JOURNAL OF FOOD TECHNOLOGY

MEDWELL PUBLICATIONS

Impact of Conventional Drying and Particle Size on the Physicochemical Properties of the Powder of the Pea (*Pisum sativum*), the Bean (*Aquadulce*) and the Artichoke (*Cynara scolymus*) By-Products

[1]Mourad Ouhammou, [1]El Mustapha Eladnany, [2]Ayoub Morjane, [1]Abderrahim Jaouad and [1]Mostafa Mahrouz
[1]Laboratory of Innovation, Green Chemistry, Expertise and Sustainable Development LICVEDDE, Department of Chemistry, Faculty of Sciences Semlalia, Cadi Ayyad University, BP 2390, Marrakech 40000, Morocco
[2]Faculty of Sciences and Techniques of Beni Mellal, Sultan Moulay Slimane University, Mghilla Campus, BP 523, 23000 Béni Mellal

Key words: Drying, legume by-products, the pea, the bean, the artichoke

Corresponding Author:
Mourad Ouhammou
Laboratory of Innovation, Green Chemistry, Expertise and Sustainable Development LICVEDDE, Department of Chemistry, Faculty of Sciences Semlalia, Cadi Ayyad University, BP 2390, Marrakech 40000, Morocco

Page No.: 17-27
Volume: 19, Issue 3, 2021
ISSN: 1684-8462
Journal of Food Technology

Abstract: The legume by-products of broad beans, artichokes and peas seem to be of little nutritional value. However, further analysis shows the presence of phenolic compounds, pigments; proteins, lipids and polysaccharides. The present study extended on the one hand to follow the classic drying kinetics in a ventilated oven of the powder of the bean peel, the pea and the leaves of artichokes, on the other hand on the influence of this drying process on color and chemical composition (polyphenols, Brix, pH, conductivity and antioxidant activity) depending on the size of the powders. Depending on the results of the drying kinetics and the physicochemical parameters, it took >24 h for the samples of by-products placed between 30 and 40°C to reach a stabilized mass and for the samples dried to more from 50°C, the drying time is very short, the polyphenol concentration, between 60 and 80°C is higher than the other temperature. In addition, the finer the powder size of the bean, artichoke and dried pea by-products, the higher the bioactive content.

INTRODUCTION

With the considerable increase in the production and transformation of plants, significant quantities of by-products intervene and represent an economic and ecological problem due to their large volumes and disposal costs[1]. Today, by-products are considered a promising source of functional compounds, which remain after isolation from the main constituents which are abundant and represent an inexpensive material that has been undervalued, only used as fuel or fertilizer[2]. Most legumes are consumed after a simple industrial process in which the pod is removed and the seed is prepared as frozen or fresh food[3]. Small birds are widely consumed and are cultivated all over the world. According to the Food and Agriculture Organization of the United Nations, the pea represents a world production of 15.87 million tonnes (including the national production of Morocco estimated at 125,482.00 t), Morocco is a country among the best producers of peas, occupying 3rd place worldwide, 67% of which are by-products. Artichoke cultivation is widely distributed around the world, world production is around 1.5 million tonnes, in Morocco around 60,200 tonnes according to the Ministry of Agriculture and the 9th place in production bean world. These have a very short shelf life, due to their highly perishable nature. To reduce post-harvest losses, many drying techniques have been developed.

Industrial activity in the fruit and vegetable sector generates a large amount of waste and agro-industrial by-products, surpluses, residues, products rejected because of size, inadequate color or other quality standards and used washing water.

In the composition of most of these wastes or by-products, there are compounds that are interesting from a nutritional point of view in the context of animal or human food, most often antioxidant compounds. The most recently used synthetics are butylhydroxyanisole (BHA) and butylhydroxytoluene (BHT)[4], despite the harmfulness in the case of chronic use[5] or in others fields such as cosmetics or medicine or which constitute a good primary material for obtaining new compounds or materials. Instead of considering this waste or by-products as a problem, we should rather consider them as a resource and therefore as an alternative business opportunity to the marketing of fresh products according to Agrosmartcoop.

In this study, the objective is to promote the by-products of the pea (*Pisum sativum*), the bean (*Aquadulce*)[6,7] and the artichoke (*Cynara scolymus*)[8], in the form of a powder with different uses in cooking and in the formulation of high added value products such as cosmetics by the conventional drying technique process. At different temperatures we studied the dosage effect of polyphenols, pH, conductivity, Brix degree, antioxidant activity and particle size of powders with a benchmarking with other plants[9,10], finally, manufacture of tablets based on by-products as a food.

MATERIALS AND METHODS

Harvesting of plant material: The plant material used in our study is the peelings of the pea (*Pisum sativum*), the bean (*aquadulce*) and the leaves of the artichoke (*Cynara scolymus*) have as below produced, the raw material is bought at the local market Moroccan in Marrakech. These varieties are characterized by a medium size of the pod and dark green color at maturity (Fig. 1).

Pretreatment and drying: In the laboratory, a preliminary sorting was carried out, elimination of the perforated, broken, damaged pods, carrying spots, rotten or presenting damage caused by harmful insects. Then the pods were washed thoroughly with tap water and then with distilled water. The empty pods were cut into two

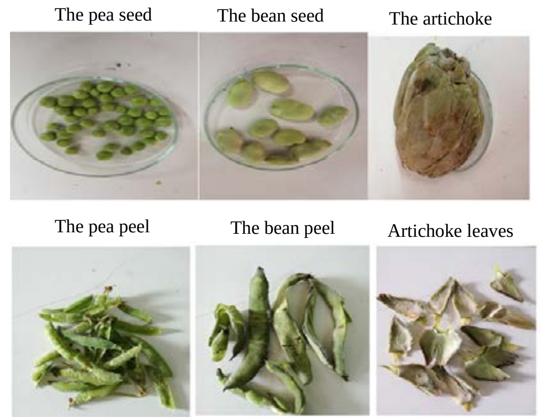

Fig. 1: The plant material

slices. Subsequently they have undergone drying, for the type of drying chosen, samples are placed in the oven at different temperatures, 30, 35, 40, 50, 60, 70, 80, 90°C and the loss by mass is monitored periodically until a constant mass is obtained.

