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En vue de l'obtention du diplôme Master II Bioprocédés et technologies -Agro-Alimentaires,spécialité : Sciences des Aliments.

Thème

Valorisation des cosses de petits pois : séchage et formulation d'une Soupe

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DEDICATION

I dedicate this work to:

God all-powerful who has given us the courage and patience to carry out this work.

For those which gave me everything without anything in return

There are no words to describe how much my parent has meant to me throughout all my life.

Mom, you have given me so much, thanks for your faith in me, and for teaching me that I should never give up. Thanks for lending me your ear on countless occasions when I needed to vent my frustrations...

My dear sisters and dear brothers

To my sister fahima who supported me during all my studies

To my sister Kahinaand her children

To my binomial and friend with which I have division a good moment Cherifi Fatima and her family

To my friends Farida, Faouzi and all

And finally all those who contributed to the realization of this work.

Hassina

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Dear Mom, you have given me so much, thanks for your faith in me, and for teaching me that I should never give up. Thanks for lending me your ear on countless occasions when I needed to vent my frustrations.

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To my dear grandmother

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To my friends Farida etFaouzi and all

And finally all those who contributed to the realization of this work.

Fatima

List of abbreviation

ANOVA: Analysis Of Varians

CE: Catechin Equivalent

CFC: Crude Fiber Content

DF: Dietary Fibers

ΔE: total color difference

DM: Dry Matter

DPPH: 2, 2-Diphenyl-1-picrylhydrazyl

DW: Dry Weight

GAE: Equivalent Gallic Acid

IDF: Insoluble Dietary Fiber

MC: The Moisture Content

MW: Microwave

MWD: Drying by Microwave

OCR: Oil Retention Capacity

OP: Open-Air

QE: Quercetin Equivalent

RC: Reducing Power

RSA: Radical Scavenging Activity

SC: Swelling Capacity

SD: Standard Deviation

SDF: Soluble Dietary Fiber

TAC: Total Ash Capacity

TFC: Total Flavonoid Content

TPC: Total Phenolic Content

TTC: Total Tannins Content

UAE: Ultrasound Assisted Extraction

WCR: Water Retention Capacity

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Introduction

Introduction

The large quantities of by-products generated during the processing of plant food imply economic and environmental problems due to their high volumes and elimination costs.Agro-industrial wastes comprise plant residual material generated by processing, such as peels, shells, husks, pods, skins, stems, exhausted pulp and other parts of the plant material are not intended for food production. **(Mateos-Aparicio et al. 2012).**

Taking into account rich chemical composition of such materials, recently a great attention has been addressed towards their re-utilization for various purposes within the biorefinery concept **(Cherubini & Ulgiati 2010)** of waste biomass conversion into high-added value products. In food industry, many plant waste streams are regarded as secondary raw materials for the extraction of nutritionally valuable components, primarily material with appreciable amounts of colorants, antioxidants, but also dietary fibre to some extent **(Galanakis. 2012; Laufenberg, Kunz & Nystroem. 2003; Schieber, Stintzing & Carle. 2001)**. Being the most abundant component of plant materials (up to 90% of the dry weight) of higher plant tissues and having positive health effects.**(O"Neill & York 2003).**

Most legumes are consumed after a simple industrial process in which the pod is removed and the seed is prepared as fresh or frozen food **(Mateos-Aparicio et al. 2012).**Among the widely consumed products and cultivated worldwide, peasare retained for their nutritional value and the significant amount of by-products (pod) that give off. According to the United Nations Food and Agriculture Organization, world production is 15.87 million tons, of which 67% are by-products and Algeria holds the fifth position with a production of 186348 tonnes **(FAO, 2013).**

In a context of resource preservation, the determination of bioactive compounds from by-products together with their re-valorization in the food, cosmetic or pharmaceutical industries give rise to an increasing social, economic and scientific interest.

In order to contribute to the valorization of this cultivation and to overcome the lack of knowledge about all aspects concerning itsby-product in Algeria, current study has been designed to investigate drying effect of pea pods local variety.

Drying is among the methods that the purposes to reduce post harvest costs and to produce high quality dried products. Conventional air-drying has been widely used in industrial drying of food products, but this method is energy-intensive and time-consuming and often produces poor quality products. Hence, advanced drying methods are often recommended to reduce long drying times and poor product quality, namely microwave drying (**Sumnu et al.2015).**

To the best of our knowledge no research was conducted to investigate the drying of pea pods. In the view of the health promoting properties and high nutritional benefits of pea pods, the present study was carried out to compare the effects of free air drying, conventional oven drying and microwave drying on their bioactive components and their antioxidant activities.

Soup with added antioxidants from natural sources appear to be a convenient food format, to satisfy consumer interest in original beneficial effects, and health benefits of added antioxidants; creation of new high value-added products. Thus, a formulation of dehydratedsoup with polyphenols and dietary fiber of pea pod, at laboratory scale, was performed.

