, salt and specific volume. Journal of Food Science, **62:** 145-149.

Goksu, S.O., Sumnu, G. &Esin, A. **2005**. Effect of microwave on fluidized bed drying of macaroni beads. Journal of Food Engineering,**66:** 463-468.

Gowen, A. A., Abu- Ghannam, N., Frias, J., & Oliveria, J. **2008**. Modeling dehydration and rehydration of cooked soybeans subjected to combined microwave-hot air drying. Innovative Food Science and Emerging Technologies, **9:** 129-137.

Guilard, V. Mauricio- Lglesias, M., & Gontard, N. **2010**. Effect of novel food processing methods on packaging: structure, composition and migration properties. Critical Reviews in Food Science and Nutrition, **50:** 969- 988.

Guo, Q., Da-Wen, S., Jun-Hu, C., & Zhong, H., **2017**. Microwave processing techniques and their recent applications in the food industry. Trends in Food Science and Technology, **67:**236–247.

Kalla A., M.&Devaraju, R. **2017**. Microwave energy and its application in food industry: A review, Asian journal of Dairy and Food Research, **36:** 37-44.

Koulchma, T., Le Bail, A.& Ramaswamy, H.S. **2001**.Comparative experimental evaluation of microbial destruction in continuous- flow microwave and conventional heating system. Canadian Biosystems Engineering, **43:** 3.1-3.8.

Kozempel, M. F., Annous, B.A., Cook, R. D., Scullen, O.J., & Whiting, R. C. **1998**. Inactivation of microorganisms with microwave at reduced temperatures. Journal of Food Protection, **61:** 582-585.

Kumar, Y. **2015**. Application of microwave in food drying. International Journal of Engineering Studies and Technical Approach, **01:** 9-23.

Lakshmi, S., Chakkaravarthi, A., Subramanian, R., & Singh, V. **2007**. Energy consumption in microwave cooking of rice and its comparison with other domestic applications. Journal of Food Engineering, **78:** 715-722.

Lehpamer, H. **2010**. Basics of microwave. In: Microwave Transmission Networks: Planning, Design, and Deployment. www.microdenshi.co.jp/en/microwave/index.html.

Lin, S. & Brewer, M. S. **2005**.Effectof blanching method on the quality characteristics of frozen peas. Journal of Food Quality, **28:** 350-360.

Marconi, E., Ruggeri, S., Cappelloni, M., Leonardi, D. &Carnovale, E. **2000**. Physicochemical, nutritional and micro structural characteristics of chickpeas (*Cicer arietinum* L.) and common beans (*Phaseolus vulgaris* L.) following microwave cooking. Journal of Agriculture and Food Chemistry, 48 : 5988- 5994.

Marra, F., De Bonis, M. V., Ruocco,& ConvectionG. **2010**. Combined microwaves and convection heating: A conjugate approach. Journal of Food Engineering, **97:** 31-39.

Marra, F., Zang, L.,& Lying, J. G. **2009**. Radio frequency treatment of foods: review of recent advances. Journal of Food Engineering, **43:** 243-250

Maskan, M. **2000**. Microwave/air and microwave finish drying of banana. Journal of Food Engineering, **44:** 71-78.

Maskan, M. **2001**. Drying, shrinkageand rehydration characteristics of kiwifruits during hot air and microwave drying. Journal of Food Engineering, **48:** 177-182.

Mayer-Miebach, E., Behsnilian, D., Regier, M., & Schuchmann, H.P., **2005**. Thermal processing of carrots: lycopene stability and isomerisation with regard to antioxidant potential. Food Research International, **38:** 1103- 1108.

Michalak, J.Y., Czarnowska-Kujawska, M., Klepacka, J. & Gujska, E. **2020**. Effect of microwave heating on the acrylamide : review. Molcules, 25 : **4140**.

Mondal, A. & Datta, A.K. **2008**. Bread making- a review. Journal of Food Engineering, **86** : 465-474.

Nguyen, L.T., Choi, W., Lee, S.H.& Jun, S. **2013**. Exploring the heating patterns of multiphase foods in a continuous flow, simultaneous microwave and ohmic combination heater. Journal of Food Engineering, **116:**65–71.

Nott, K. P. & Hall, L. D. **1999**. Advances in temperature validation of foods. Trends in Food Science and Technology, **10:** 366- 374.

Oliveira,M.E. C. & Franca, A.S. **2002**. Microwave heating of foodstuffs. Journal of Food Engineering, **53:** 347-359.

