EFFECT OF DEHYDRATION BY MICROWAVE ON THE FUNCTIONAL PROPERTIES OF THE CULTIVATED APPLE IN ALGERIA

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Abstract
Slices to 8 mm of apple variety Golden delicious yellow color cultivated in Batna,Algeria, were dried by microwave at different powers (100, 180, 300, 450, 600 and 900W).The apple drying kinetics describes regularly decreasing curves, the shortest drying time was recorded for the 900 W (600 sec). The functional properties which have been determined showed that the retention of water is important and clearly superior to that of the oil.Excellent dried apple solubility for all powers (greater than 80%).were determined for the emulsifying capacity and stability which exceeds 60%, who's the best emulsification capacity was observed for the apple dried at 180W (69.67 ± 3.51%).The foaming property is important for concentrations 16 and 20% are excellent it reaches 100%. For the color of the dried apple, the brightness L is inversely proportional with the increasing of power (From 100 W (44.07 ± 3.20) to 900 W (29.66 ± 4.06), the apple dried at 100 and 180W has a yellow color (respectively b * 24.60 ± 1.29 and 24.30 ± 2.38).*

Keywords: Microwave drying, Apples, *Golden delicious*, functional properties, color, drying kinetics

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1. INTRODUCTION

The apple is the fruit of the common apple-tree, *Malus domestica*, of the Rosaceae family (Subfamily of the Pomoides) (Hellier et *al.*, 2000). From a botanical point of view, apple is a berry that is to say, fleshy fruit without core. Apple is now one of the most cultivated fruit in the world especiially in temperate zones with a total production of 52 million tonnes in 2001 According to FAO numbers (Mehinagic, 2004).

The cultivation of apple trees in Algeria is mainly located in Medea, Batna, Tiart, Blida and Khenchela. The Algerian apple production amounted to 181 000 tons (FAO, 2009),including Golden delicious which is the most cultivated variety in Algeria and even in Batna.

Due to the seasonality of production, fruit preservation over long periods requires the implementation of specific treatments for inactivation of tissue enzymes and microorganisms and protect against further contamination (Colas, 2003).

According to Bimbenet and Bonazzi(2003), the drying process is one of the oldest methods of preserving food and agricultural products. It can convert perishable food products stabilized by lowering the water activity (a_w) to a value less than 0.5. Most often, these products are stored at room temperature, before being used in an industrial process or in a food preparation.The functional properties occupy a very important place in the food world. The functional properties of proteins and polysaccharides are often very well characterized. The functional properties are the physical properties or physicochemical which affect their sensory behavior of these in food systems during technological, food preparation, storage and processing (Linden and Lorient, 1994)

Deferent functionality can be broken down on the basis of molecular interaction (interaction between components and between components and water) in solution or interfaces these interactions are dependent on the molecular or supra-molecular structures in cases of protein and polysaccharide macromolecules and the ionic environment (pH, ionic strength, type of ions) (Romain et *al.*, 2004).

In order to prevent quality damage due to long drying time, microwave drying has-been introduced. Microwave heating is a sort of dielectric heating,which uses electromagnetic

radiation in the frequency ranging from 300 MHz to 300 GHz. According to Changrue (2006), the decrement of drying time due to volumetric heating of dielectric material Increases the use of the microwave as a source of thermal energy.
Although studies have focused on the drying kinetics of *Golden délicious* couleur jaune., the lack of published work on the effect of microwave drying at levels power on funcional properties including solubility, emulsifying, retention of water and oil, gelation and foaming properties of apples explains the interest for the present work.

2. MATERIALS AND METHODS

2.1. Preparation of fruit and Calculates dry matter

The fruit of apple *Malus domestica* studied in this work is part of the *Golden delicious* variety of yellow color, it is grown in the wilaya of Batna from Algeria. The fruit was harvested in of October.
After washing the apples were cuted into slices to 8 mm (cross sectional) using a stainless steel knife.
The dry matter (DM) and humidity (H) of the apple are calculated by baking a well determined weight to 103 ± 2 ° C until a constant weight (Audigie et *al*., 1984). Dehydration is carried out in an oven (Model: Memmert DO 6836, Germany) and the results are calculated using the following equation.

$$H\% = \frac{W_1 - W_2}{W_1} \times 100$$

$$DM\% = 100 - H\%$$

W_1 : weight of sample before tempering(g)
W_2: weight of sample after tempering(g)