Bibliography

I.1. By-products in the food industry

Food wastes are organic residues from the processing of agricultural raw materials to food.The fact that these substances are removed from the production process as undesirable ingredients makes them, by definition of most European legislations, wastes.The term ‘‘by-product,’’ which is common in industry, points up that these are mostly ulterior usable substances, often with a market value.The specific amount of waste production is defined as the mass of accumulated waste divided by the mass of the saleable product, hereafter referred to as the ‘‘specific waste index’’(**Oreopoulou, V. and W. Russ. 2007).**

I.1.1.Management and ecological problems

Waste disposal and by-product management in the food processing industry cause problems within the areas of environmental protection and sustainability.Biological stability and the potential growth of pathogens**(Kirchgessner. 1997; Westendorf. 2000).**

- High water content;
- Changes due to enzymatic activity **(Oreopoulou, V. and W. Russ. 2007).**
- Rapid autoxidation**(Oreopoulou, V. and W. Russ. 2007).**

The primary objective in waste management is to completely prevent the production of waste all together, if possible **(Faulstich and Schenkel. 1994).** Second, if waste must be produced, then it is to be recycled.Many of the existing agricultural solutions of waste disposal are balancing acts between legal regulations and the best ecological and economical solutions.**(Werschnitzky et al. 1985; Russ et al. 1997; Russ and Meyer-Pittroff. 2004).** Typical ways of reuse of food wastes:

- *General Methods*: three general methods of waste disposal not associated with agricultural practices are: incineration, anaerobic fermentation and composting**(Oreopoulou, V. and W. Russ. 2007).**
- *Agricultural Methods*: the two general methods of traditional waste utilization have been to use the waste as either animal feed or fertilizer.**(Werschnitzky et al. 1985; Russ et al. 1997; Russ and Meyer-Pittroff. 2004).**
- *New Methods***:** new methods of disposal focus on certain contents of the food waste**:** Using of vegetable by-products for the recovery of proteins, dietary fibers, antioxidants and colorants **(Oreopoulou, V. and W. Russ. 2007).**

I.2.Overview of Pea pod

Peas (*Pisum sativum* L.)originated in Abyssinia andAfghanistan, with areas in the Mediterranean area colonized later.From these areas the pea spread to other parts of Europe and Asia.Botanists have described wild species which differ from cultivated peas only by morphological characters**(Cousin, 1997).**

I.2.1. Morphological description

The pea pod (or pod) is an oblong-oval dry fruit 3.5-15 cm × 1-2.5 cm, pendent **(Westphal and Arora 1989),** its colour before maturity is generally green, is made up of a single carpel (unilocular) and opens at maturity by two dehiscence slits, one at the level of the placentas and the other at the midrib of the carpel. The pod is divided into two valves **(Fig.1)**, this property makes it possible to shell and collect the seed The pea pod is provided with a parchment (a thin solid film), which gives it a rigid appearance and allows its dehiscence **(Fig.1).(Trebuchet et al. 1953)**

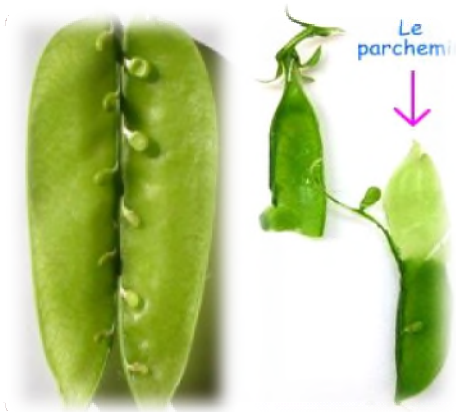

Figure 1: Photograph ofpea pod (a) and parchment (b)

I.2.2. Chemical composition

Pea pod is a prized diet component since it contains considerable amounts of valuable nutrients: fiber, sugar, protein, minerals **(Tab.01)**, and secondary metabolites namely phenolic compounds.**(Mateos-Aparicio et al. 2010).**

Table 01: Chemical composition of pea pod(g/100g dry matter)**(Mateos-Aparicio et al. 2010)**

Element	Content	Element	Content
Protein	10.8 ± 0.2		
Fat	1.3± 0.5	Potassium	1.03 ±0.3
LMWC	22.7± 0.5	Sodium	0.14 ±0.0
Sucrose	7.9± 0.2	Calcium	0.77 ±0.0
Glucose	11.9±0.5	Magnesium	0.21 ±0.0
Fructose	1.2± 0.3		
Starch	3.7± 0.2	Iron	1.20 ±0.1
Dietary fibre (DF)	58.6±1.0	Manganese	0.27 ±0.0
Insoluble DF	4.2 ±1.2	Zinc	0.16 ±0.0
Soluble DF	54.4± 0.6		
Ash	6.6±0.1		

LMWC: low molecular weight carbohydrates

I.2.3. Phenolic composition

Phenolic compounds include a wide range of chemicals comprising at least one aromatic ring and one or more hydroxyl groups, in addition to other constituentspolyphenols range from simple molecules to highly polymerized compounds, the most important are: phenolic acids, flavonoids and tannins**(Scalbert et al. 2005).**

a- Flavonoids

Flavonoids have the C6–C3–C6 general structural backbone in which the two C6 units (Ring A and Ring B) are of phenolic nature. Due to the hydroxylation pattern and variations in the chromane ring (Ring C), flavonoids can be further divided into different sub-groups such as flavones, flavonols and anthocyanins **(Tsao 2010).**

b- Phenolic acids

There are two main classes of phenolic acid; the derivatives of benzoic acid (C1-C6) and derivatives of cinnamic acid (C3-C6) **(Tsao 2010).**The concentration of the hydroxybenzoic acid is generally very low in edible vegetable. These derivatives are quite rare in the human diet by abondanthydroxycinnamic acids (**Macheix et al. 2005).**

c- Tannins

Tannins are complex phenolic compounds obtained from the condensation of simple phenols. They are divided into two groups: hydrolysable tannins (carbohydrate ester and phenolic acids) and condensed tannins (dimers, oligomers and/or polymers of flavannes-3-ols or flavannes -3, 4-diols)(**Macheix et al. 2005).**

- Pea pod showed to contain polyphenols such as phenolic acids, flavonoids and tannins**(Mateos-Aparicio etal., 2012).**