Grinding and sieving: After obtaining a constant mass by drying in the temperature-controlled oven, the samples were ground using an electric mill.

The powders obtained were sieved using an electromagnetic sieve until there were four particle size fractions >125 μm, between 125 and 50 μm, between 50 and 25 μm and <25 μm (Fig. 2). After grinding and sieving, the powders were kept in closed glass bottles and stored protected from light.

The liquid-solid extraction was carried out by maceration, the solvent used is pure methanol. One gram twice of fresh samples, dried (powders) regularly at different temperatures were weighed and then macerated in a volume of 10 mL of the solvent. The mixture is kept under magnetic stirring for 3 h at room temperature. The solution obtained is then filtered on Wattman filter paper under vacuum, the filtrate is collected in a glass bottle is labeled and then stored in a refrigerator for analysis (Fig. 3).

Analysis of polyphenols, conductivity, Brix degree, pH: The analysis of total polyphenols was carried out using the method of reduction of the reagent of Folin-Ciocalteu[11]. George *et al*.[11], the blue coloration produced is proportional to the content of total phenolic compounds present in the sample[12]. For conductivity and pH using a multi-parameter device of the SELECTA brand, MP-2006 multi-parameter analyzer, a refractometer for the Brix degree and Atomic Absorption Spectroscopy (AAS) for the trace elements.

Analysis by Chromatographie Liquide à Haute Performance (HPLC): The analysis of polyphenols by

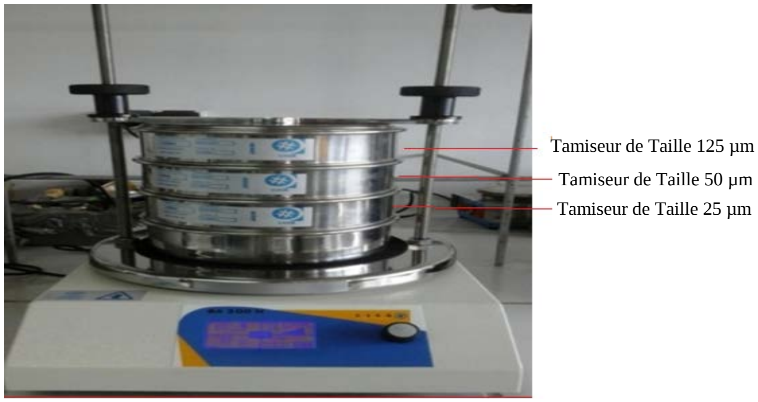

Fig. 2: The electromagnetic screen

Fig. 3: Maceration with pure methanol and filtration

liquid chromatography was carried out at the analysis and characterization center of Cadi Ayyad University, Semlalia Faculty of Sciences in Marrakech, the method uses that used by Puigventos *et al*.[13]. The chromatographic separation was carried out with a Kinetex C18 reversed-phase (100×4.6 mm, 2.6 µm particles) column and gradient elution with 0.1% formic acid aqueous solution and methanol mobile phases as previously established by HPLC with UV absorbance detection. The flow rate of mobile phase entering into the instrument was 500 µL min^{-1}. Under these conditions, an acceptable chromatographic separation of the 16 polyphenolic compounds was obtained in <30 min.

Determination of antioxidant activity: The antioxidant activity was measured by the free radical 2,2 diphenyl-1-picrylhydrazyl (DPPH)[14]. A volume of 0.1 mL of the extract was mixed with 3.9 mL of DPPH solution (0.1 mM). The absorbance of samples was measured at 515 nm after 1 h of incubation in the dark. Methanol solvent was used as blank. The inhibition activity was calculated:

$$\text{\% of radical scavenging activity} = ((\text{abs control-abs sample})/(\text{abs control}))\times 100$$

The results obtained were reported as DPPH% per 100 g of dry weight.

Fig. 4: Device for manufacturing tablets based on artichoke, bean and pea by-products

Manufacture of tablets based on artichoke, bean and pea by-products: The by-product tablets are prepared on a tablet-type compression device (TDP 1.5 Desktop Tablet Pill Press, Tablet Pill Press Machine 2019) (Fig. 4). Running a simulation profile of a tablet press as a food. The excipients were mixed with 0.5% magnesium stearate for 10 min in à mixer, picture below according to the protocol of Bellini *et al*.[15].

RESULTS AND DISCUSSION

Physico-chemical analyzes of bean (*Aquadulce*), pea (*Pisum sativum*) and artichoke (*Cynara scolymus*) by-products: The analysis of some physico-chemical parameters carried out in the laboratory are illustrated in Table 1.