Peng, J., Tang, J., Donglei, L., Frank, L. B., Zhongwei, T. B., Feng, L. B. C., & Wenjia, Z. **2017**. Microwave pasteurization ofpre-packaged carrots. Journal of Food Engineering, **202:** 56- 64.

Pereira, R.N., & Vincente, A.A., **2010**. Environmental impact of novel thermal and non- thermal technologies in food processing. Food Research International, **43:** 1936- 1943.

Ponne, C.T., Baysal, T., &Yuksel, D. **1994**. Blanching leafy vegetables with electromagnetic energy, Journal of Food Science, **59:** 1037-1041.

Puligundla, P., Abdulla, A.S., Choi, W., Jun, S., Sang-Eun, O.H., & ko, S., **2013**. Potentials of microwave heating technology for select food processing applications – a brief overview and update. Journal of Food Process Technology, **4:** 1-9.

Ramesh, M.N., Wolf, W., Tevini, D., &Bognar, A. **2002**. Microwave blanching of vegetables. Journal of Food Science, **67:** 390-398.

Salazer- Gonzaler, C., San Martin- Gonzaler, M.F., Loppez-Malo,A., & Sosa- Morales, M.E. **2012**. Recent studies related to microwave processing of fluid foods. Food Bioprocess and Technology, **5:** 41- 46.

Scanlon, M.G. & Zghal, M.C. **2001**. Bread properties and crumb structure. Food Research International, **34:** 841-864.

Severini, C., Giuliani, R., De Filippis, A., Derossil, A., & De Pilli, T., **2016**. Influence of different blanching methods on color, ascorbic acid and phenolics content of broccoli. Journal of Food Science and Technology, **53:**501–510.

Sevimli, K.M., Sumnu, G.,& Sahin, S. **2005**. Optimization of halogen lamp – microwave baking of cakes: a response surface methodology study. European Food Research Technology, **221:** 61-68.

Shahen, S. M., El- Massry, F.K., El-Ghorab, H. A., & Anjum, M. F. **2012**. Microwave application in thermal food processing. In: The Development and Application of Microwave Heating. Wenbin Cao (Ed), pp: 1-16. INTECH, Science technology and medicine Access Publisher.

Sharma, G.P. & Prasad, S. **2001**. Drying of garlic (Allium sativum) cloves by microwave- hot air combination. Journal Food Engineering, **50:** 99-105.

Shenga, E., Singh, R.P., & Yadav, A. S. **2010**. Effect of pasteurization of shell egg on its quality characteristics under ambient storage. Journal of Food Science and Technology – Mysore, **47:** 420- 425.

Song, X., Zhang, M., Mujumdar, A. S. & Fan, L. **2009**. Drying characteristics and kinetics of vacuum microwave – dried potato slices. Drying Technology, **27:** 969 – 974.

Sukhwant, M. K., Harvindr, K., & Tejinder, G. **1992**. Effect of cooking on fibre content of vegetables. Journal of Food Science and Technology, **29:** 185- 186.

Sumnu, G., **2001**. A review on microwave baking of food. International Journal of Food Science and Technology, **36:** 117-127.

Sumnu, G., Sahin, S.,& Sevimli, M., **2005**. Microwave, infrared and infrared- microwave combination baking of cakes. Journal of Food Engineering, **71:**150-155.

Severini, C., Giuliani, R., De Filippis, A., Derossil, A., & De Pilli, T., **2016**. Influence of different blanching methods on color, ascorbic acid and phenolics content of broccoli. Journal of Food Science and Technology, **53:**501–510.

Szadzińska,,J., Lechtanska,I., Pashminehazar, R. Kharaghani, A. &Tsotsas, E. **2019**. Microwave- and ultrasound-assisted convective drying of raspberries: Drying kinetics and microstructural changes. Drying Technology, **37** : 1-12.

Szadzińska,,J., Mierzwa, D., Pawłowski, A., Musielak, G., Pashminehazar, R. &Kharaghani, A. **2020**. Ultrasound- and microwave-assisted intermittent drying of red beetroot. Drying Technology, **38:** 93-107.

Tewari, G. **2007**. Microwave and radio- frequency heating. In: Advances in Thermal and Non- Thermal Food Preservation. Tewari, G.&Juneja, V. K. (Eds). Blackwell Publishing. pp: 91- 98.