I.2.4. Potential use

With the considerable increase in production and processing of plants, significant quantities of by-products represent a major problem of elimination for the industry. However, these by-products are promising as a source of some compounds and ingredients that are of high value **(Mateos-Aparicio Cediel. 2009).** Indeed, pea husk as the main by-product of the traditional pea cannery industry presents, like many wastes from the agro-food industry, economic and environmental problems**(Mateos-Aparicio Et al. 2012)**

At first glance, pea pods appear to be a by-product of little food interest. More in-depth analyzes show the presence of phenolic compounds, pigments, fibers and minerals, whose valorization as food or functional ingredients (with a view to improving the functionality of food products) could be of great economic interest.**(Mateos-Aparicio et al. 2012)**

Pods could be important in the food industry as an ingredient rich in dietary fibers. It is a rich source of cellulose, with a non-negligible proportion of pectin. Both of these compounds are important in human nutrition, but the expected potential effects of such by-products are mainly related to those associated with insoluble fibers, such as regulation of intestinal function and water retention.**(Mateos-Aparicio et al. 2010)**

Pods generated from the agro-industrial practices might be alsoconsidered a key source of bioactive and functional components, polyphenols that can be used for their nutritional and added value properties. Indeed, the antioxidant activity of phenolic compounds is of particular interest in the development of new products or bio-additives having great functional properties. In addition, extracts rich in phenolic compounds could significantly improve the quality of food products in the color, flavor and flavor of fresh and / or processed foods.**(Scalbert et al. 2005)**

I.3. Drying process

Drying is one of the oldest methods of preserving food. During drying, moisture is removed from the food, reducing the growth potential of microorganisms and undesirable chemical reactions **(Gowen et al. 2008).**Drying is an operation consisting in removing a part of the water from a biomaterial, by vaporization, the final product called "dried product" is obtained in a solid form of variable size, an operation of thermal separation, in the sense that it is necessary to supply the vaporization energy of the solvent, so that it leaves the product in the form of steam.**(Vasseur 2009)**

The reasons for drying are almost as numerous as the products to be dried, but they can be grouped in three main categories:

- Allow or facilitate the conservation of products and cushion the seasonal nature of certain agricultural or industrial activities;
- To reduce the mass and the volume of the food, to reduce their bulk and facilitate their transport;
- Give a presentation, structure or functionality specific to the product.**(Alibas 2007; Bimbenet et al. 2002).**
- Interactions between water and other constituents depend on the mobility of water and solutes, resulting in reactions, physical transformations, and mechanical phenomena during drying, storage and consumption **(Bonazzi and Dumoulin 2011):**

Biochemical reactions: Maillard reactions, oxidation of vitamins and fats, denaturation of proteins, enzymatic reactions, etc. Some pre-treatments reduce the speed of these reactions **(Bonazzi and Bimbenet 2003).**

Mechanical phenomena: Crusting, deformation cracks, etc... These changes are only partially reversible during rehydration **(Mafart 1991).**

Physical Transfers: Decreased water activity, vitreous transition, fat melting, evaporation of volatile constituents, migration or retention of volatile or non-volatile constituents **(Bonazzi and Bimbenet 2008).**

I.3.1. Drying techniques

There are many different drying methods that have been applied to fruits and vegetables, from the most basic technique such as air drying to methods like microwave drying:

a- Open-air drying

Drying/dehydration in the open air are the world's oldest food preservation methods. For millennia, vegetables were exposed in open air before being stored. Naturel open air-drying is practiced widely in the world, but has some problems related to the contamination by dirt, dust and infestation by insects, rodents and other animals. Therefore, the drying process should be undertaken in closed equipment’s to improve the quality of the final product

(**Ertekin and Yaldiz. 2004).**

b- Oven drying

Conventional air-drying or hot air drying is one of the most frequently used operations for food dehydration. Air-drying, in particular, is an ancient process used to preserve foods in which the solid to be dried is exposed to a continuously flowing hot stream of air where moisture evaporates. The phenomena underlying this process are a complex problem involving simultaneous mass and energy transport in a hygroscopic, shrinking system. Air-drying offers dehydrated products that can have an extended life of year but, unfortunately, the quality of a conventionally dried product is usually drastically reduced from that of the original foodstuff **(Vasseur J.2009).**

c- Microwave drying

Drying by microwave (MWD) is an alternative drying method-gaining popularity in recent years for a wide variety of industrial food products **(Krokida and Maroulis 2000)**. It can be regarded as a rapid dehydration process significantly reducing the drying time, up to 89% of the hot air drying time according to certain authors **(Maskan 2001); (Therdthai and Zhou 2009).**

MWD can be assigned as a " volumetric heating process", MW electromagnetic energy being directly absorbed by water-containing materials and converted into heat by molecular agitation **(Khraisheh, Cooper et al. 1997; Piyasena, Mohared et al. 2003)**. A MWD process consists in three drying periods: (1) a heating-up period in which MW energy is converted into thermal energy within the moist materials and the product temperature increases with time, (2) a rapid drying period during which thermal energy is used for moisture vaporization and transfer and (3) a reduced drying rate period during which the local moisture is reduced to a point that the energy needed for moisture vaporization is lower than the thermal energy induced by MW **(Maskan 2001; Zhang, Himmel et al.2006; Bakirci, Ozyurt et al. 2011).**

I.4. Soup

I.4.1. Definition

Asoup is a liquid or creamy food (exceptionally without liquid part), cold or hot, which is usually served at the beginning of the meal **(Dukan, P. 1998)**.Industrial soups, intended for direct consumption, are in liquid, dehydrated or frozen form.

