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# Maximizing the Benefit of Orange Pomace

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## ABSTRACT

A study was carried out to maximize the benefits of orange pomace through different treatments including chopping process at different times (5, 10 and 15 s), pressing using a laboratory scale hydraulic press unit at four different levels of applied pressure (50, 100, 150 and 200 bar) for exposure times of (5, 10, 15 and 20 min) with pre-treatment of the samples using $Ca(OH)_2$ in comparison with non-treated samples. Following this process, the most proper pressing treatment was assigned for a drying process using a conduction rotary heating unit at heating surface temperatures of (100, 110, 120, 130 and 140 $^oC$) for drying times of (10, 20, 25, 30, 35 and 40 min). Two different drying models (Lewis model and Henderson & Pabis's model) were assigned for describing the drying data and predicting the change in orange pomace moisture content. Quality evaluation tests were also conducted for the dried samples including chemical composition, water retention capacity (WRC) and oil holding capacity (OHC). The results show that chopping process for 10s showed the highest extraction efficiency, the samples treated with $Ca(OH)_2$ and pressed at 150 bar for 15 min recorded the lowest value of moisture content (105.46% d.b.). Meanwhile, the drying process at heating surface temperature of 110 $^oC$ for 40 min showed the lowest reduction in pomace quality. Also, Lewis model could describe the drying behavior of orange pomace satisfactory.

## INTRODUCTION

Oranges are one of the most important fruits grown in Egypt. Orange's area, yield and production in Egypt during season 2014 were 300813 feddan10.42 ton/fed and 3135931 ton, respectively (Faostat, 2014).

During orange juice production, only around half of the fresh orange weight is transformed into juice (Braddock, 1995), generating great amounts of residue (peel, pulp, seeds, orange leaves and whole orange fruits that do not reach the quality requirements), which accounts for the other 50% of the weight of the fruit and has a moisture content of approximately 82 g 100 g−1 (Abecitrus, 2008; Garcia-Castello *et al*., 2011). This huge amount of waste is, in most cases, spread on soil in areas adjacent to the production locations, for its final use as a raw material in animal feed, or else it is burned (Martin *et al*., 2010). This method of waste handling produces highly polluted wastewater in terms of chemical and biological oxygen values which can negatively affect the soil and the ground and superficial waters (Braddock, 1995).

One alternative to improve the management of these residues is the implementation of new processes for their recovery, for instance, through the production of organic fertilizers, pectin, bio-oil, essential oils, and antioxidant compounds, or as a substrate for the production of several compounds with high added value, such as microbial proteins, organic acids, ethanol, enzymes and biologically active secondary metabolites and adsorbent materials. These are excellent alternatives to avoid environmental pollution and to add value to these substances (Abecitrus, 2008).

However, citrus pomace are sensitive to biochemical and microbial degradations because of their high amount of moisture (70-80%). Moreover, the phenolic compounds of citrus pomace could be submitted to enzymatic oxidation at different steps of processing. Citrus pomace stabilization is an essential step to facilitate the further uses (extractions of bioactive compounds for healthy products formulation). Dehydration at appropriate conditions, allows a decrease of moisture and water activity of the product and the inhibition of both oxidative enzymatic reaction and micro-organisms growth allowing prolonging the shelf life of the product (Mhiri *et al*., 2015).

The main objective of the current study is to maximizing the benefits of orange pomaces by reducing the moisture content to the limit which allows to storage the pomace for a long time without changes in quality and permit utilizing this pomace in different ways.

## MATERIALS AND METHODS

### Materials:

Pomace samples were taken from the residues obtained immediately after pressing baladi orange for juice extraction. The orange pomace was obtained from Egyptian Canning Company (Best), Meniat Samannud, Aga, Dakahlia Governorate, Egypt. The Fresh pomace were mixed with a uniformity homogenate pattern, sealed in plastic bags and stored in refrigerator at 5 oC to prevent fungal growth. Before any experimental it was taken out of the refrigerator and kept in the laboratory to attain room temperature.

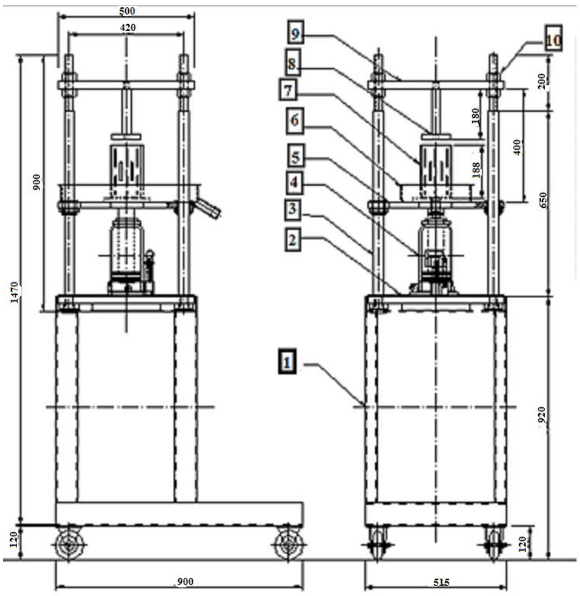
### Apparatus:

**The chopping unit:** A simple laboratory scale electric chopping unit working at 220 volt with rotated stainless steel knife made in Turkey (Arnica Company) was used for sample chopping.