Separation and analysis by (HPLC): For HPLC separation, several full or partial coelutions as standards

Table 1: Analysis of some physicochemical parameters of bean by-products (*Aquadulce*), pea (*Pisum sativum*) and artichoke (*Cynara scolymus*)

Parameters	The pea (*Pisum sativum*) peel	The bean (*Aquadulce*) peel	The artichoke (*Cynara scolymus*) leaves
pH (±0.02)	5.3	4.5	6
Conductivity (mS±0.05)	0.895	1.938	2.33
The Brix degree	1	3	1
The water content (%)	87.58	89.32	85
The ashes (%)	5.3	8.5	6.8
The total phenolics content of by-products (mg ÉqAG/100 g)	303.9	1535.2	257.2
Cd	<0.001	<0.001	<0.001
Cu	<0.001	<0.001	<0.001
Fe	<0.001	0.007	0.002
Mn	<0.001	<0.001	<0.001
Ni	<0.001	<0.001	<0.001
Zn	<0.001	<0.001	<0.001

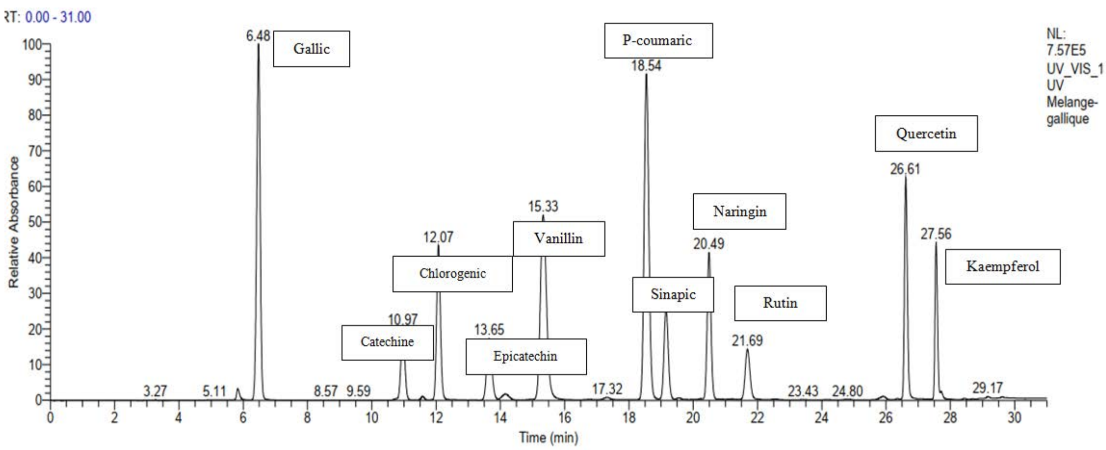

Fig. 5: Chromatogram peaks of pyrogallic mixture standards

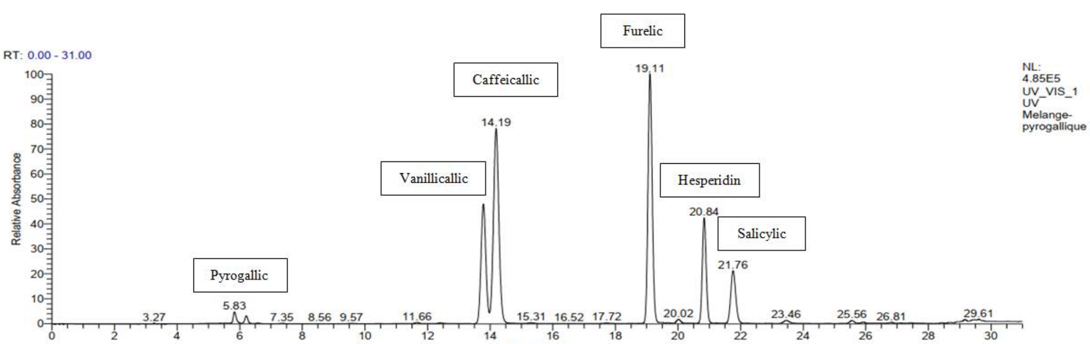

Fig. 6: Chromatogram peaks of gall mixture standards

of Pyrogallique, Vanillique, Cafeique, Furelique, Hesperidine, Salicyclique, Gallique, Catechine, Chlorogenique, Epicathechine, vaniline, p-coumarique, Sinapique, Naringine, Rutine, Quercetine and Kaempferol (Fig. 5 and 6).

Analysis of the three samples, to be shown from Fig. 7-9, the appearance of the peaks in the chromatograms obtained by HPLC.

HPLC analysis made it possible to identify the presence of certain predominant phenolic compounds, especially the retention time tablets 5.78, 28.33 and 29.65 min, often flavonoids but are not identifiable given the non-availability of the standards.