Dehydrated soups are dry products that can be consumed after reconstitution with water. One distinguishes the instant soups dehydrated (preparations from boiling water, without cooking) and soups dehydrated to cook. For the latter, several minutes of cooking, to the pan, are necessary to reconstitute the product.

According to the "Code of Good Practice for Soups, Broths and Consumptions", the raw materials that can be used for making soups are:Meat, fish, cereals and legumes, vegetables, pasta, dairy products, edible fats, spices, natural extracts, flavorings, sodium chloride or any other foodstuff intended to improve the palatability of product, as well as authorized additives. **(Dukan, P. 1998)**

I.4.2. Health Benefits

- Source of vitamins and minerals: Soup is a quick and effective way to refill vegetables; it provides a variety of essential nutrients to our body.

- A satisfying meal:A soup at the opening of a meal would have a satietogenic effect, thanks to its richness in fibers; it would be extremely satisfying, thus limiting the nibbles between meals.

- Reduces cholesterol: Due to its richness in vegetables (rich in soluble fiber), the soup has a positive effect on cholesterol, limiting its absorption in our body and intestinal absorption of glucose.

- Hydrate: Consuming soups also helps to consume water, thus promoting the hydration of the body.

- Reduces cardiovascular risks: Thanks to its high dietary fiber content, its consumption also promotes the fight against cardiovascular risks, reducing the risk of coronary heart disease and certain types of cancer has been underlined by several epidemiological studies.

- Fight against overweight: Soup would be an excellent cut of hunger on our body - hence the interest of the consumption of soups during a low-calorie meal, thus preventing overweight thanks to the low caloric density of vegetables.

- Intestinal regulation: Due to its richness in insoluble dietary fiber.**(Cogos et al. 2010)**

Material & methods

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0II. Material and methods

II.1. Plant materiel

Fresh pea (*Pisum sativum*)was purchased from local market, Bejaia city (Algeria) in March 2017, then washed by distilled water. The removal of pea seed from its pod was made manually. The whole pods were dried by different methods.

II.2. Evaluation of moisture content

Thermal drying method was used in the determination of moisture content of the sample **(AOAC, 1990)**. 5g of samples were placed in an oven (ECOCELL) at 105 °C, until constant weight. The moisture content (MC) was calculated by expressing the weight loss upon drying as a fraction of the initial weight of sample used: $MC\,(\%) = \left(\frac{w_i - w_f}{w_i}\right).100$. Where: w_i: initial weight of sample (g) and w_f: final weight after drying (g)

II.3. Drying process

Three methods for drying pea pods were investigated, open air drying, oven drying and microwave drying. Before drying, samples were cut into squares (≈ 1 cm of dimension)

II.3.1. Open-air drying

Open-air drying experiments were conducted by placing broad bean pod, on wire mesh racks placed on a table(**Fig.3),** and set out in the open outdoors away from any structures that would disrupt the natural air flow patterns. Air temperatures were taken using a digital thermometer and the mass was periodically measured until constant value.

Figure02: Photograph of pea pods in open air-drying process

II.3.2. Oven drying

The pea pods were dried in a ventilated oven (MEMMERT, UFB400), at different temperatures (40 °C, 60 °C, 80 °C, 100 °C and 120 °C), until constant weight.

II.3.3. Microwave drying

Microwave drying experiments were performed in a domestic microwave oven (Maxipower. Germany) The apparatus was equipped with a digital control system for irradiation time and microwave power (the latter linearly adjustable from 100 to1000 W). Different microwave power (100, 300, 500, 700 and 900W), were used in the drying of broad bean pod, until constant weight.

II.4. Grinding, sieving and water activity

The dried pods were ground using an electric coffee mill (KSW445 CB) and sieved to granulometry < 500 µm and < 250µm prior to extraction. The water activity (aw) of powders was determined by HygroPalm AW. The fine powderswere stored in air tight containers until use.

II.5. Color assessment

Color of the samples was measured using a color reader (PCE-TCR 200, USA) under white light at 90° angle. The colorimetric coordinates of the powders of cactus peel, were computed in the CIELAB scale. In this scale, each color is numerically specified by a unique set of three cylindrical coordinates ($L^*a^*b^*$): L^*indicates the luminance and changes from 0 for black to 100 for white, a^*changes from - 60 for green to + 60 for red, b^*changes from - 60 for blue to + 60 for yellow**(Achat et al. 2012).**The total color difference (ΔE) was then determined using the following equation: $\Delta E = \sqrt{(L - L_0)^2 + (a - a_0)^2 + (b - b_0)^2}$. The subscript "$_0$" refers to the fresh sample for pea pod by-product.

II.6. Functional properties

Functional properties measured included swelling, water retention capacity and fat adsorption capacity based on the methods described by**Gouw, V. P., J. Jung, et al. 2017**. as follow:

II.6.1. Swelling capacity (SC)

The sample (100 mg) was hydrated in a measuring cylinder with 10 ml distilled water at room temperature. After 18 h, the volume (ml) occupied was recorded, and SC was expressed as volume (ml)/g of original sample.

II.6.2. Water retention capacity (WRC)

The sample (500 mg) was hydrated in 30 ml distilled water in a centrifuge tube at room temperature. After 24 h, samples were centrifuged (5000g; 30 min). The supernatant was decanted and residue fresh weight was recorded. WRC was calculated as the amount of water retained by the pellet (g water/g sample dry weight)

II.6.3. Oil retention capacity (ORC)

The same protocol as above was followed, substituting extra virgin olive oil (acidity 0.7°) for distilled water. ORC was expressed as g oil/g sample dry weight.