**The hydraulic press unit:** A local hydraulic press unit consists of 50 tons manual hydraulic piston with pressure gauge (600 bars) and stainless steel perforated cylinder rested over a stainless steel oil receiving tray was used for pressing the chopped orange pomace. Schematic diagram of the hydraulic press unit is shown in fig. (1).

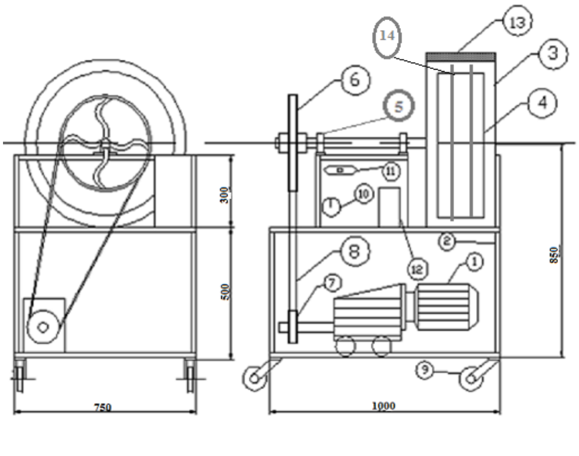
**The conduction heating unit:**

An experimental scale rotary conduction heating unit developed by El-Sahrigi *et al*. (1999) was used for the experimental work. The unit consists of a rotary cylinder (0.6 m diameter and 0.2 m long) made of 1mm galvanized iron sheet enclosed by a fixed insulated cylinder (0.8 m diameter and 0.3 m long). One side of the rotary cylinder connected to a driving mechanism consists of 0.15 m diameter steel flange fixed to the side cover of the rotary cylinder and welded to a steel bar riding with a heavy duty ball bearing. The other side of the rotary cylinder serves as an inlet for the pressed orange pomace samples through a 0.2m diameter center hole. The power source was 0.5 kW electric motor, while the heating process was conducted through electric heaters (2 kW) fixed at the inner surface of the fixed insulated outer cylinder. Schematic diagram of the conduction heating unit is shown in fig. (2).




| No. | Description |
|---|---|
| 1 | Main frame |
| 2 | Lower plate of the press |
| 3 | Steel rods of the press |
| 4 | Hydraulic Jake |
| 5 | Middle plate of the press |
| 6 | Collected liquid phase tray |
| 7 | Perforated cylinder |
| 8 | Stainless steel pressing piston |
| 9 | Upper plate of the press |
| 10 | Counter nut |

**Fig. 1. Schematic diagram of the hydraulic press unit.**




| | | |
|---|---|---|
| 1-Electric motor | 2-Frame | 3-Fixed cylinder |
| 4-Rotary cylinder | 5-Ball bearing | 6-Pulley |
| 7-Pulley | 8-V, belt | 9-Wheel |
| 10-Electric thermostat | 11-Electric contactor | 12-Switch |
| 13-Insulation | 14 - Heater | |

**Fig. 2. Schematic diagram for the conduction heating unit**

**Measurements:**

**Moisture content of pomace samples:**

The moisture content of orange pomace was obtained according to the AOAC method No. 934.06 (AOAC, 1990) using a hot air drying oven set at 70 $^{o}$C for 16 h.

**Bulk temperature of orange pomace**

The bulk temperature of the dried orange pomace was immediately measured at the end of each experimental run using one point temperature meter model (A.W. SPERRY DM-8600, Taiwan) with range of 0 to 400 $^{o}$C.

**Tests to Evaluate Orange pomace Quality:** The quality evaluation tests may be assessed as follow:

**Protein content of orange pomace:**

Total nitrogen content was determined by the Kjeldahl method using Tecator equipment (digester model 2020 and Distillation and Tritation Kjeltec 1035/38 system). Protein content was estimated by multiplying the nitrogen value by 6.25.

**Ash content of orange pomace:**

Ash contents of the dehydrated samples were gravimetrically determined by overnight heating at 550 $^{o}$C, according to the AOAC method no. 945.46 (AOAC, 1997).

**Lipids content of orange pomace:**

Total content of lipids was determined gravimetrically by extraction with diethyl ether using a Soxhlet apparatus.