2.2. Microwave drying kinetics

Apple drying is carried out in a microwave (Model: Samsung oven (GE107Y, SAMSUNG Electronics) with technical features characteristics of 230 V, 50 Hz with a frequency of 2,450 MHz. The dimension of the microwave cavity was 335 mm × 330 mm × 195 mm. Drying is carried out per cycle (30 sec on / 30 sec OFF) at different powers(100, 180, 300, 450, 600 and 900 respectively), the samples were weighed after each cycle, drying is stopped when the apple water content reaches 6%. The drying curve represents the variation of the water content (X) versus time (t); this curve is obtained experimentally by following the evolution of the wet basis moisture content of the product (mh) during drying by successive equidistant weighed until the weight corresponding to the set residual moisture (6%) . By the equation below it can be determined the variation of the dry base moisture content (X) versus time (Sec).

$$X = \frac{Ww - Wd}{Wd}$$

X : Moisture content on a dry basis (kg H_2O/ kg dry matter)
Ww: weight of the sample in a wet basis (g)
Wd:weight of dry matter of the sample (g)
Given the heterogeneity of the microwave heating we realized the average of ten repetitions for each power.

2.3. Functional properties analyses

2.3.1. Water and oil absorption capacity

Measurements of water and oil retention capacity are performed according to the method of Phillips et *al*. (1988). 1g of the dried apple is mixed (m0) in 10 ml of water or oil and the whole was mechanically stirred for 30 min using a stirrer. The mixture was then centrifuged at 4500 rpm / min for 30 min in a centrifuge (Model: SIGMA 3K20). The pellet after centrifugation is weighed (m1), but for measuring the water retention capacity, it is first dried at 105° C in an oven for 8 h (m2). The water retention capacity (CRE) and oil retention capacity (CRH) is calculated by the following formulas:

$$CRE\ (\%) = \frac{m2 - m1}{m1} \times 100$$

$$CRH\ (\%) = \frac{m1 - m0}{m0} \times 100$$

2.3.2. Solubility properties

0.1 g of the dried apples were placed into a centrifuge tube (known weight) then dissolved with 10ml of1 %acetic acid for 30min, using an incubator shaker operating at 240rpm and 25°C. The solution was then immersed in a boiling water bath for 10minutes, cooled to room temperature (25°C) and centrifuged at 10.000rpm for 10min. The supernatant was decanted. The undissolved particles were washed in distilled water (25ml) then centrifuged at 10.000 rpm. The supernatant was removed and undissolved pellets dried at 60°C for 24hr. Finally, weighed the particles and determined the percentage solubility (Fernandez-Kim, 2004). Calculation:

$$\text{solubility}\ (\%) = \frac{\text{iw} - \text{fw}}{\text{iw}} \times 100$$

iw: Initial weight of sample(g)
fw: Final weight of sample (g)

2.3.3. Emulsifying properties

Emulsifying activity and stability were determined using the method of Neto, Narain, Silvia and Bora (2001). Five millilitres portion of dried apple dispersion in water (10mg·ml^{-1}) was homogenized with 5 ml oil for 1 min. The emulsions were centrifuged at 1100*g* for 5 min. The height of emulsified layer and that of the total contents in the tube was measured. The emulsifying activity was calculated as:

$$\text{Emulsifying property}(\%) = \frac{\text{h1}}{\text{h2}} \times 100$$

h1: height of emulsified layer in the tub (ml)
h2: height of the totale content in the tube(mL)

Emulsion stability was determined by heating the emulsion at 8°C for 30 min before centrifuging at 1100g for 5 min. Height of emulsified layer after heating. Calculation:

$$\text{Emulsifying stability}\ (\%) = \frac{\text{h1}}{\text{h2}}$$

h1: height of emulsified layer heating (mL)
h2:
height of emulsified layer before heating (mL)

2.3.4. Foaming properties

The method of Coffman and Garcia (1977) is used for the determination of the foaming capacity and stability of dried apple. A weighed amount of flour is dispersed in 100 ml distilled water, after which the suspension was whipped vigorously for 2 min using a Phillips kitchen blender set at speed 2. Volumes were recorded before and after whipping. The percentage volume increase was calculated according to the following equation:

$$\mathit{Volume\ increase}\ (\%) = \frac{v_2 - v_1}{v_1} \times 100$$

v_1: volume of apple solution after whipping (mL)
v_2: volume of apple solution (mL)