Total phenolic compounds

Effect of the drying temperature on the dosage of total

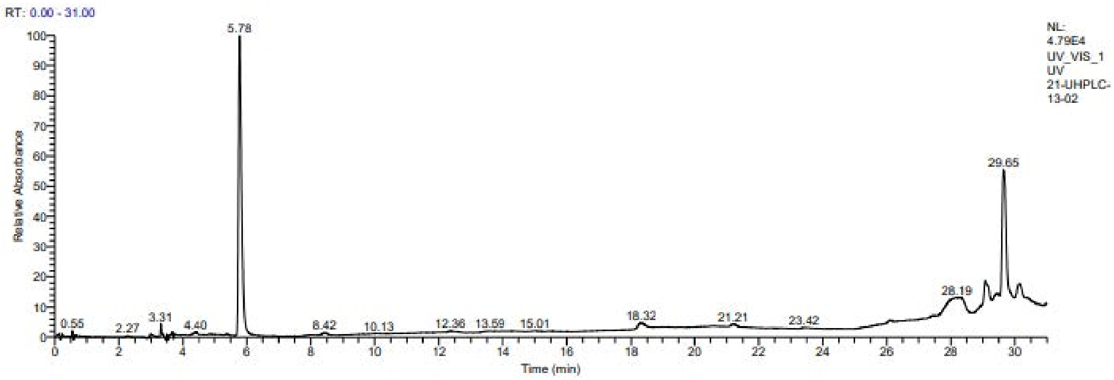

Fig. 7: Chromatogram peaks of bean (*Aquadulce*) by-products

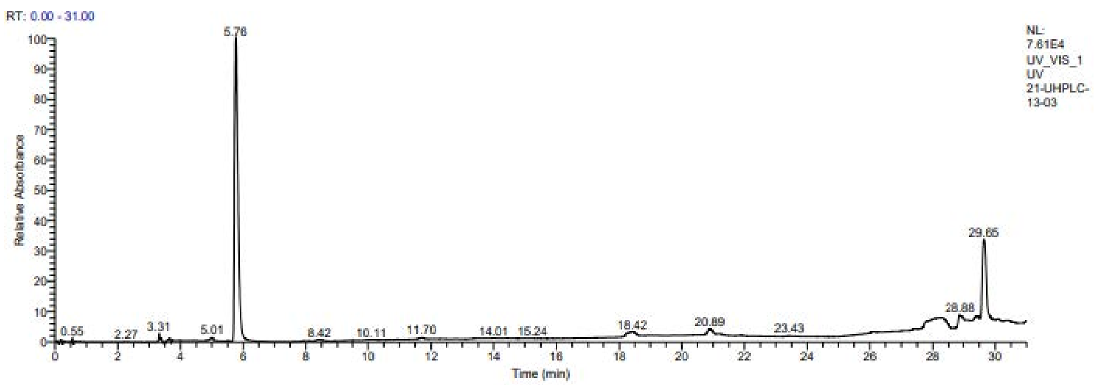

Fig. 8: Chromatogram peaks of pea (*Pisum sativum*) by-products

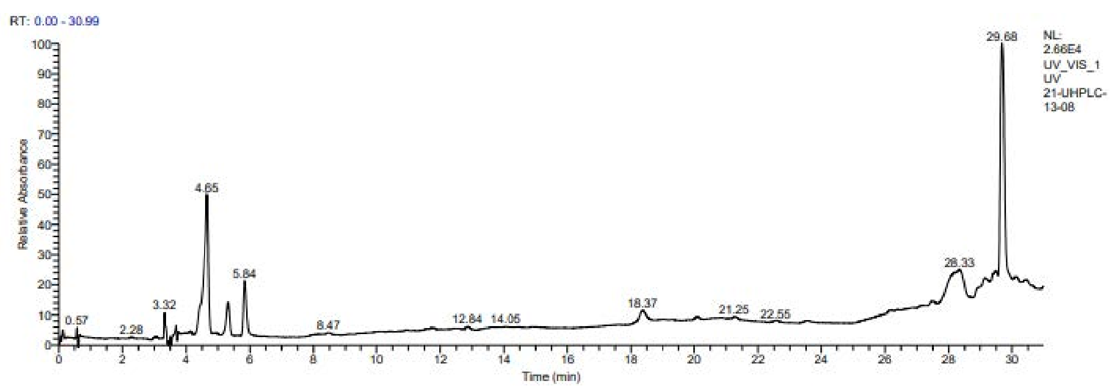

Fig. 9: Chromatogram peaks of artichoke (*Cynara scolymus*) by-products

polyphenols: Phenolic compounds are specific molecules of the plant kingdom which have interesting biological properties[16]. The results of the determination of total phenolic compounds (PPT) for the various extracts of the fresh material and of the powders obtained after drying are illustrated in Fig. 10-12. The results of the determination of the total polyphenols of the extracts of the byproducts of the bean (*aquadulce*) of the little pea (*Pisum sativum*) and of artichoke (*Cynara scolymus*) show that the concentrations vary between 0.1 and 2 g Eq AG/100 g, respectively of the dry matter. These fluctuations in the content of phenolic compounds can be explained by their degradations under the effect of temperature and time[17]. The same results, we were

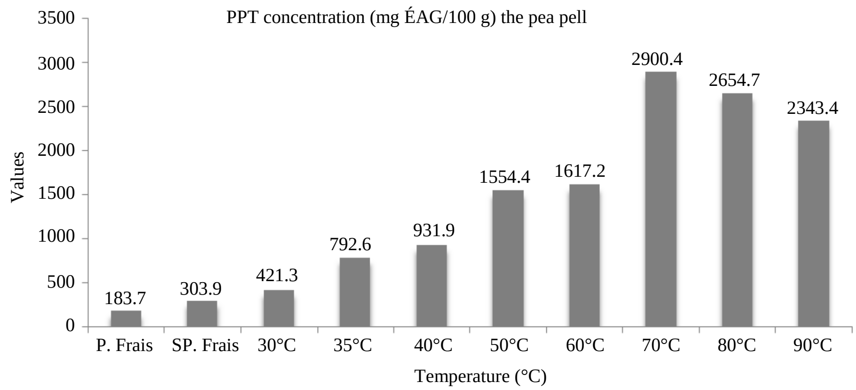

Fig. 10: The concentration of total polyphenols in the pea by-products (*Pisum sativum*) as a function of temperature

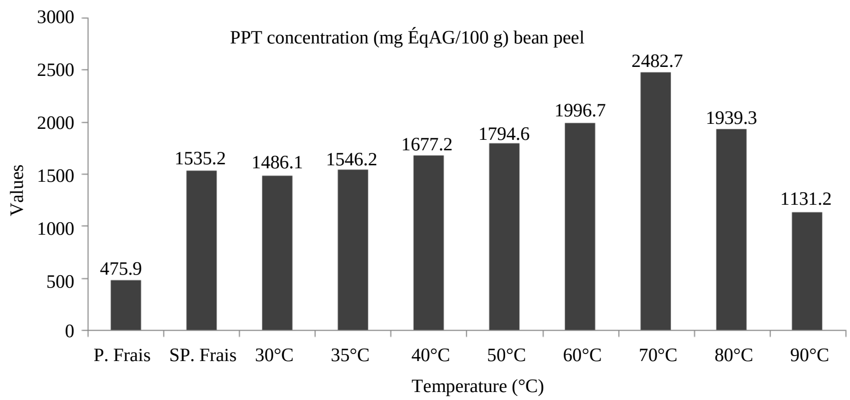

Fig. 11: The concentration of total polyphenols in Bean by-products (*Aquadulce*) as à function of temperature