Therdthai, N. &Zhou, W.B. **2003**. Recent advances in the studies of bread baking process and their impact on the bread baking technology. Food Science and Technology Research, **9:** 219- 226.

Vadivambal, R.& Jayas, D.S. **2010**. Non-uniform Temperature Distribution During Microwave Heating of Food Materials: A Review. Food Bioprocess Technology, **3**; 161–171.

Wang, J., Xu-Hai, Y. A. S., Mujumdar, D. W., Jin-Hong, Z., Xiao-Ming, F., Qian, Z., Long, X., Zhen-Jiang, G., & Hong-Wei, X. **2017**. Effects of various blanching methods on weight loss, enzymes inactivation, phytochemical contents, antioxidant capacity, ultrastructure and drying kinetics of red bell pepper (*Capsicum annuum* L.). LWT – Food Science and Technology,**77:** 337–347.

Xiao, H.-W., Pan, Z., Deng, L.Z., El-Mashad, H., Yang, X.H., Mujumdar, A.S., Gao, Z..J.& Zhang, Q. **2017**. Recent developments and trends in thermal blanching-A comprehensive review. Information Processing in Agriculture. **4:**101-127.

Yolacaner, E.T., Summnu, S., & Sahin, S. **2017**. Microwave assisted baking, In: The Microwave Processing of Foods.(Schubert, H. & Regier, M (Eds).Cambridge CRC press. pp 117-141.

Zhang, D. & Hamauzu, Y. **2004**. Phenolics, ascorbic acid, carotenoids and antioxidant activity of broccoli and their changes during conventional and microwave cooking. Food Chemistry, **88:** 503-509.

Zhang, M., Tang, J., Mujumdar, A. S. & Wang, S. **2006**. Trends in microwave-related drying of fruits and vegetables. Trends in Food Science and Technology, **17:** 524-534.

Zia-ur-Rehman, Z., Islam, M.,& Shah, W. H. **2003**. Effect of microwave and conventional cooking on insoluble dietary components of vegetables. Food Chemistry, **80:** 237-240.

Zielinska, M., Markowski, M.&Zielinska, D. **2019**. The effect of freezing on the hot air and microwave vacuum drying kinetics and texture of whole cranberries. Drying Technology, **37:** 1714- 1730

تطبيقات استخدام الميكروويف فى مجال التصنيع الغذائى: نظرة شاملة

تيسير محمود أبوبكر

قسم علوم وتقنية الأغذية – كلية الزراعة – الشاطبى – ٢١٥٤٥ –

جامعة الأسكندرية – الأسكندرية – مصر

انتشر فى السنوات الأخيرة استخدام تطبيقات الميكروويف العديدة فى جميع أنحاء العالم. تطبيقات استخدام الميكروويف فى مجال التصنيع الغذائى كثيرة مثل استخدامه فى العمليات التصنيعية التالية: السلق– الطبخ – التجفيف للمواد الغذائية – تفكيك المواد الغذائية المجمدة – الخبيز – البسترة والتعقيم. تتميز طاقة الميكروويف بعدة صفات أفضل من التسخين بالطرق التقليدية.

تهدف هذه الدراسة المرجعية الى دراسة مختصرة لطاقة الميكروويف وتطبيقات استخدامها فى مجال التصنيع الغذائى. أيضا القاء الضوء على مميزات وعيوب استخدام طاقة الميكروويف على جودة المواد الغذائية ومقارنتها بطرق التسخين التقليدية. كذلك الإشارة الى مميزات استخدام البسترة والتعقيم على درجة حرارة منخفضة فى تثبيط نمو الأحياء الدقيقة. وأيضا استخدام طاقة الميكروويف فى حفظ الأغذية بالتجفيف ومدى استخدامها كمرحلة مكملة فى الحفظ بالتجفيف بواسطة الهواء الساخن والتجفيف تحت تفريغ وايضا الحفظ بالتجفيد مع المقارنة بالطرق التقليدية.

Alex. J. Fd. Sci. & Technol. *Vol. 17, No. 2, pp. 23-28, 2020*

Milling Damaged Starch (MDS) in wheat flour: Formation, Structure, Functionality and its Effects on Baking Quality: An Article

Abo-Dief , M. F.

Arabian Milling and Food Industries Company, Bourge El Arab, Alexandria, Egypt.