**Total carbohydrate of orange pomace:**

The carbohydrate content could be determined by calculating the percent remaining after all the other components had been measured: % carbohydrate = 100 – (% moisture + % protein + % lipids + % Ash).

**Total sugar of orange pomace:**

Total sugar was measured according to AOAC (1995)

**Total fiber content of orange pomace:**

Total fibers content was measured according to AOAC (2005)

**Water retention capacity (WRC) of orange pomace:**

WRC is expressed as the mL of water/g of dry orange residue powder, and was determined by centrifugation as described elsewhere (Jiménez *et al.* 2000) with slight modifications. The samples (2.00 g ± 0.02 g) were suspended in water (25 mL). After 24 h of equilibration at room temperature (approximately 25 °C), the suspension was centrifuged at 4,200 r/min for 15 min. The supernatants were discarded and the hydrated samples were weighed.

**Oil holding capacity (OHC) of orange pomace:**

OHC is expressed as the mL of oil/g of dry orange residue powder, and was determined under the same conditions as those for WRC using soybean oil (0.925 g/mL density) (Lou, *et al*. 2009).

**Experimental Procedures:**

**Preliminary experiments:**

The most proper particle size for the chopped orange pomace was determined. A laboratory chopping machine was used for the chopping process at three different chopping times of 5, 10 and 15 min. The resulted sizes of chopped samples were analyzed using an electric vibrator machine and sieves with opening sizes from 5 mm to 0.149 mm.

The resulting chopped samples using 100g of fresh orange pomace were dried using an electric oven at 70 $^{o}$C for 16 h, then the samples were manually grinded to get particles with different sizes. The electric vibrator and sieves with diameters from 5 mm to 0.148 mm were assigned to separate the samples particle sizes by placing them on the upper sieve (5 mm) and operating the vibrator machine until the full separation of the particles into different categories. The obtained categories of each samples particle were weighted separately to determine the proportion of each category to the original sample. After determination of particle sizes of each experimental treatment, the obtained samples were tested for the process. The moisture extraction efficiency was determined to assess the optimum particle sizes that lead to higher moisture extrication efficiency. For the moisture extraction process, 500g samples were chopped for 5, 10 and 15 min and used to determine the moisture extraction efficiency of each treatment using the hydraulic press unit at similar applied pressure of 100bar for 10 min.

The moisture extraction efficiency could be determined as follow:

$$E = \frac{IMC - FMC}{IMC} \, x\, 100 \quad \ldots\ldots\ldots \quad (1)$$

**Where: E: the moisture extraction efficiency, %**

**IMC & FMC: initial moisture content of the sample, % d.b.**

Pressing treatments was conducted using the hydraulic pressing unit at four different levels of applied pressure (50, 100, 150and 200 bar ) and four different holding times (5, 10, 15 and 20 min) with and without adding for 0.3% hydrated lime Ca(OH)2.). The best choice of the pressed samples which have low moisture content was used for pressing another amount of orange pomace to be used in the drying experiments. Then, the drying experiments were carried out at five different surface temperatures (100, 110, 120, 130 and 140 oC) and sex different drying times (10, 20, 25, 30, 35 and 40 min).

**Theoretical Analysis of the Drying Process:**

To find the most convenient drying model describing the drying behavior of orange pomace under the studied ranges of the experimental variables, two different drying models were examined for fitting the drying data. The simple exponential model (Lewis, 1921) and the modified simple exponential model (Henderson and Pabis's, 1961)

**Lewis, (1921) model:**

$$MR = \frac{M - M_e}{M_O - M_e} = \exp(-k_L t) \ldots\ldots \quad (2)$$

**Henderson and Pabis (1961) model:**

$$MR = A \exp(-K_H t) \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

**Where:**

**MR: Moisture ratio, dimensionless**

**t: Time, min**

**M: Moisture content, (d.b) kg water/kg dry solid.**

**$M_o$ and $M_e$: Initial and Equilibrium moisture content, (d.b).**

**$K_L$ &$K_H$ : Drying constants, $min^{-1}$**

**A : equation constant, dimensionless**

However, at temperature range of 105 to 145°C the air relative humidity and the corresponding equilibrium moisture content become very low. After prolonged heating under the above mentioned conditions the orange pomace samples will be bone dried and the moisture ratio was approximated by dropping the equilibrium moisture content term and thus the moisture ratio could be simplified to ($M/M_0$), as reported by (El-Kholy, 1998; Yaldiz *et al*, 2001; Sacilik and Unal, 2005 and Doymaz, 2004).