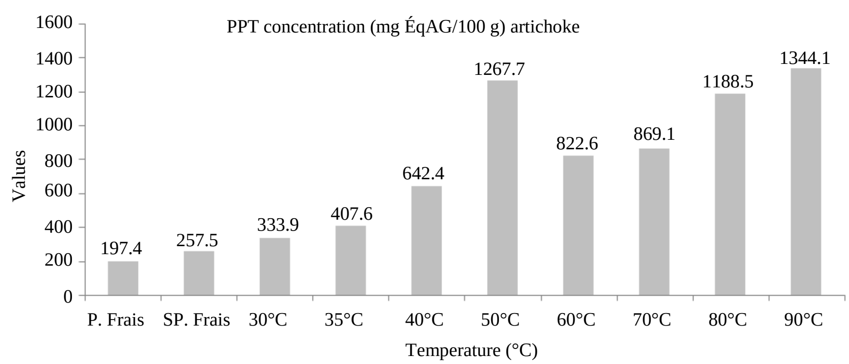

Fig. 12: The concentration of total polyphenols in artichoke (*Cynara scolymus*) by-products as a function of temperature

found by Lahnine *et al*.[18], the significant increase in the phenolic composition of irradiated Fagonia arabica compared to unirradiated after application of doses between 1-10 kGy. Similar results were confirmed by accumulation of phenolic substances in irradiated Strawberry fruit studied by Cheng and Breen[19].

Likewise, increasing the drying temperature has a significant effect on the phenolic content; an increase in the content of total polyphenols, these results are confirmed with the results of drying in the open air the red pepper (Capsicum annuum, L. var. Hungarian)[20]. In addition, the activation of phenolic compounds at high temperatures may be due to the availability of precursors of phenolic molecules by enzymatic inter-conversion between phenolic molecules.

Arslan and Ozcan[21] demonstrated the effect of the drying temperature on total polyphenols as a function of drying processes and they linked the increase in the concentration of total phenolic compounds to the release of the compounds phenolics of the plant matrix during the

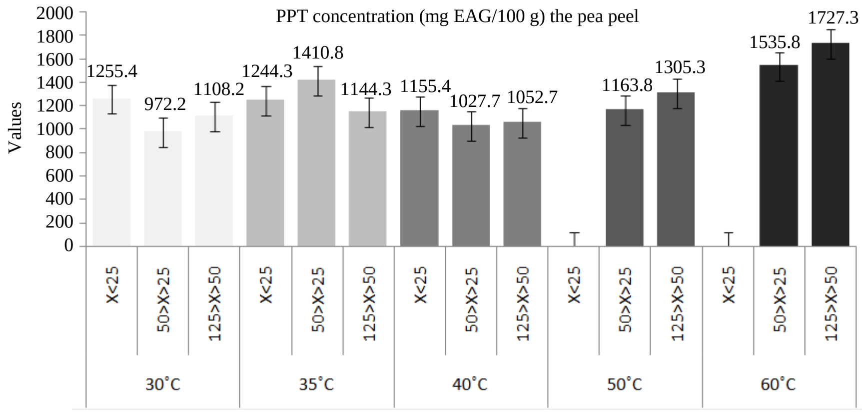

Fig. 13: The concentration of polyphenols in pea by-products as a function of the size of the powder at different temperatures

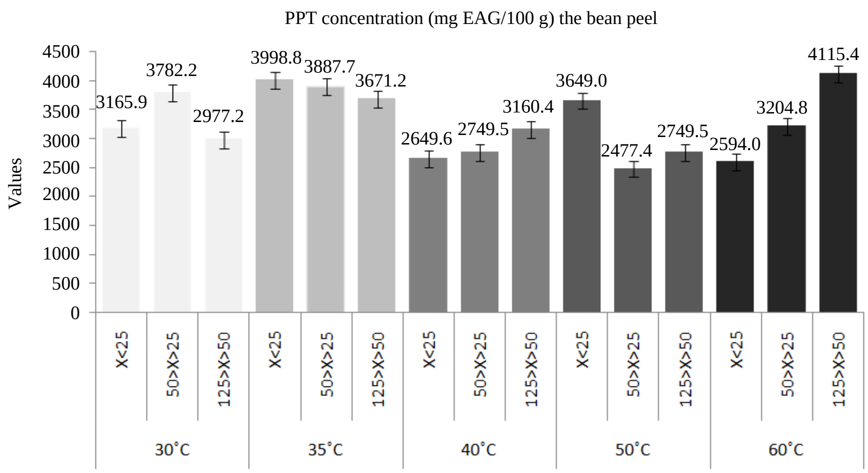

Fig. 14: The concentration of polyphenols in bean by-products as a function of the size of the powder at different temperatures

process. In addition, drying could accelerate the release of phenolic compounds by breaking the bonds and breaking down the cellular constituents.

Effect of granulometry of powders on the dosage of polyphenols (Sieving): In this part, the objective is to know the effect of the size of the seeds of the powder of the by-products of the pea, of the bean and of the artichoke on the bioactive (polyphenols), the fractions <25 µm, between 25 and 50 µm and between 50 and 125 µm. The finer the size, the higher the polyphenol content, given the contact between the extraction solvent, so the powder is very mixed, these results are consistent with found by Nabil *et al*.[9], for the cladode powder (*Opuntiaficus-indica*), the results are illustrated in Fig. 13-15.

Antioxidant activity: DPPH radical scavenging assays were applied for determining the antioxidant activity of different drying temperature and for a uniform sieve size (Fig. 16-18). The maximum antioxidant activity estimated by DPPH was recorded for the three matrices: 48% for the artichoke leaves; 79% for the pea peel and 94% for the bean peel.