Received: 13 December, 2020 ***Revised: 26 December, 2020*** ***Accepted: 30 December, 2020***

ABSTRACT

In this article, the Milling Damaged Starch (MDS) in discussed in terms of formation, structure, functionality and its effects on the quality of baking products. The MDS is different from native starch regarding granular structure, crystalinity and molecular degradation. Such a diversity is responsible for the different functionality of MDS. So ,gelatinization ,pasting properties , in vitro enzymatic digestibility of wheat flour containing high level of MDS vary considerably as compared with their counter parts properties in wheat flour containing low MDS. This article discusses all the aforementioned information.

Keywords: Damaged starch, structure, gelatinization, functionality, baking quality.

INTRODUCTION

Due to forces (friction, shear, collision and impingement) applied on wheat kernels during milling , breaking of starch granules occurs , resulting in formation of Milling Damaged Starch (Suki *et al*., 2016, Zhang *et al*., 2019).

The MDS level in wheat flour affects considerably the baking quality of bread. Such an effect can be attributed to the elevation of both water absorption capacity (WAC) and rate of enzymatic hydrolysis in MDS as compared to the native starch. In other words, moderate MDS level could be improve dough quality, on contrary to high MDS level which leads to starch dough as found by Barrera *et al*., (2013) and Wang *et al*., (2017)

Recently, numerous researches have targeted at uncovering the diversity in structure, physicochemical and functionality of MDS (Hackenberg *et al* 2016, Ooms *et al*, 2018). Meanwhile, Wang & Zheng (2020) published an extensive review on MDS in terms of generation, measurement, functionality along with its effect on starch–based food systems. The present article summarizes the effect of milling conditions on MDS and thereby its effect on the quality of baking products.

Factors affecting formation of MDS

Quality of wheat kernels, flour coarseness and milling conditions are the main three factors affecting formation of MDS. Harder wheat grains possess higher MDS than the soft ones. This can be attributed to the requirement of stronger milling force to destroy the tightly structure of starch grains belonging to harder grains. Consequently, the damaged severity increases (Makowska *et al*., 2014, Abo-Dief, 2020).

Wheat flour contains starch in a range of 78-82%. The level of MDS depends on hardness of the kernel as well as grinding severity as reported by Scanlon *et al*., (1988).Obviously, more grinding energy is required for hard grains to mill endosperm into flour (Posner & Hibbs, 2005, Abo-Dief *et al* ., 2019)

It is noteworthy that MDS content affects the quality of flour. Wet gluten along with MDS play a pivotal role in determining dough and thereby bread quality. According to Wang & Zheng (2020), higher level of MDS and lowest gluten content (by hard milling) causes a dilution of gluten network and consequently reduces its ability to holding more water. The wide variation in the amount of MDS in wheat flour can be attributed to the tempering conditions and process of reduction during milling. Notwithstanding, it was reported that the flour physical properties including colour, particle size and MDS are influenced by each of the following factors: wheat quality, milling system (Barak *et al*., 2014, Rahil *et al*., 2015, Sakhare *et al*., 2015).

Leon *et al* (2006) found that Properties of bread during storage is controlled by higher level of MDS. This effect is a result of lowering starch-gelatinization enthalpy (ΔH) and higher melting enthalpy of amylase-lipid complex.

Compared to dry milling, wet milling could better ensure starch granular integrity as a result of absorption the heat generated through milling. Such an effect is due to the excessive water addition. Accordingly, hindering the temperature elevation and decline MDS (Ahmad & Rajab, 2018).

Abo Dief (2020) found that prolonging the period of tempering to 36 hr at 12C° resulted in a decline in the level of MDS for Australian and Russian wheat. This can be attributed to the lower tempering temperature which lower water penetration within the wheat grain and thereby required longer time until the endosperm becomes moist. So, the starch granules become more resistant to pressure and shear forces applied by milling rollers as a result of extending tempering period to 36 hr.

Structure of MDS

Granules of MDS are rough, distored and deformed. The greater MDS level is, the rougher and more irregular and distroed starch granule is (Barrera *et al*., 2013, Sakhare & Inamdar, 2014, Wu *et al*., 2018).

Scanning electron microscopic (SEM) examination was used by Abo-Dief (2020) to illustrate the effect of tempering conditions (tempering and time) along with milling systems on the appearance and size of starch granules. The photographs showed that the hard milling gave more damaged starch, cracked flatted or less rouned for the flour of the two cultivars (Australian and Russian) than that of normal milling (Figure 1 and 2). Also, the tempering at 12C° had generally some effects for different tempering times being less pronounced on the appearance of starch granules. Such n effect can be explained on the basis that the amorphous amylose, like a flexible mechanical plasticizer, could absorb excessive shock and cushion the destruction of amylopectin crystalinity via external forces in starch granules, and thereby alleviating the particle size reduction (Liu *et al*., 2018).