2.3.5. Gelation properties

Gelation properties were studied by employing the method of Coffman and Garcia (1977). Sample suspensions of 2–20% were prepared in distilled water. Ten millilitres of each of the prepared dispersions was transferred into a test tube. The test tubes were heated in a boiling water bath for 1 h, after which they were cooled in a bath of cold water. The test tubes were further cooled at 4°C for 2 hr. The least gelation concentration was taken as the concentration when the sample from inverted test tube did not fall or slip.

$$\text{Gelation properties} = \frac{\text{h1}}{\text{h2}} \times 100$$

h1 : height of gélation layer in the tube (mL)
h2 : height of the totale content in the tube (mL)

2.4. pH

1 g of the dried apple is homogenized in 3 ml of distilled water. The pH of the solution obtained was determined using a pH-meter (Model: HANNA HI 2210).

2.5. Color Measurement

The color of dried apples slices was determined using a Color reader, Minolta CR10 (Minolta Camera, Japan) referring to color space CIE L*a*b*.

2.6. Statistical analysis

The experimental data were expressed as means ± standard deviations. All determinations were carried out in five replicates. A statistical analysis of the results was performed using the 2009 XLStat software. An equal average hypothesis was tested by analysis of variance (ANOVA). The medium was significantly different when compared with the method of Newman-Keuls ($p \leq 0.05$).

3. RESULTS AND DISCUSSION

3.1. Water content

Thetenure water and dry matter found for the studied apples were 84.87 ± 0.89% and 15.08 ± 0.80%respectively. These results are consistent with the values given by Aprifel (2008) with 84.3% water and 15.7% dry matter for the same variety studied. This high water content results in a high water activity and therefore the installation of biochemical and microbiological chemical alterations. This requires experts food technology field to inhibit or remove water from perishable foods by applying the proper conservation techniques that best retain these properties.

3.2. Drying Kinetics

The variation of the water content (X) versus time (Sec) for six powers of the microwave oven is shown in Figure 1.

Overall we see regularly decreasing curves (Figure 1), this is due to the high evaporation of water free of all samples.

At the beginning, the water content is important, which results in an acceleration of evaporation of water under the heating of the samples by the microwave rays.

Trade is less and less important as drying takes place because the amount of water remaining in the product is low and difficult to remove.

The drying time is reduced with increasing power and energy delivered by microwave. The power of 900 W showed the shortest time (600 Sec).

3.3. Water and oil absorption capacity

Table 1 presents the water absorption capacity and oil absorption capacity (in %) of apple dried by microwave at different powers (100, 180, 300, 450, 600 and 900 W respectively).

For the water absorption capacity, overall the results found described two phases: the first increases from 100W to 450W respectively (50 ±2.64, 107.33±2.51 167±2.64 and 222.33±2.51%) and a second decreasing phase from 450W to 900W respectively (222.33±2.51, 168±3.00 and 55.3±3.32%).The moderate power 450W matched the best ability to absorb water.

From Table 1 it is noticed that the oil absorption capacity is inversely proportional to the water absorption capacity.

The capacity of the water and oil retention depend by the structure of protein and polysaccharide nature of macromolecules; interactions between water and the components are established at the level of acid groups and amine group present in the polysaccharide or in uncharged polar group capable of forming hydrogen bonds with water while the non-polar groups in character hydrophobic may contributed to structure the water found in their environment. According to Cloutour (1995), heat treatment such as drying by microwave is capable of modifying the content of polysaccharide and protein, and consequently the water and oil capacity respectively.

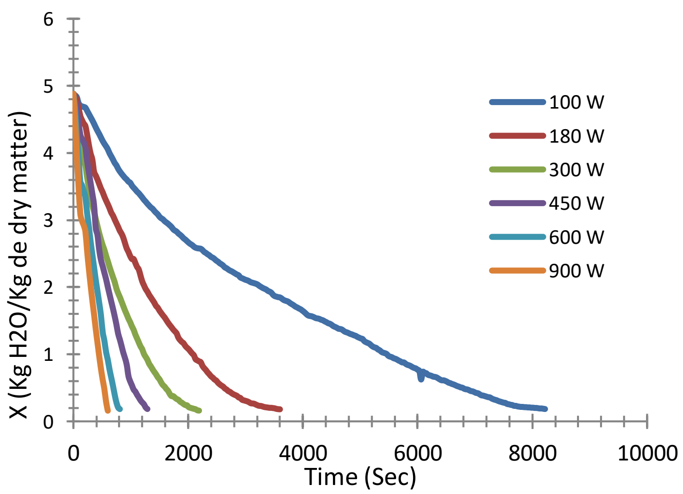

Fig. 1: Variation in moisturecontent X (kg H_2O / kg dry matter) versus time (sec) of dried apples in microwave oven at different power