Also, Regression analyses were done by using the Statistical routine. The coefficient of correlation (r) was one of the primary criterions for selecting the best equation to define the drying curves (O'Callaghan *et al.*, 1971, Verma *et al.*, 1985 and Kassem, 1998). In addition to r, the various statistical parameters such as; reduced chi-square ($x^2$), mean bias error (MBE) and root mean square error (RMSE) were used to determine the quality of the fit. These parameters can be calculated as following:

$$x^2 = \frac{\sum_{i=1}^{N}(MR_{exp,i} - MR_{pre,i})^2}{N - n} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

$$MBE = \frac{1}{N}\sum_{i=1}^{N}(MR_{pre,i} - MR_{exp,i}) \ldots\ldots\ldots\ldots\ldots \quad (5)$$

$$RMSE = \left[\frac{1}{N}\sum_{i=1}^{N}(MR_{pre,i} - MR_{exp,i})^2\right]^{1/2} \ldots\ldots\ldots \quad (6)$$

**Where, $MR_{exp,i}$ stands for the experimental moisture ratio found in any measurement and $MR_{pre,i}$ is predicted moisture ratio for this measurement. N and n are the number of observations and constants, respectively.**

## RESULTS AND DISCUSSION

**Optimum particle size for pressing the chopped orange pomace:**

Table (1) shows the size distribution of the particles resulting from the chopping process at different times and the extraction efficiency at different levels of chopping times.

As shown in table (1), the pressed orange pomace after the chopping process for 10 and 15 min showed very close moisture extraction efficiency of 33.11 and 33.16%. However, the chopping process at 10 min was selected for energy and time saving. In general, the higher percentage of particle size category ranged from 0.84 to less than 5mm resulted in higher extraction efficiency.

**Table 1. Particle size distribution and the extraction efficiency.**

| | Weight of different particle sizes, g | | |
|---|---|---|---|
| **Sieve size** | **5 sec** | **10 sec** | **15 sec** |
| up to 5 mm | 20.17 | 0.86 | 0.79 |
| up to 2 mm | 33.82 | 19.31 | 16.25 |
| up to 1.19 mm | 24.11 | 43.84 | 44.31 |
| up to 0.84 mm | 12.33 | 21.08 | 22.63 |
| up to 0.59 mm | 7.46 | 9.03 | 10.63 |
| up to0.297 mm | 1.57 | 4.97 | 4.93 |
| up to 0.149 mm | 0.54 | 0.91 | 0.95 |
| Initial moisture content, % | 346.65 | 345.29 | 340.57 |
| Final moisture content, % | 245.33 | 230.94 | 227.63 |
| Extraction efficiency, % | 29.228 | 33.117 | 33.162 |

**Effect of $Ca(OH)_2$ treatment on the extraction process of orange pomace:**

A comparison evaluation for the effect of samples pre-treating with $Ca(OH)_2$ and the non-treated samples on the final moisture content of the pomace samples after the extraction process was conducted under different levels of applied pressure and holding times. Data of the final moisture content of the pressing experiments are presented in table (2).

As shown in table (2) under all levels of applied pressure and holding times the $Ca(OH)_2$ treated samples showed lower final moisture content in comparison with the non-treated samples. The reduction percentages of moisture content were ranged from 22.97 to 50.25%. The final moisture content of the $Ca(OH)_2$ treated samples at 150 bar and 15 min holding time was 105.5% d.b. in comparison with 210.7105.5% d.b. for the non-treated samples. So, the $Ca(OH)_2$ treated samples, pressed at applied pressure of 150 bar and holding time of 15 min was selected for the pressing process.

**Table 2. Final moisture content of the non-treated and Ca(OH)2 treated orange pomace samples.**

| Pressure, bar | Holding time, min | Final moisture content, % d.b. | | The reduction percentage, % |
|---|---|---|---|---|
| | | Non-treated | treated | |
| 50 | 5 | 243.9870 | 185.7155 | 23.8830 |
| | 10 | 235.4546 | 155.2803 | 34.0508 |
| | 15 | 228.9214 | 131.5639 | 42.5288 |
| | 20 | 220.6810 | 120.7875 | 45.2660 |
| 100 | 5 | 238.9075 | 174.3034 | 27.0415 |
| | 10 | 230.9359 | 145.0954 | 37.1707 |
| | 15 | 219.0858 | 118.3494 | 45.9803 |
| | 20 | 212.6771 | 112.6354 | 47.0393 |
| 150 | 5 | 219.2997 | 165.3111 | 24.6186 |
| | 10 | 215.3955 | 128.7777 | 40.2134 |
| | 15 | 210.7163 | 105.4654 | 49.9491 |
| | 20 | 210.1261 | 104.5477 | 50.2453 |
| 200 | 5 | 212.7810 | 163.9068 | 22.9692 |
| | 10 | 208.1750 | 123.3663 | 40.7391 |
| | 15 | 206.3593 | 104.4800 | 49.3699 |
| | 20 | 203.5198 | 104.0107 | 48.8941 |

**Change in the pressed orange pomace moisture content during the conduction drying process:**

A typical plot showing the change in the pressed orange pomace moisture content as related to drying time and cylinder surface temperature of the oreange pomace is illustrated in Fig. (3).