Functionality of MDS

Generally, a decreasing of tendency in both gelatinization temperature and enthalpy (ΔH) could be traced as a results of high MDS level (Shi *et al*., 2016). This phenomenon can be attributed to the increased disorder in crystalinity structure of starch, which in turn reduces the energy required for gelatinization. Obviously, moisture content plays a pivotal role in gelatinization of MDS (Liu *et al*., 2018).The MDS often has lower viscosity, which results in fragile surface of broken MDS when they get swollen during gelatinization (Tan *et al*., 2015)

Regarding water hydration property of MDS, the higher the milling severity is m, the greater the MDS solubility is (Dhital *et al*., 2010 & Liu *et al*., 2017). The point of interest is that the MDS has augmented rate of *in vitro* digestibility, on contrary to native starch. It was reported that higher MDS could be result in greater digestibility percentage.

Effect of MDS on baking quality

The MDS plays a key role in determining the quality of baking products. For instance, texture of these products is influenced by MDS (Liu *et al*., 2019)

Bread produced from flour has high MDS level gives loves of low specific volume (Hackenberg *et al*., 2016). Due to the high water capacity of MDS, enzymatic hydrolysis is reported in addition to lowering the formation of fermentable sugar and consequently dimishing the amount of gas generated during fermentation (Hackenberg *et al*., 2016). In other words, MDS may cause disruption of gluten network. Such an effect lead to poor ability of dough to hold gas. Moreover, it was found that MDS has effect on colour of the baked products and accordingly affects the appeal of consumers (Vouris *et al*., 2018).

Use of wheat flour containing high MDS was found to diminish the diameter of cookies. This can be explained based on the MDS which leads to stiff dough (Barak *et al*., 2014, Mancebo, *et al*., 2015)

In a conclusion, MDS plays a pivotal role in determining quality of wheat flour and subsequently the baking products made from it (Abo-Dief, 2020, Wang & Zheng, 2020).

REFERENCES

Abo-Dief, M., Abo-Bakr, T., Youssef, M., & Moustafa, A. **2019**. Quality of wheat flour and pan bread as influenced by the tempering time and milling system. Cereal Chemistry, **96**:429–438.

Abo-Dief, M.F. **2020**. Modification of some technological conditions of wheat milling process to improve the quality and the functionality of flour. Phd. Thesis, University of Alexandria.