It is noted that the capacity of the water retention is much higher than that of the oil. This is explained by the abundance of hydrophilic groups to hydrophobic groups by contribution, the apple is rich in polysaccharides (12.6 to 15, 3%) and low in lipid (0.3%) (Colin-Henrion, 2008).

3.4. Solubility property

From Table 2 water-solubility of apples dried by microwave at different wattages is excellent with no significant difference (≥ 90%). the solubility of the macromolecules is influenced by several parameters (pH, ionic strength, drying, concentration, temperature). Generally, the components of the apple as pectin and sugars are water soluble, while proteins and lipids are readily soluble in dilute acid solutions below pH 6 (pH 4), which explains the use of acetic acid in this technique (an acetic acid solution of 1% is equivalent to pH 4).
Linden and Lorient (1994) shows that the property of solubility has major consequences on other functional properties (Emulsification, gelling). On the other hand, depending on the results obtained, the microwave drying does not have a negative effect; on the other hand it retains this property. Hence the other properties will be more or less conserved.

3.5. Emulsifying properties

Table 3 shows the emulsifying capacity and the stability of emulsions apple dried at different powers. Good capacity is observed for all samples (over 60%). Precisely the best capacity is given for the power 180W (69.67±3.51%), whereas for the powers 300, 100, 450W there are no significant differences respectively (64±4.58%, 63%±2.64 and 65,67±0.57%). And finally powers 600 and 900W with emulsifying capacity respectively (60±3.46 and 61.67±3.51%) are tired last.
Firstly these results show that the applied power has an effect on this property, a moderate assay power (180W) is sufficient to have a good emulsion. On the other hand drying by microwave does not have a dramatic effect negative vis-à-vis the emulsifying capacity
The emulsifying properties are due to the reduction of inter-facial trying among the hydrophilic groups are hydrophobic groups, they are often linked to the protein solubility in water (Roudot, 2002; Chandi and Sogi, 2006).
According to Table 3 excellent emulsion stability can be seen (> 80%) for all dried apples by microwave at different powers. nevertheless dried apples at 100, 180, 300 and 450 W respectively (92.33±1.51, 92.33±0.57, 93.33±0.57 and 93.67±0.57%) has a significantly higher emulsion stability contribution to dried apple at600 and 900 W (respectively 81.67±2.88 and 86.33±3.51%).

3.6. Foaming properties

The results in Table 4 show that the foaming power is zero for all the dried apples by microwave at different powers. According to Lorient et *al*. (1988) the formation of foams is based on the presence of protein quantity and quality, thereby apple protein (0.3%) (Kaushal and Sharma, 1995) is not sufficient to form a foam.

3.7. Gelation properties

Table 5 shows the gel forming ability of the apple dried by microwave at different powers (100, 180, 300, 450, 600 and 900 W), this property is studied as a function of dried apples concentration which ranges from 2 to 20 %.
Overall, in point to all powers a proportional increase in the gelation capacity with increasing concentration, by this, that the concentration expresses the percentage of gelling agents (Proteins, polysaccharides: specifically fibers and pectin).
According Marléne and Vierling (2001), a gel is a colloid system in which the macromolecules (proteins and polysaccharides) are organized locally in networks to fixed structure surrounded by water, more or less stable because the interactions of macromolecules - water and

water -macromolecules evolve towards greater organization.
According to Table 5 for the gelation capacity of dried apples at 100, 180, 300 and 450 W and for concentrations 16 and 20% are excellent, it reaches 100%, the results are explained by the richness of apples in polysaccharide 12.6 to 15.3 while apple Macs contains 15 to 20% pectin (Lorient et *al*., 1988) they are considered as an industrial source of pectin (Doublier and Thibault 1984). Lorient et al. (1988) show that the presence of polysaccharides completely modifies the rheological properties of large quantities of water, bringing the desired changes in the texture of the food, this is conditioned by the nature of the polysaccharide and the conditions of implementation (pH, temperature....). Note that Apple studied in this work is not purchased; for apple keeps all of its compounds.
The effect of drying by microwave is confirmed by the significant differences observed in Table 5, for the powers 100, 180, 300, 450W and for concentrations 16 and 20% gel forming ability being not affected by drying microwave, while it is less important for the powers 600 and 900W respectively (76.18±0.00% and 50±0.00%).