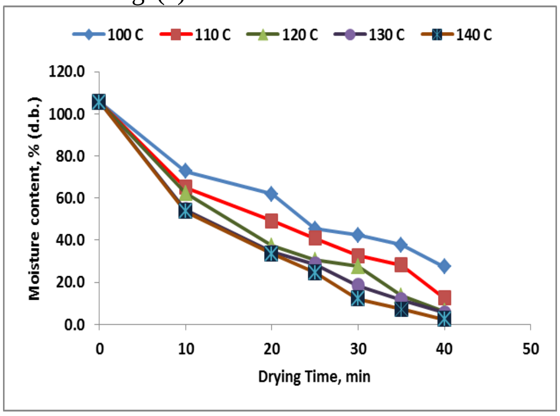



**Fig. 3. Change in the orange pomace moisture content as related to drying time at different levels of cylinder surface temperature.**

As shown in Fig. (3), rapid moisture removal from the orange pomace was obvious particularly at higher levels of heating surface temperature and drying time. At the minimum cylinder surface temperature of 100 °C and drying time of 10 min, the final moisture content of pomace samples decreased from an initial level of 105.5% d.b. to a final level of 72.69% d.b. While, at the maximum level of 140 °C and drying time of 40 min, the corresponding final moisture content was 2.47% d.b. However, the selection of the proper drying condition will be dependent upon the nutrition constitutes of the dried orange pomace samples.

**Change in the orange pomace bulk temperature during the conduction drying process:**

A typical plots showing the change in pomace bulk temperature as related to the drying time are illustrated in Fig. (4). As shown in figure the grain bulk temperature was lower during the early stage of heating process and it was gradually increased with longer exposure duration. In general, for all levels of heating surface temperature, as the exposure time increased, the difference between the pomace bulk temperature and the heating surface temperature decreased and the heating rate also decreased. The bulk temperature of pomace samples ranged from 66 to 95 °C.

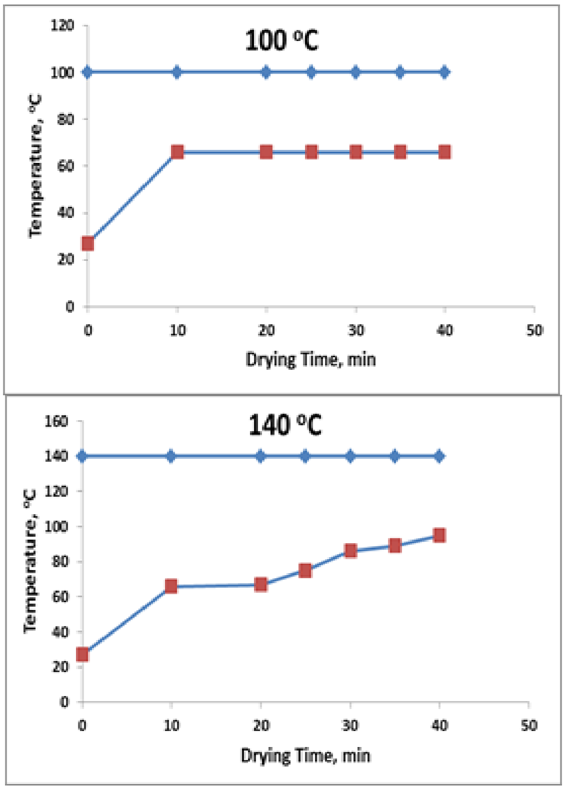



**Fig. 4. A typical plots of the change in orange pomace bulk temperature as related to drying time at the minimum and maximum heating surface temperature.**

**Analysis of drying behavior of orange pomace:**

The moisture ratio was calculated from the obtained data of all experiments, then the plotted curves for the relationship between the moisture ratio and time were fitted for the two drying models by using Microsoft office Excel. Values of computed drying constants for the two models are presented in table (3).

**Table 3. Values of computed drying constants for Lewis, Henderson and Pabis models.**

| Heating surface temperature, °C | Lewis model | Henderson and Pabis model | |
|---|---|---|---|
| | $K_L$ | $K_H$ | A |
| 100 | 0.0315 | 0.0315 | 1.0009 |
| 110 | 0.0433 | 0.0457 | 1.0747 |
| 120 | 0.0583 | 0.0630 | 1.1547 |
| 130 | 0.0634 | 0.0688 | 1.1784 |
| 140 | 0.0773 | 0.0868 | 1.3322 |

In order to compare the two drying models, straight line was fitted by least square method to the values of the calculated and the observed values of moisture contents. The values of coefficient of correlation (r), chi-square ($\chi^2$), mean bias error (MBE) and root mean square error (RMSE) were then computed. Fig. (5) and fig (6) show the fitted straight line of the calculated and observed values of moisture contents for the two examined models at the minimum and maximum heating surface temperature. Tables (4) also show the values of coefficient of correlation (r), chi-square ($x^2$), mean bias error (MBE) and root mean square error (RMSE), for all drying runs and the two examined drying models.