The DPPH assay gave comparable results for the antioxidant activity with that find for the total polyphels, especially at drying temperatures between 60 and 80°C.

The heating effect may have à positive impact on the content of bioactive compounds and antioxidant activity. Correlation between antioxidant activity obtained from DPPH and the determination of total polyphenols as a function of the drying temperature assays was positively high.

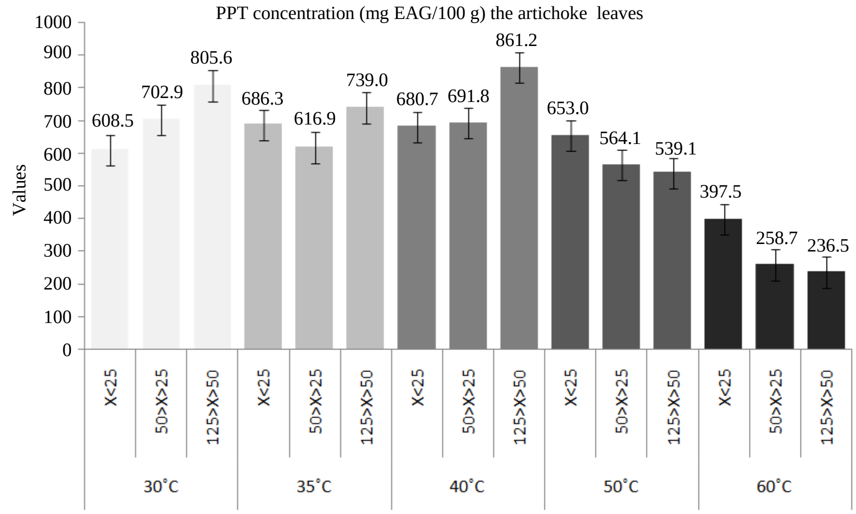

Fig. 15: The concentration of polyphenols in artichoke by-products as a function of the size of the powder at different temperatures

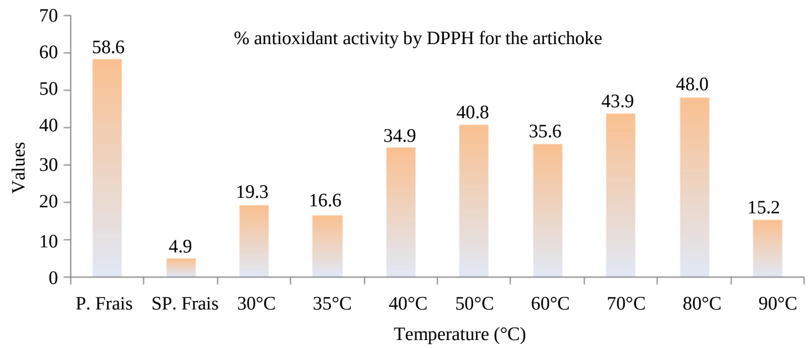

Fig. 16: % of radical scavenging activity methanolic extract of by-product of artichoke at different temperatures

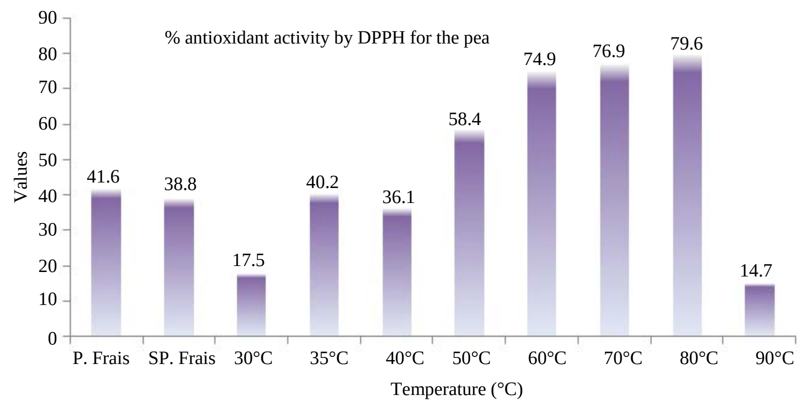

Fig. 17: % of radical scavenging activity methanolic extract of by-product of pea at different temperatures

Drying effect on pH, conductivity and Brix degree: For the drying temperature effect of by-products of pea, bean and artichoke on pH, conductivity, and Brix degree are illustrated in the figures below, the results are illustrated in Fig. 19-21. For the effect of the drying temperature on the pH, the conductivity and the Brix degree, according to the figures note a decrease in the pH value, given a degradation of the ions H^+ during drying, also for the

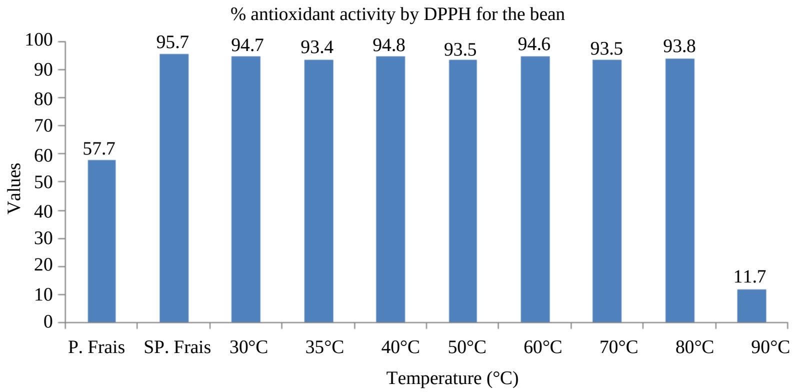

Fig. 18: % of radical scavenging activity methanolic extract of by-product of bean at different temperatures