II.7. Determination of total ash content

The ashes of a biological material represent the inorganic residues, obtained after calcinationof the organic matter. This ash, which is generally whitish, gives an idea of the amount of mineral elements present in the food **(Treche 1986).**

The total ash content of the dried samples is determined according to the method described by**Treche, 1986:** 1g of the sample in crucible is placed in a muffle furnace at 550°C, for five hours and reweighed after cooling in a desiccator.Thus,the percentage of the total ash content (TAC) is calculated: $TAC = \frac{Mm-Mc}{M0-Mc} \times 100$. Where$M_m$: Mass of sample after incineration, Mc: Masse of crucible and M_0: Mass of sample before incineration

II.8.Determination of crude fiber

The method is based on the solubilization of non-cellulosic compounds by sulfuric acid and sodium hydroxide solutions, according to the method of**(Weende1985).**

-Weigh in a crucible 1g of sample add 100 ml of sulfuric acid (1, 25%)

-Preheating until the beginning of boiling, to count exactly 30 minute

-Draining sulfuric acid wash three times with 30ml of hot distilled water

-Add 100 ml of NaOH (0,313N)

-Preheating until the beginning of boiling, (30 minute)

-Filter and wash 3 times, with 30 ml of hot distilled water

-Perform a last washing with cold distilled water and then wash 3 times the crucible content with 25 ml of acetone,

-Remove the crucibles and determine the dry weight, after drying at 105°Cfor an hour or up to constant weight. Let cool in a desiccator. This weight represents the crude fiber plus ash content in comparison to initial weight.

-When ash content is also required, the crucible are placed in a muffle furnace at 550°C for five hours and reweighed after cooling indesiccators.

- The difference in weight in comparison to preceding weight represents the crude fiber content without ash.

II.9. Extraction of polyphenols

Extractions were performed using an ultrasonic processor (SonicsVCX 500, Connecticut, USA)according to the protocol proposed by **Dahmoune et al.2014.** Briefly, 1 g of powder of pea pod was extracted with 40 mL of ethanol 64 % during 15 min of holding time and 78 % for amplitude. The extracts were filtered through Whatman n°3 paper and the recovered was transferred to 100 mL volumetric flask.

II.10. Determination of polyphenols

II.10.1. Total phenolic content

The polyphenol content of the pea pod extract was quantified using the Folin-Ciocalteu reagent by reference to the method described by **George et al. 2005.**Oxidations of phenolic compounds with this reagent include reaction with the mixture of $H_3PW_{12}O_{40}$ and $H_3PMo_{12}O_{40}$ acids in the alkaline medium. At this reaction a mix of blue oxides is formed. Thus, a 2.5 mL sample of water-diluted Folin-Ciolcateu reagent (1/10) was added to the different extracts. The mixture was incubated for 2 min at room temperature, and 2 mL of sodium carbonate (75 g/L) was added. The mixture was incubated for 15 min at 50 °C and finally cooled in a water-ice bath. The absorbance was then read at 760 nm versus the prepared blank using UV-Vis light spectrophotometer (SHIMADZU-UV-1800, Germany), was immediately measured.TPC concentration was calculated from a calibration curve, using gallic acid as a standard and the results were expressed as mg gallic acid equivalents perg of dry matter (mg GAE/ g DM).

II.10.2.Total flavonoïds content

Flavonoïds have a free hydroxyl (OH) group at the 5-position which is capable of giving, with the group CO, a complex colored with aluminum chloride. They form yellowish complexes by chelation of metals (iron and aluminum). This reflects the fact that metal (Al) loses two electrons to join two oxygen atoms of the phenolic nucleus acting as an electron donor **(Chang et al. 2002).**Briefly, 1 mL of extract was added to 1 mL of 2% methanolic $AlCl_3 \cdot 6H_2O$ (2%),and mixed using vortex mixer (Ev-120, tehtnicazelezniki, Germany) for ≈ 10 s,then incubated for 10 min at room temperature. The absorbance was after read at 415 nm versus the prepared blank using Uv-Vis light spectrophotometer (SHIMADZU-UV-1800, Germany). Results of TFC were expressed in mg quercetin equivalents/g dry weight of fine powder of pea pod (mg EQ/ g DW).

II.10.3. Total tannins content

The condensed tannins are determined by the Vanillin in an acid medium **(Price et al. 1978).**This method is based on the ability of vanillin to react with condensed tannin units in the presence of acid to produce a colored complex measured at 500 nm.
0.l mL of extract are added to 1 mL of reagent of vanillin [mixture of equal volume of 8% HCl (37%) and vanillin (4%)] for the determination of condensed tannins. , the tubes are maintained at 30 ° C for 20 min, The absorbance was then read at 500 nm versus the prepared blank using Uv-Vis light spectrophotometer (SHIMADZU-UV-1800, Germany). Catechin is used as a standard and results are expressed in mg of catechin equivalent per 100 mg of flour dry matter(mg CE/ 100 mg DM).