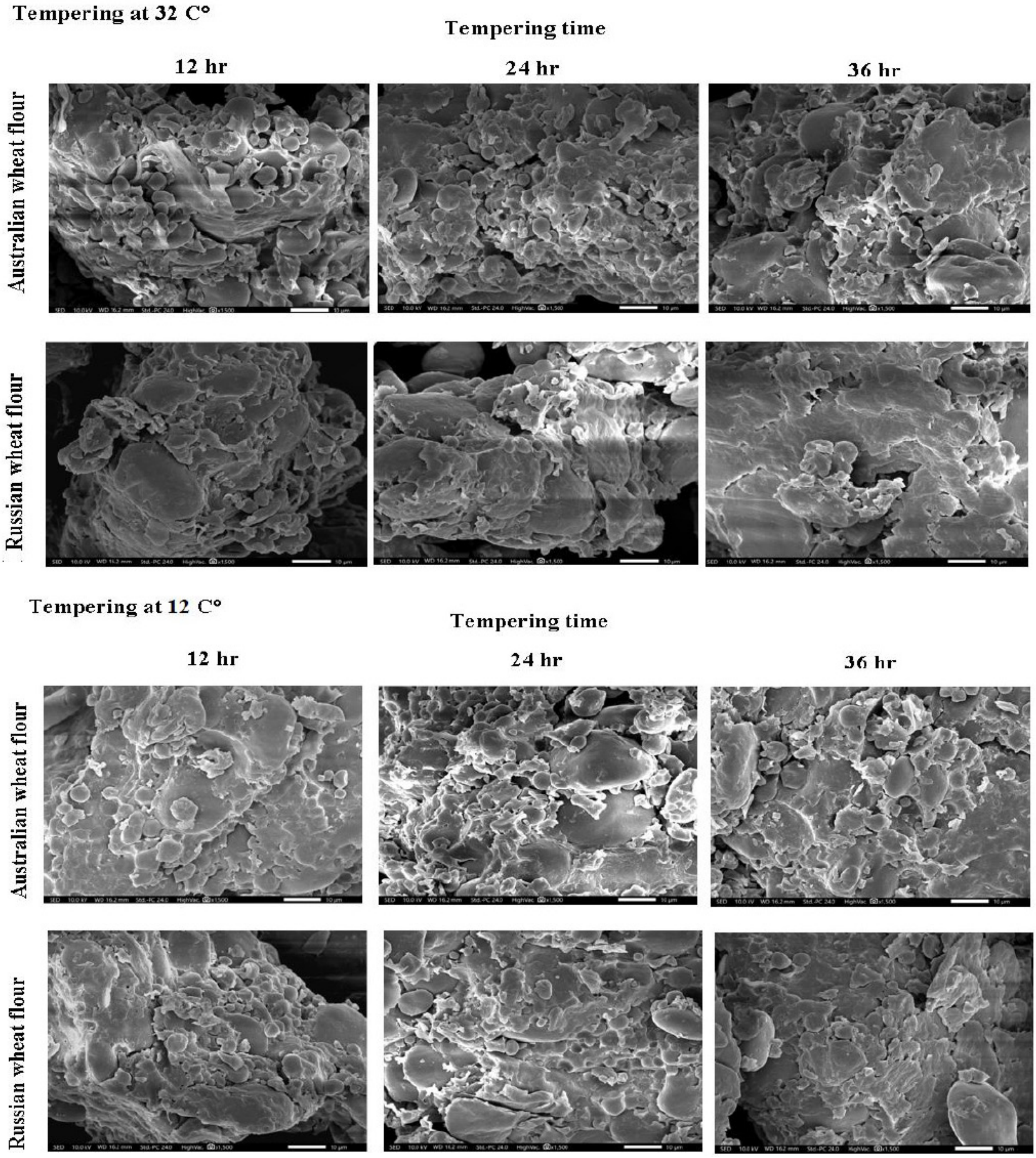

Fig. 1: Effect of tempering conditions and hard milling system on starch appearance for Australian and Russian wheat flour

References: Abo-Dief (2020)