3.8. pH

Table 6 present the pH of apples dried by microwave at different powers (100, 180, 300, 450, 600 and 900 W).
Generally the pH is recorded as acid at about 4, This is explained by the presence of free organic acids in the apple (0.2 to 0.6%) such as citric acid and malic acid (Kaush and Sharma, 1995).
These results are consistent with the values given by Espiard (2002) which show that the apple pH is 4 to 5
As shown in the introduction, this parameter affects the functional properties, which explains the purpose of his determination.

3.9. Color

The apple dried by microwave at 900 W appear darker compared to apple dried using other powers (100, 180, 300, 450 and 600 W). This visual observation was confirmed by the results of instrumental measurement of color (Table 7, Figure 2). Namely, apple dryied at 900 W obtained the lowest value of parameter *L** amounting to 29.66±4.06. The change of color could be because of enzymatic browning and caramelization effect or due to the protein and sugar denaturation (Krokida et *al*., 1999) occurring to microwave heating, which gives rise to high temperature within the dried material. On the other hand, the brightest samples were obtained at 100(L*44.07±3.20) and 180 W (L*45.08±1.29) powers, which indicate that low power drying provides brighter color dried product. Apple has high amount of reducing sugars. It contains 5.36 g fructose, 1.61 g glucose, 1.39 g sucrose, and 2.04 g sorbital per 100 g of fresh weight (Fourie et *al*., 1991) and 11 to 17 mg of vitamin C per 100 g of fresh weight (Samotus, 1988).With these amounts of reducing sugars, Maillard reaction and oxidation of ascorbic acids took place when the apples had been exposed to high powers (600 et 900 W).
According to Table 7 apple dried at powers by 100, 180 and 300W respectively retains the yellow color of apple (*b**20.22±3.20, 24.60±1.29and 24.30±2.38respectively). The power of 450, 600 and 900 W could produce dehydrated apple with attractive appearance such as golden yellow (*b**28.86±0.7) and golden light brown colors which were confirmed by relatively high *b** values amounting to 34.32±3.33 and 37.48±4.06, respectively.

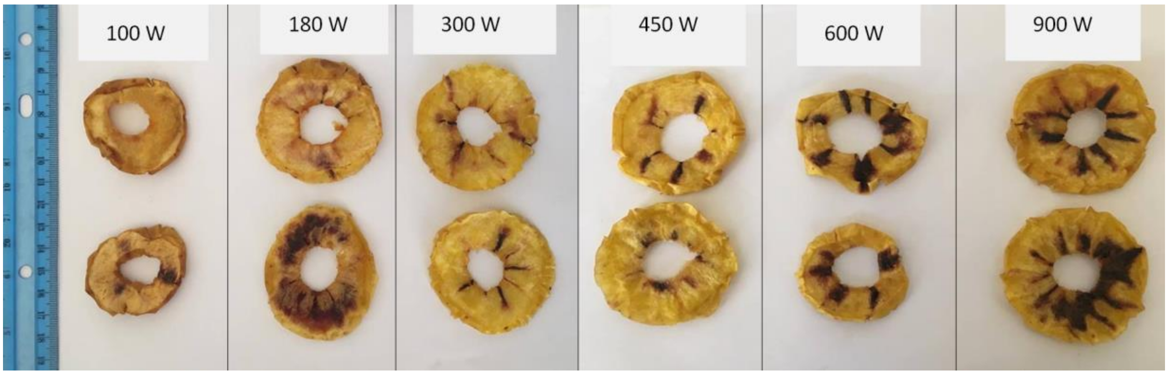

Fig. 2 : Dried apple slices in microwave at different power

Table 1.Water and oil absorption capacity (%) of dried apple in microwave at different power

Power (W)	Water absorption capacity (%)	Oil absorption capacity (%)
100	50±2.64[e]	23.67±1.52[d]
180	107.33±2.51[c]	33.33±4.16[b]
300	167±2.64[b]	29.33±3.05[c]
450	222.33±2.51[a]	35.33±4.05[b]
600	168±3.00[b]	36.33±4.16[b]
900	55.33±3.05[d]	49.33±4.72[a]