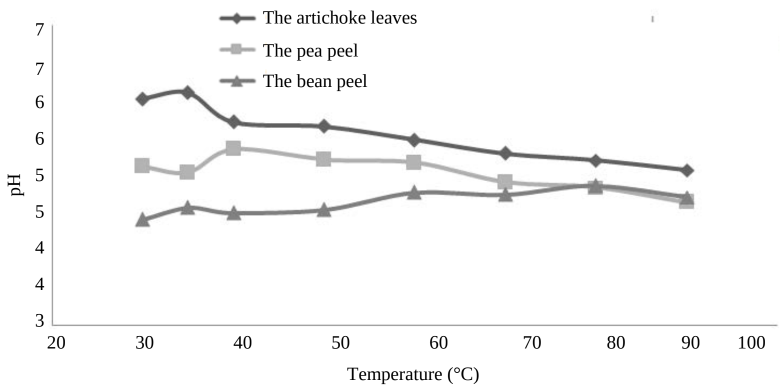

Fig. 19: The pH value of the by-products as a function of the temperature

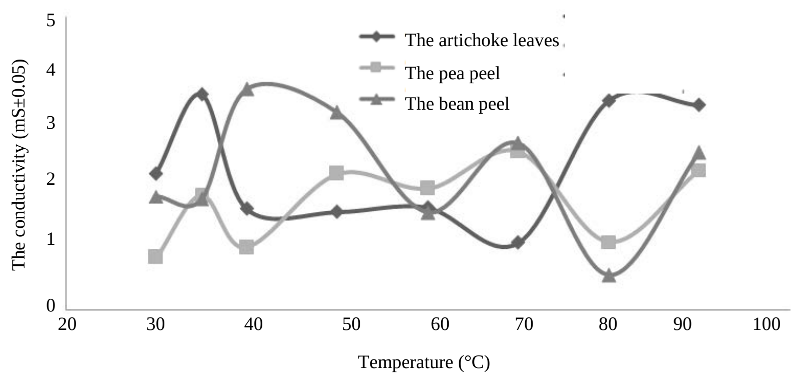

Fig. 20: The value of the conductivity of the by-products as a function of the temperature

conductivity a random variation due to the disappearance and degradation of mineral salts during drying, finally for the Brix degree which represents the solid matter soluble in legume by-products, there is a drop in Brix degree due to the degradation of the constituents of by-products[20].

Manufacture of tablets as a food: The by-product tablets are prepared on a tablet-type compression device (TDP 1.5 Desktop Tablet Pill Press, Tablet Pill Press Machine 2019), running a simulation profile of a tablet press as a food. The excipients were mixed with 0.5% magnesium stearate for 10 min in a mixer (Fig. 22).

Since, the drying temperature and the particle size have an effect on the bioactive by-products of artichoke, peas and beans, we chose the powder with a homogeneous size of <125 µm at a drying temperature 70°C and cooking, for the manufacture of tablets as a food or as a good compliment for athletes,

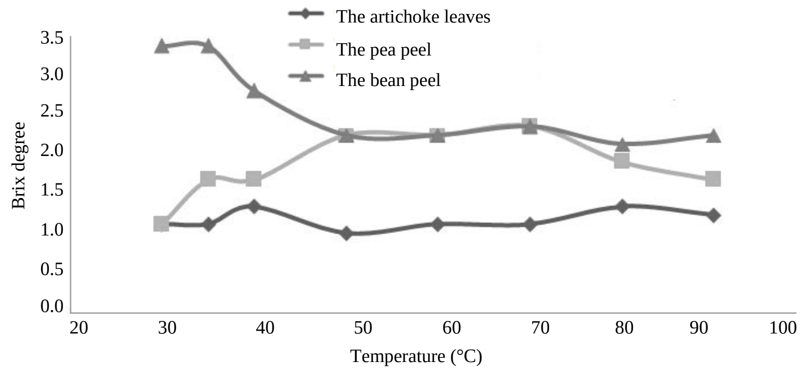

Fig. 21: The value of the Brix degree of the by-products as a function of the temperature

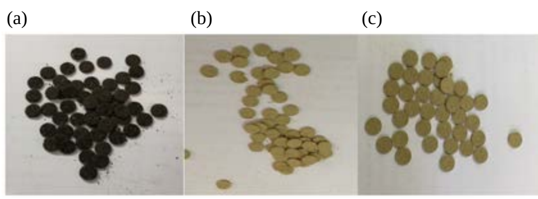

Fig. 22(a-c): (a) Artichoke, (b) Bean and (c) Pea by-product tablets

especially the bean which is very rich in fiber and antioxidant compounds, this powder can even replace vegetable activated carbon (like Charcoal-Fennel) (Fig. 22), used to absorb intestinal gases and preserve the good health of the digestive tract. these ingredients are characterized.

CONCLUSION

The leguminous by products bean, petit pois and artichoke seem to be no great food interest. But further analysis showed the presence of phenolic compounds, minerals and pigments.

The present study has spread on the one hand to the follow-up of the kinetics of classic drying in a ventilated oven of the peel of the bean, the pea and the leaves of artichoke. On the other hand the influence of this drying process on the color, the chemical composition of bioactive (polyphenols), pH, conductivity, Brix deg, antioxidant activity and manufacture of food tablets.

According to the results, the samples set at 60° and 70°C have a value of polyphenols important at other drying temperatures with a very fine particle size. The study then focuses on the analysis of the different types of polyphenols by liquid choromatography and the other chemical compounds by Flasch chromatography and spectral analyzes in a second article.

ACKNOWLEDGMENTS

The authors acknowledge the Ministry of Higher Education, Scientific Research and Professional Training of Morocco and the National Center for Scientific and Technical Research. Priority Research program: PPR-B-Mahrouz-FS-UCA-Marrakech, (R2B INNOVA) for the financial support.

Data availability: I declare the availability of data in ca of need.