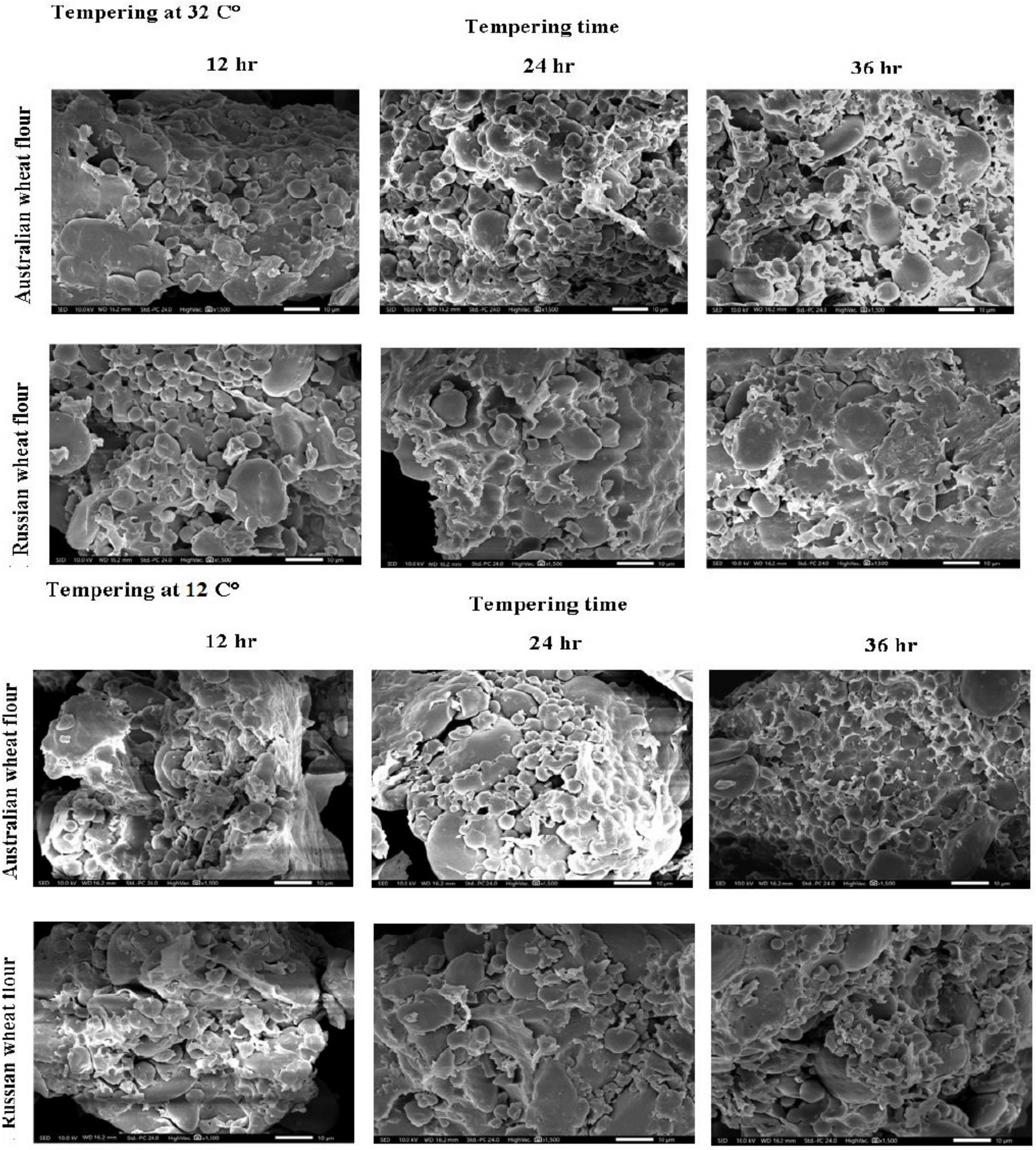

Fig. 2: Effect of tempering conditions and normal milling system on starch appearance for Australian and Russian wheat flour

References: Abo-Dief (2020)

Ahmad, N., & Rajab, A. **2018**. Textural and cooking qualities of dry Laksa noodle made from semi-wet and wet MR253 flours. Cereal Chemistry, **95**: 872–880.

Barak,S.,Mudgil,D.& Khatkar,B,S. **2014**. Effect of flour particle size and damaged starch on the quality of cookies. Journal of Food Science and Technology, **51:** 1342–1348.

Barrera, G. N., Bustos, M. C., Iturriaga, L., Flores, S. K., León, A. E., & Ribotta, P. D. **2013**. Effect of damaged starch on the rheological properties of wheat starch suspensions. Journal of Food Engineering, **116:** 233–239.

Dhital, S., Shrestha, A. K., & Gidley, M. J. **2010**. Effect of cryo-milling on starches: Functionality and digestibility. Food Hydrocolloids, **24:** 152–163.

Hackenberg, S., Verheyen, C., Jekle, M., & Becker, T. **2016**. Effect of mechanically modified wheat flour on dough fermentation properties and bread quality. European Food Research and Technology, **243**: 287–296.

Leon,A.E.,Barrera,G. N., Perez, G. T., Ribotta, P. D., & Rosell, C, M. **2006**. Effect of damaged starch levels on flour thermal behaviour and bread staling. European Food Research and Technology*,* **224:**187–192.

Liu, C., Hong, J., & Zheng, X. **2017**. Effect of heat-moisture treatment on morphological, structural and functional characteristics of ball milled wheat starches. Starch – Stärke, **69:** 1-9.

Liu, R., Sun, W., Zhang, Y., Huang, Z., Hu, H., Zhao, M., & Li, W. **2019**. Development of a novel model dough based on mechanically activated cassava starch and gluten protein: Application in bread. Food Chemistry, **300**: 196-201.

Liu, X., Li, E., Jiang, Y., & Tian, Y. **2018**. Milling Process of Starch. 155-174.

Makowska, A., Szwengiel, A., Kubiak, P., & Tomaszewska-Gras, J. **2014**. Characteristics and structure of starch isolated from triticale. Starch – Stärke, **66:** 895–902.

Mancebo, C. M., Picón, J., & Gómez, M. **2015**. Effect of flour properties on the quality characteristics of gluten free sugar-snap cookies. LWT – Food Science and Technology, **64**: 264–269.

Ooms, N., Vandromme, E., Brijs, K. & Delcour, J.A. **2018**. Intact and damaged wheat starch and amylase functionality during multilayered fermented pastry making. Journal of Food Science, **83**: 2489–2499.