The means followed by a different letter are significantly different at the threshold of $p<5\%$

Table2.Solubilitycapacity(%) of dried apple in microwave at different power

Power (W)	Solubility capacity (%)
100	90±0.00[a]
180	91.50±0.61[a]
300	91.67±0.58[a]
450	93.83±0.06[a]
600	93.33±0.58[a]
900	91.67±0.58[a]

The means followed by a different letter are significantly different at the threshold of $p<5\%$

Table 3. Emulsifyingactivityand stability (%) of dried apple in microwave at different power

Power (W)	Emulsifyingactivity(%)	Emulsifyingstability(%)
100	64±4.58 [ab]	92.33±1.51[a]
180	69.67±3.51 [a]	92.33±0.57[a]
300	63±2.64 [ab]	93.33±0.57[a]
450	65.67±0.57 [ab]	93.67±0.57 [a]
600	60±3.46 [b]	81.67±2.88 [c]
900	61.67±3.51 [b]	86.33±3.51 [b]

The means followed by a different letter are significantly different at the threshold of $p<5\%$

Table 4.Foaming capacity (%)of dried apple in microwave at different power

Power (W)	Foaming capacity (%)
100	00
180	00
300	00
450	00
600	00
900	00

Table 5.Gelation properties (%) of dried apple in microwave at different power

Power (W)	Gelation Capacity					
	Concentrations (%)					
	2	4	8	12	16	20
900	20±1 [fg]	23.63±0,01[f]	40±1[d]	46.36±0.00 [c]	46.54±0.00[d]	50±0.00[d]
600	16.36±0.01[g]	55.45±0.01[d]	43.63±0.00[d]	74.54±0.00[c]	75.18±0.00[c]	76.18±0.00[c]
450	12.72±0.01[g]	27.27±0.01[f]	31.81±0.00[e]	59.09±0.00[cd]	100±0.00[a]	100±0.00[a]
300	14.54±0.01[g]	14.54±0.01[g]	50±1 [d]	100±0.00 [a]	100±0.00[a]	100±0.00[a]
180	13.63±0.01[g]	21.18±0.00[fg]	25.45±0.00[f]	97.27±0.01[b]	100±0.00[a]	100±0.00[a]
100	15.45±0.01[g]	36.36±0.00[e]	76.36±0.00[c]	54.54±0.00[d]	100±.00[a]	100±0.00[a]

The means followed by a different letter are significantly different at the threshold of p<5%

Table 6. pH of dried apple in microwave at different power

Power (W)	pH
100	3.94±0.01[a]
180	3.87±0.01[b]
300	3.84±0.02 [bc]
450	3.94±0.01[a]
600	3.92±0.02 [a]
900	3.92±0.01 [a]

The means followed by a different letter are significantly different at the threshold of p<5%

Table 7. Color of dried apple in microwave at different power

Power (W)	L^*	a^*	b^*
600	48.180[a]	20.220[a]	37.600[a]
180	47.880[a]	19.800[a]	36.560[a]
900	47.080[a]	19.280[a]	36.300[a]
450	44.075[a]	18.080[a]	34.225[ab]
300	35.600[b]	17.500[a]	32.320[bc]
100	29.660[c]	17.000[a]	30.280[c]

The means followed by a different letter are significantly different at the threshold of p<5%

4. CONCLUSION

The microwave dehydration of the *Golden Delicious* apple cultivated in Algeria appear encouraging results on the conservation and improvement of the functional properties of this fruit, namely water retention, solubility, gelation and emulsifying. Except for the ability of the oil retention that relatively small and lack of foaming ability; the studied apple is unable to form foam.
These results show the important role of this fruit in the food industry, such as the manufacture of beverages on the basis of solubility and its ability to retain water, the manufacture of jellies and creams for its ability its related to emulsifying and gelling, and any other applications especially in confectionery and pastry.
Statistical analysis shows that moderate powers by 180, 300 and 450Wdelivered the best functional properties and same for color, then it is not worthwhile to apply the higher powers.
Dried by microwave of apple retains relatively its original color (yellow), all take into account the microwave drying heterogeneity induces heterogeneity on color.
Moreover, the kinetics of the dehydration of apple shows that microwave drying time is short in supply to other drying methods. This reveals economic importance of dehydration by microwave of the apples.

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