Contributions of authors: Authors 1-4 designed the study, managed the writing of the manuscript and performed the analysis. Authors 5 and 6 performed the evaluations of the parameters analyzed in the study. The author 7 managed the bibliographic searches. All authors read and approved the final manuscript.

REFERENCES

01. Carle, R., P. Keller, A. Schieber, C. Rentschler, T. Katzschner, D. Rauch, G. Fox and H. Endress, 2001. Method for obtaining useful materials from the by-products of fruit and vegetable processing. Patent Application, WO 1, A1, World Intellectual Property Organization, Geneva, Switzerland.
02. Grigelmo-Miguel, N. and O. Martin-Belloso, 1999. Comparison of dietary fibre from by-products of processing fruits and greens and from cereals. LWT-Food Sci. Technol., 32: 503-508.
03. Mateos Aparicio, I., A. Redondo Cuenca and M.J. Villanueva Suarez, 2012. Broad bean and pea by products as sources of fibre rich ingredients: Potential antioxidant activity measured *in vitro*. J. Sci. Food Agric., 92: 92-703.
04. Hinneburg, I., H.J.D. Dorman and R. Hiltunen, 2006. Antioxidant activities of extracts from selected culinary herbs and spices. Food Chem., 97: 122-129.

05. Martinez-Tome, M., A.M. Jimenez, S. Ruggieri, N. Frega, R. Strabbioli and M.A. Murcia, 2001. Antioxidant properties of Mediterranean spices compared with common food additives. J. Food Prot., 64: 1412-1419.

06. Mateos-Aparicio, I., A. Redondo-Cuenca, M.J. Villanueva-Suarez, M.A. Zapata-Revilla and M.D. Tenorio-Sanz, 2010. Pea pod, broad bean pod and okara, potential sources of functional compounds. LWT-Food Sci. Technol., 43: 1467-1470.

07. Sofi, B.A., I.A. Wani, F.A. Masoodi, I. Saba and S. Muzaffar, 2013. Effect of gamma irradiation on physicochemical properties of broad bean (*Vicia faba* L.) starch. LWT-Food Sci. Technol., 54: 63-72.

08. Mahmoudi, S., M. Khali and N. Mahmoudi, 2013. [Study of the extraction of phenolic compounds from different parts of the artichoke flower (*Cynara scolymus* L.) (In French)]. Nature Technol., 9: 35-40.

09. Nabil, B., R. Ouaabou, M. Ouhammou, L. Saadouni and M. Mahrouz, 2020. Impact of particle size on functional, physicochemical properties and antioxidant activity of cladode powder (*Opuntia ficus-indica*). J. Food Sci. Technol., 57: 943-954.

10. Ouaabou, R., B. Nabil, M. Ouhammou, A. Idlimam and A. Lamharrar *et al*., 2020. Impact of solar drying process on drying kinetics, and on bioactive profile of moroccan sweet cherry. Renewable Energy, 151: 908-918.

11. George, S., P. Brat, P. Alter and M.J. Amiot, 2005. Rapid determination of polyphenols and vitamin C in plant-derived products. J. Agric. Food Chem., 53: 1370-1373.

12. Boizot, N. and J.P. Charpentier, 2006. [Rapid method for evaluating the content of phenolic compounds in the organs of a forest tree (In French)]. Cahier Techniques l'INRA, 1 : 79-82.

13. Puigventos, L., M. Navarro, E. Alechaga, O. Nunez, J. Saurina, S. Hernandez-Cassou and L. Puignou, 2015. Determination of polyphenolic profiles by liquid chromatography-electrospray-tandem mass spectrometry for the authentication of fruit extracts. Anal. Bioanal. Chem., 407: 597-608.

14. Brand-Williams, W., M.E. Cuvelier and C. Berset, 1995. Use of a free radical method to evaluate antioxidant activity. LWT-Food Sci. Technol., 28: 25-30.

15. Bellini, M., M. Walther and R. Bodmeier, 2019. Evaluation of manufacturing process parameters causing multilayer tablets delamination. Int. J. Pharm., Vol. 570, 10.1016/j.ijpharm.2019.118607

16. Ladoh, Y.C.F., S.D. Dibong, M.A. Nyegue, T.R.P. Djembissi and N.B. Lenta *et al*., 2014. [Antioxidant activity of methanolic extracts of *Phragmanthera capitata* (Loranthaceae) harvested from *Citrus sinensis* (In French)]. J. Applied Biosci., 84: 7636-7643.

17. Klimczak, I., M. Malecka, M. Szlachta and A. Gliszczynka-Swiglo, 2007. Effect of storage on the content of polyphenols, vitamin C and the antioxidant activity of orange juices Inga. J. Food Compos. Anal., 20: 313-322.

18. Lahnine, L., S. Mghazli, M. Mahrouz, N. Hidar and M. Ouhammou *et al*., 2017. Decontamination by gamma irradiation at low doses of *Thymus satureioides* and its impact on physico-chemical quality. Food Bioprod. Process., 104: 48-56.

19. Cheng, G.W. and P.J. Breen, 1991. [Phenylalanine Ammonia-Lyase (PAL) activity and concentrations of anthocyanins and phenolic compounds in the development of strawberry fruit jam (In French)]. Soc. Hortic. Sci., 116: 865-869.

20. Vega-Galvez, A., K.D. Scala, K. Rodriguez, R. Lemus-Mondaca, M. Miranda, J. Lopez and M. Perez-Won, 2009. Effect of air-drying temperature on physico-chemical properties, antioxidant capacity, colour and total phenolic content of red pepper (*Capsicum annuum*, L. var. Hungarian). Food Chem., 4: 647-653.

21. Arslan, D. and M.M. Ozcan, 2010. Study the effect of sun, oven and microwave drying on quality of onion slices. LWT-Food Sci. Technol., 43: 1121-1227.