II.11. Antioxidant assays

II.11.1. Radical scavenging test

The radical-scavenging activity (RSA) of samples was evaluated by the DPPH• assay. DPPH (2,2-diphenyl-1-picrylhydrazyl) is a stable highly colored free radical that can abstract labilehydrogen atoms from phenolic antioxidant (ArOH) with concomitant formation of a colorless hydrazine (DPPH-H), according toequationand figure 4**(Molyneux 2004)**. The free RSA of an extract can be expressed as the percentage of DPPH reduced by a given amount of extract. The free RSA was measured, following **(Achat et al. 2012)** method. 1 ml of extract was added to 2 ml of DPPH solution (2.10^{-4}M/L in methanol) and the mixture was left in the dark at room temperature for 20 min and the absorbance was measured at 515 nm**.**The quantity (mg) of dry extract per mL of reaction medium necessary to decrease the initial DPPH radical concentration by 50% (IC_{50}) was determined using an exponential curve. The total RSA of each extract was expressed as the percentage of DPPH reduced and was calculated by the following equation:

$$\text{RSA (\%)} = \frac{\text{Ac}-\text{As}}{\text{AC}} \times 100$$

Ac: Absorbance of DPPH solution after reaction with the extract

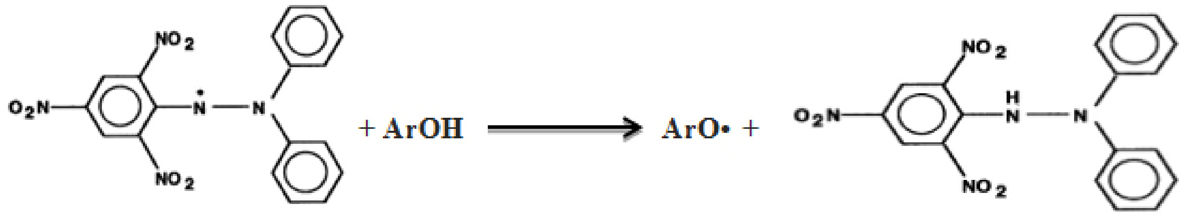
As: Absorbance of DPPH solution without any antioxidant

A_0, absorbance of DPPH•solution without any antioxidant;A, absorbance of DPPH solution after reaction with the extract.

.

:

$$DPPH^{\bullet} + ArOH \xrightarrow{k} DPPH\text{-}H + ArO\bullet$$



Diphenylpicrylhydrazyl (free radical)

Diphenylpicrylhydrazine (Non radical)

Figure03: DPPH• radical reduction **(Molyneux 2004; Achat et al. 2012)**

II.11.2. Reducing power assay

The reducing power was determined according to the method of **(Oyaizu 1986).** Various concentrations of ethanolic extracts (1 ml) were mixed with 2.5 ml of 0.2 M/L sodium phosphate buffer (pH 6.6) and 2.5 ml of potassium ferricyanide (1%). The mixture was incubated at 50°C for 20 min. After, 2.5 ml of trichloroacetic acid (10 %, w/v) were added to 2.5 ml of mixture. The whole was mixed with 2.5 ml distilledwater and 0.5 ml of ferric chloride (0.1%). The absorbance was measured at 700 nm against a blank. A higher absorbance indicates higher reducing power. EC_{50} (**µ**g ml^{-1}) is the effective concentration at which the absorbance was 0.5 for reducing power and was obtained by interpolation from linear regression analysis.

II.12. Formulation of soup at laboratory scale

II.12.1. Manufacturing of soup

The preparation of soup was made in the laboratory 3BS (University of Bejaia) respecting the diagram for making standardlyophilized vegetable soup with addition of the pea pod (**Fig04).**