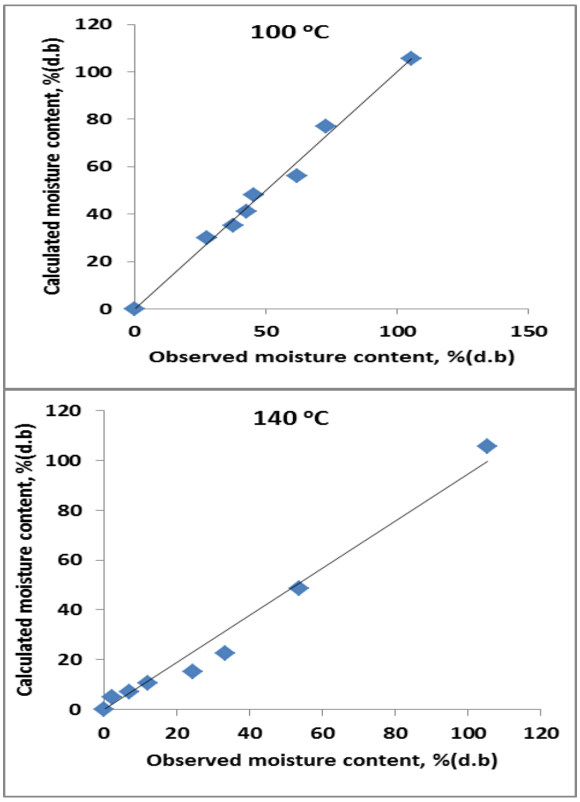



**Fig. 5. The calculated and observed moisture content of orange pomace at heating surface temperature of (100 and 140°C) for Lewis's model**

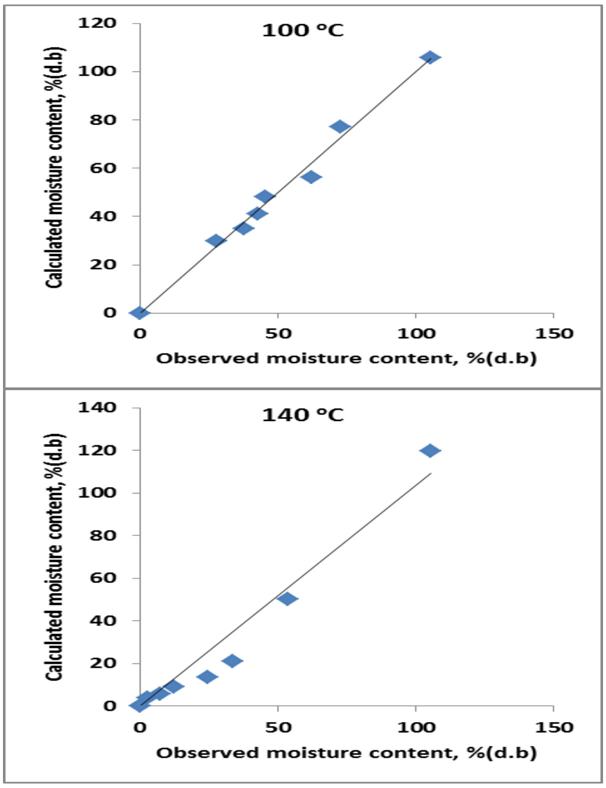



**Fig. 6. The calculated and observed moisture content of orange pomace at heating surface temperature of 100 and 140°C for Henderson and Pabis model.**

**Table 4. Values of coefficient of determination (r), chi-square ($x^2$), mean bias error (MBE) and root mean square error (RMSE) of Lewis's model and Henderson and Pabis's model.**

| Heating surface temperature, °C | Lewis's model | | | | Henderson and Pabis's model | | | |
|---|---|---|---|---|---|---|---|---|
| | r | $x^2$ | MBE | RMSE | r | $x^2$ | MBE | RMSE |
| 100 | 0.9947 | 0.0011 | -0.0008 | 0.0308 | 0.9947 | 0.0013 | -0.0008 | 0.0308 |
| 110 | 0.9913 | 0.0021 | -0.0132 | 0.0424 | 0.9888 | 0.0037 | -0.0286 | 0.0516 |
| 120 | 0.9936 | 0.0019 | -0.0214 | 0.0402 | 0.9887 | 0.0045 | -0.0412 | 0.0568 |
| 130 | 0.9948 | 0.0017 | -0.0224 | 0.0378 | 0.9894 | 0.0044 | -0.0422 | 0.0564 |
| 140 | 0.9889 | 0.0036 | -0.0337 | 0.0556 | 0.9788 | 0.0088 | -0.0575 | 0.0794 |
| average | 0.9927 | 0.0021 | -0.0183 | 0.0413 | 0.9881 | 0.0046 | -0.0341 | 0.0550 |