Posner, E. S.,& Hibbs, A. N. **2005**. Wheat flour milling (2nd ed.). St. Paul, MN: AACC International, USA.

Rahil, A., Ali, R., Khan, M. S., Moin, M., & Kazmi, S. I. **2015**. Comparative study on the physicochemical and rheological parameters of soft wheat flour obtained from three countries. American Journal of Food Science and Nutrition Research*,* **2:** 89–93.

Sakhare, S. D., Inamdar, A. A., Gaikwad, S. B., D, I., & G, V. R. **2014**. Roller milling fractionation of green gram (Vigna radiata): optimization of milling conditions and chemical characterization of millstreams. Journal of Food Science and Technology, **51:** 3854-3861.

Sakhare,S.D.,Inamdar,A.A.,Indrani,D.,Kiran,M,H ,M.,& Rao,G.V. **2015**. Physicochemical and microstructure analysis of flour mill streams and milled products. Journal of Food Science and Technology*,* **52**,407–414.

Scanlon, M.G., Dexter, J. E., & Biliaderis,C.G.**1988**. Particle size related physical properties of flour produced by smooth roll reduction of hard red spring wheat farina. Cereal Chemistry*,* **65:** 486–492.

Shi, L., Li, W., Sun, J., Qiu, Y., Wei, X., Luan, G., Tatsumi, E. **2016**. Grinding of maize: The effects of fine grinding on compositional, functional and physicochemical properties of maize flour. Journal of Cereal Science, **68:** 25–30.

Suki, F. M. M., Azura, A. R., & Azahari, B. **2016**. Effect of ball milled and ultrasonic sago starch dispersion on sago starch filled natural rubber latex (SSNRL) films. Procedia Chemistry, **19**: 782–787.

Tan, X., Zhang, B., Chen, L., Li, X., Li, L., & Xie, F. **2015**. Effect of planetary ball-milling on multi-scale structures and pasting properties of waxy and high-amylose cornstarches. Innovative Food Science & Emerging Technologies, **30:** 198–207.

Vouris, D. G., Lazaridou, A., Mandala, I. G., & Biliaderis, C. G. **2018**. Wheat bread quality attributes using jet milling flour fractions. LWT – Food Science and Technology, **92:** 540–547.

Wang, S., Yu, J., Xin, Q., Wang, S., & Copeland, L. **2017**. Effects of starch damage and yeast fermentation on acrylamide formation in bread. Food Control, **73**: 230–236.

Wang,Q., Li, L. & Zheng,X.**2020**.A review of milling damaged starch: Generation, measurement, functionality and its effect on starch-based food systems. Food Chemistry, **315**:1-12.

Wu, F., Li, J., Yang, N., Chen, Y., Jin, Y., & Xu, X. **2018**. The roles of starch structures in the pasting properties of wheat starch with different degrees of damage. Starch – Stärke, **70:** 1-11.

Zhang, K., Dai, Y., Hou, H., Li, X., Dong, H., Wang, W., & Zhang, H. **2019**. Influences of grinding on structures and properties of mung bean starch and quality of acetylated starch. Food Chemistry, **294**:285–292.

نشا الطحن المحطم فى دقيق القمح: التكوين، التركيب، الوظيفة والتأثير على جودة الخبيز : مقال

محمد فتحي أبوضيف

الشركة العربية للمطاحن والصناعات الغذائية – برج العرب

الإسكندرية - جمهورية مصر العربية

فى هذا المقال تم مناقشة نشا الطحن المحطم وذلك من منظور التكوين، التركيب، الوظيفة بالإضافة إلى تأثيراته على جودة منتجات الخبيز. يتباين نشا الطحن المحطم عن نظيره العادى (السليم أو غير المحطم) من حيث البناء الحبيبى، البللورية و التكسير الجزيئي. وتعتبر هذه الاختلافات مسئولة عن الصفات الوظيفية المختلفة لنشا الطحن المحطم .بناء على ما تقدم فإن عملية الجلتنة، صفات العجينة، الهضم الإنزيمي تحت ظروف المعمل تتباين بشكل واضح فى حالة دقيق القمح الذى يحتوى على نسبة عالية من نشا الطحن المحطم وذلك مقارنة بنظيره المحتوى على نسبة أقل من هذا النشا. يناقش هذا المقال كل المعلومات المذكورة أيضا.