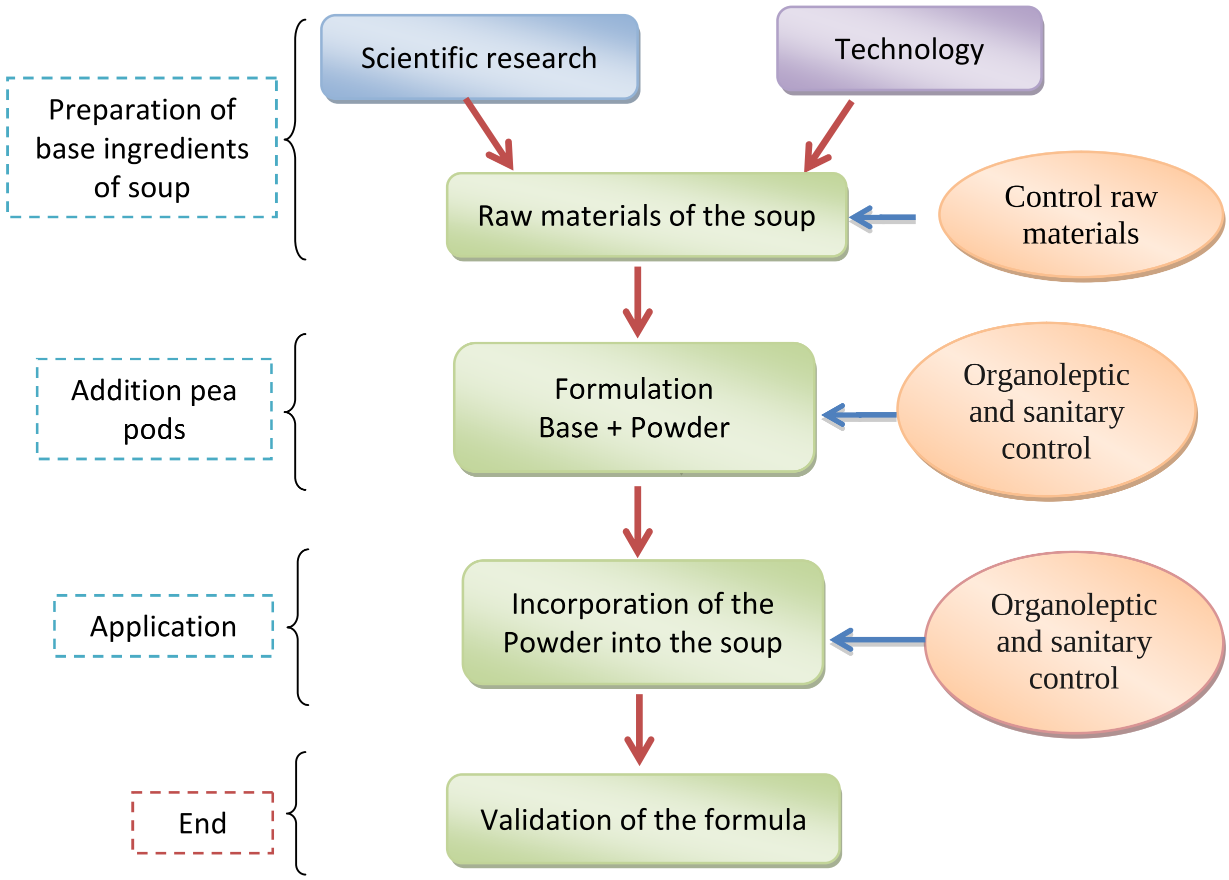


Figure 04: Diagram for making a soup enriched with pea pod powder

- After several attempts to optimize the formula of soup, we opted for the recipe summarized in the table below:

Table 02:Recipe for a dehydrated soup enriched with polyphenols and dietary fiber.

Recipe	Base (g)	Pea pod polyphenols (g)	Pea pod fiber (g)
Soup Enriched with Polyphenols and Dietary Fiber	86g	(5g)	(5g)

- Ingredients:

Pea pod powder, Broth of vegetables in the lyophilized state, Potato powder, Sugar, Salt, Powder milk, Spices and flavors

II.12.2. Physicochemical properties of soup

The physicochemical control of the soup aims to guarantee a better stability and a consistency of its organoleptic characteristics.Physico-chemical properties of the dehydrated soup enriched with dried pea pod at 24°C and 1000 W) were determined **(Table 03).** These tests were carried out at the laboratory of the QualilabTesting and Quality Analysis.

Table 03: Physicochemical properties of dehydrated soup

Measure	Method
pH at 10%	/
Titrable acidity expressed as 10%	/
Water Activity (AW)	/
Dry extract %	/
Humidity %	/
Dissolution %	/
Not dissolved %	/
Texture at 10 %	/

II.12.3. Microbiological analysis

The purpose of the microbiological analysis is to ensure that the prepared soup is of adequate hygienic and commercial quality.

Table 04: Microbiological analysis of manufactured soup

Microorganisms	Selective mediums	Incubation temperature	Incubation time	Method
Aerobic germs	PCA	30°C	72h	N°12.59.52
Coliforms	VRBL	37°C	24h	GALZY
Fecal coliforms	Water peptone exempt d'indole	44°C	24h	GALZY
Staphylococcus aureus	Baird-Parker	37°C	48h	ISO 6888-1
Clostridium sulfito-reducer	TSC	46°C	24h	NF T 90-415
Salmonella	SS	37°C	24h	JO N°42 Arr du 23.01.05

PCA: Plate count agar
VRBL: Violet crystal / Neutral red / Biliary salts / agar lactose
Baird-Parker:isolation medium of staphylococcus
TSC: Tryptone / Sulfite / Cycloserine
SS: Salmonella-Shigella

II.12.4. Antioxidant activity

The Radical scavenging capacity was measured in manufactured soup by the DPPH$^{\bullet}$ assay (Section II.11.1). The TPC content in enriched soupwas also determined by using colorimetric methods (Section II.10.1).

II.12.5. Total crude fiber content

The amount of total fiber in standard soup and enriched soup were determined by using the protocol of (**Weends 1985)**(Section II.8).

II.13. Statistical analysis

All experiments were conducted in triplicate and results are expressed as mean ± standard deviation (SD). Data were treated for multiple comparisons by analysis of variance (ANOVA) in the software JMP7 (Trial Version 7.0.3, Stat Ease Inc., Minneapolis, MN, USA), Evaluations were based on the $p< 0.05$ significance level.

Results & discussion

III. Results and discussion

III.1. Moisture content and water activity

Drying is the process of removing the moisture in the product up to certain threshold value by evaporation. In this way. The product can be stored for a long period. Inactivate enzymes and deteriorative microorganisms and reduce water activity (**Maskan 2001**; **Alibas 2007).**The drying efficiency was evaluated in terms of water loss; moisture and water activity for the various powders obtained (after drying and grinding) in the various conditions applied**(Tab.5).**The water content of pea pods was 90.160 ± 0.671%.

Table 05: The water activity of dried pea pods

Températures (°C)	a_w
24 (Open-Air)	0.587± 0.009
40	0.326± 0.043
60	0.309± 0.014
80	0.266± 0.003
100	0.260± 0.012
120	0.244± 0.036
Power (W)	a_w
200	0.379± 0.043
400	0.362± 0.043
600	0.314± 0.119
800	0.266± 0.016
1000	0.211± 0.034

High water activity indicates more water available for biochemical reactions and hence, shorter shelf life. Generally food with a_w< 0.6 is considered as microbiologically stable and if there is any spoilage occurs, it is induced by chemical reactions rather than by micro-organism **(Quek et al. 2007)**. From the results, the water activities of the pea pod powders were in the range of 0.21 – 0.58. This means that the pea pod powders were relatively stable microbiologically. However, the storage conditions also played an important role in this matter.

The results of the water activity show that there is no difference between microwave and oven drying methods. On the other hand, the water activity of the open-air drying method is higher compared to the two other methods. This confirms the microbiological efficiency of drying by microwave and oven.

The drying process enhances qualities characteristics of fruits and vegetables, while preserving the polyphenol composition. Indeed, water represents a source of degradation of phenolic compounds by enzymatic oxidation such as polyphenol oxidase, which modifies their structures **(Tomás-Barberán and Espin. 2001).**

III.2. Colour assessment

Color is one of the more important quality parameters in dehydrated fruits and vegetables. Undoubtedly, possible color changes would influence the organoleptic properties of dried pea pod and would limit their potential applications **(Femenia et al. 2003)**.The differences in color index (ΔE) as a function of temperature and drying power are shown in table 06.