As shown in Table (4), Lewis's model showed the highest value of coefficient of correlation (r) and the lowest values of chi-square ($\chi^2$), mean bias error (MBE), root mean square error (RMSE).

Further regressions were undertaken to relate the drying constant $k_L$ with the heating surface temperature for the selected lewis's model as follows:

**$k_L = 0.0038 \exp(0.0218\, T_s)$ …………………… (7)**
**($R^2 = 0.9587$; SE = 0.002576)**

**Where: $k_L$ : The drying constant, 1/min**
**$T_s$: The heating surface temperature, in the range (100 to 140 °C)**

**Effect of drying on the chemical Composition of Orange Pomace:**

Table (5) illustrates the chemical composition of fresh, pressed and dried orange by product. It can be shown that the fresh and pressed orange pomace are rich in nutritional ingredients specially total carbohydrates, proteins, crude fibers and total sugars . Also, it can be said that, the conduction heating process not affecting both fibers and ash contents. While, it was reduced the sugar content by 2-4%, protein content by 1-2% and fat content by 1-2%.

**Table 5. The chemical composition (% d.b.) of fresh, pressed and dried orange pomace.**

| sample | Crude protein, % | Total fat, % | Ash content, % | Total carbohydrates, % | Crude fiber, % | Total sugar, % |
|---|---|---|---|---|---|---|
| fresh | 4.5016 | 3.6630 | 3.3497 | 88.4867 | 11.7394 | 11.4304 |
| Pressed cake | 2.4456 | 2.5689 | 1.6441 | 93.6715 | 10.9948 | 5.7132 |
| 110 °C /40min | 2.4324 | 2.5475 | 1.6432 | 93.3769 | 11.1456 | 5.6572 |
| 120 °C /35 min | 2.4305 | 2.5452 | 1.6444 | 93.3799 | 11.0006 | 5.6193 |
| 120 °C /40 min | 2.4266 | 2.5372 | 1.6434 | 93.3928 | 11.0038 | 5.6068 |
| 130 °C /30 min | 2.4250 | 2.5292 | 1.6441 | 93.4018 | 11.0946 | 5.5820 |
| 130 °C /35 min | 2.4233 | 2.5277 | 1.6445 | 93.4046 | 11.9227 | 5.5597 |
| 130 °C /40 min | 2.4161 | 2.5247 | 1.6433 | 93.4159 | 11.6891 | 5.5523 |
| 140 °C /30 min | 2.4123 | 2.5225 | 1.6424 | 93.4229 | 11.2430 | 5.5014 |
| 140 °C /35 min | 2.4080 | 2.5192 | 1.6452 | 93.4276 | 11.1754 | 5.4977 |
| 140 °C /40 min | 2.4042 | 2.5160 | 1.6435 | 93.4362 | 11.8808 | 5.4935 |

**Effect of drying treatment on the water retention capacities (WRC):**

Fig. (7) Shows the water retention capacity of the fresh, pressed and dried orange pomace samples. As it can be seen, the WRC of the pressed samples treated with $Ca(OH)_2$ was higher than that of the fresh orange pomace. This may be due to the treatment with $Ca(OH)_2$ which allow maintaining the initial texture, leading to cellular structure stability.

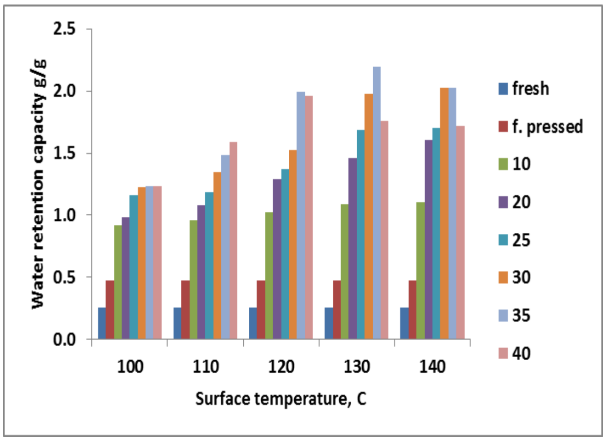



**Fig. 7. The water retention capacity of the fresh, pressed and dried orange pomace at different surface temperature and drying time.**

As it can be observed, the WRC increased with the increase of the heating surface temperature and drying time until it reaches its highest value (2.1922 g water/g d.b.) when the dried orange pomace reach final moisture content (11.788 % d.b.) at surface temperature 130 $^{o}$C for 35 min then higher surface temperatures and drying time decreased the WRC of the orange pomace to (1.7178 g water/ g d.b. at 140 °C for 40 min). It also can be seen that WRC values obtained in this study were lower than those presented by Garau *et al*. (2006) and Wi *et al*., (2014)

**Effect of drying treatment on oil holding capacities (OHC):**

Fig. (8) shows the oil holding capacity of the fresh, pressed and dried orange pomace.. As it can be seen, the OHC of the pressed samples treated with $Ca(OH)_2$ was lower than that of the fresh orange pomace.

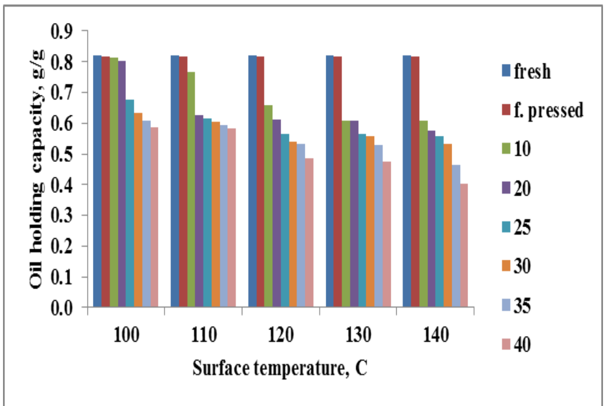



**Figure 8. The oil holding capacity of the fresh, pressed and dried orange pomace.**

In general, the drying process promoted a general decrease of OHC of all processed samples in comparison to the OHC corresponding to the fresh samples. It also can be seen that OHC values obtained in this study for the orange pomace were lower than those obtained by Garau *et al*. (2006) for the Citrus aurantium peel and lower than those presented by Wi *et al*., (2014).

## CONCLUSION

1. Chopping process of orange pomace for 10 min showed the highest extraction efficiency.
2. Pre-treatment of orange pomace samples with Ca(OH)2 and pressing at 150 bar for 15 min recorded the lowest values of moisture content.
3. The drying process at heating surface temperature of 110 oC for 40 min recorded the lowest reduction in orange pomace quality.
4. Lewis model could describe the drying data and predict the moisture content of orange pomace satisfactory.

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## تعظيم الاستفادة من مخلف البرتقال

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يهدف هذا البحث الى تعظيم الاستفادة من مخلف البرتقال وذلك لاطالة فترة الحفظ للمخلف وتسهيل استخدامه في الأغراض المختلفة وذلك من خلال اجراء عملية الفرم للمخلف لأزمنة فرم مختلفة (٥ و ١٠ و ١٥ ثانية) ثم اجراء عملية الكبس باستخدام مكبس هيدروليكي معملي على أربعة مستويات مختلفة من الضغط (٥٠ و ١٠٠ و ١٥٠ و ٢٠٠بار) وأربعة مستويات مختلفة لزمن الكبس (٥ و ١٠ و ١٥ و ٢٠ دقيقة) وذلك لعينات تمت بمعاملتها بهيدروكسيد الكالسيوم ومقارنتها بعينات لم تتم معاملتها. وبعد اختيار الظروف المثلى للكبس والتي تعطي أقل محتوى رطوبي لناتج الكبس تم دراسة تجفيف مخلف البرتقال باستخدام مجفف دوراني يعمل بالتوصيل الحراري عند خمس مستويات مختلفة من درجة حرارة السطح الساخن تراوحت بين ١٠٠ و١٤٠°م بالإضافة إلى ست مستويات مختلفة من زمن التجفيف تراوحت بين ١٠ و٤٠% واختبار نموذجين رياضيين نموذجين (Lewis's model and Henderson model) لوصف سلوك التجفيف للمخلف. وقد أظهرت النتائج أن أنسب زمن للفرم هو ٥ ثواني حيث أعطى أعلى كفاءة استخلاص وأن أنسب ظروف للكبس كانت للعينات المعاملة بهيدروكسيد الكالسيوم ومعرضة لضغط ١٥٠ بار لفترة زمنية ١٥ دقيقة حيث اعطت اقل محتوى رطوبي لناتج الكبس. ومن ناحية اخرى كانت العينات المجففه باستخدام درجة حرارة للسطح الساخن ١١٠°م لمدة زمنية ٤٠ دقيقة هي الأفضل حيث أظهرت أقل انخفاض في خصائص الجودة للمخلف. وكانت معادلة لويس Lewis model هي الأنسب في وصف سلوك التجفيف لمخلف البرتقال.