Table 06: The color assessment of dried pea pod

Temperature (°C)	Color(ΔE)	Power (W)	Color (ΔE)
24 (Open-Air)	17.057±0.360	200	14.55±0.673
40	24.19± 0.813	400	16.797±0.602
60	25.34± 0.081	600	19.380±0.575
80	28.30± 0.186	800	28.572±0.889
100	40.91± 0.262	1000	68.794±0.092
120	49.76± 0.020		

The powders dried in the open air, oven and in the microwave oven show a variability of color. The lowest total color difference ΔE value, which indicates the magnitude of the color difference between fresh and dried pods, was obtained with microwave at 200 W(14.55± 0.673), followed by open-air drying (17.71±0.360). Howeverthe highestΔE was recorded at the high microwave power level (68.794±0.092, at 1000W) and at high temperature (49.76± 0.020 at 120 °C).This could be explained by Maillard reactions taking place oven drying. **Martins et al. 2005** stated that increased temperature caused an increase of the reactivity between the sugar and the amino group.

Many reactions can affect color during the thermal process of fruits and their derivatives. The most common are pigment degradation, especially carotenoids and chlorophyll, browning reactions, oxidation of ascorbic acid **(Barreiro et al. 1997; Lee and Coates. 1999; Lozano and Ibarz. 1997).**

In microwave heating the temperature on the surface could not be reached to the required level for browning reactions. **Sumnu, Sahin et al. 2005**,also showed that microwave heating did not resulting in any significant color change in cakes.

III.3. Functional properties

These properties are related to the fiber characteristics to allow a fiber to swell, including crystallinity, the surface property (e.g. porosity, charge density, and polar groups), and hydrophobic nature **(Gouw et al. 2017)**, which might be varied depending on the types of functional properties.

III.3.1. Swelling capacity

SC of pea pod dried with different methods drying was measured. The corresponding results are shown in figure 07.

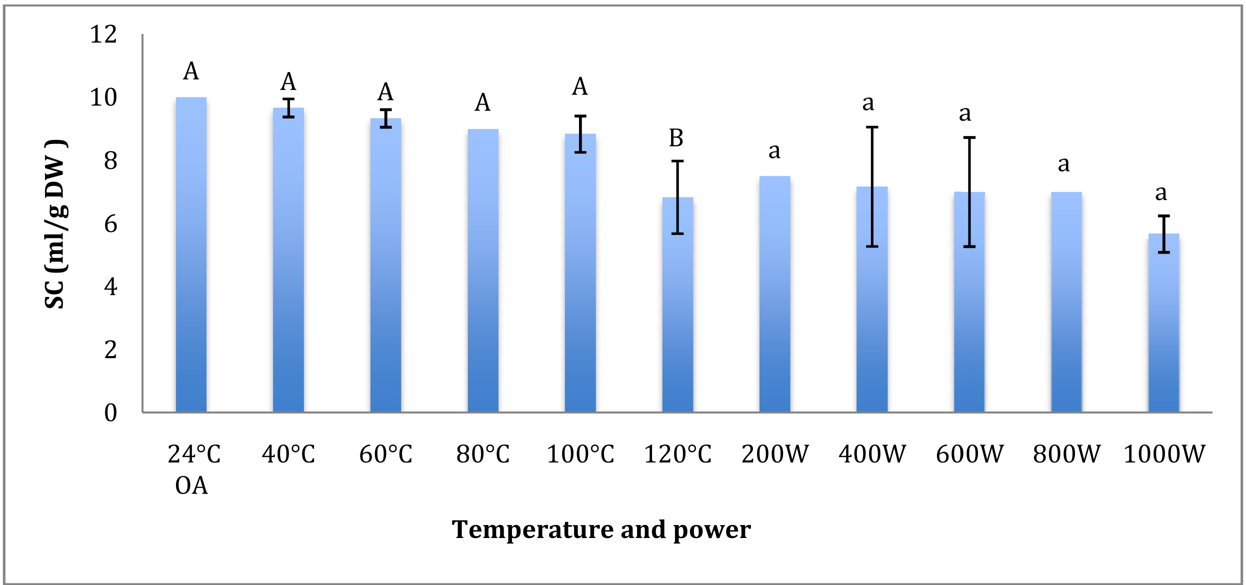


Figure 05: Effect of drying methods on swelling capacity(SC) of the pea pod.

Open-air drying possessed the highest SC (10± 0.00ml/g DW), compared to other drying methods.The microwave drying decreases the SC pea pod until 5.666 ± 0.577 ml/g DW at 1000W. The statistical study showed that there is nosignificant difference (p<0.05), between powers (200 to 1000 W) and temperatures (24 to 100 °C). Whereas, the SC of 120 °C was significantly higher (6.833± 1.154 ml/g DW), at p<0.05.Thus, SC is influenced only by high temperatures. The dried pea pods in the open air are rich in fibers which have many voids: presentingavailable areas for water binding. **(Gouw et al. 2017)**

III.3.2. Water retention capacity

Water retention capacity is an important property of dietary fiber from both a physiological and technological point of view; and was related to the dietary fiber soluble content. Therefore, the high WRC of DF concentrates from vegetables suggests that these materials can be used an functional ingredients to reduced calories, and modify the viscosity and texture of the products**(N. Ghanem et al. 2012).**WRC results of pea pod, dried at different drying microwave power levels and temperatures were illustratedin figure 08.

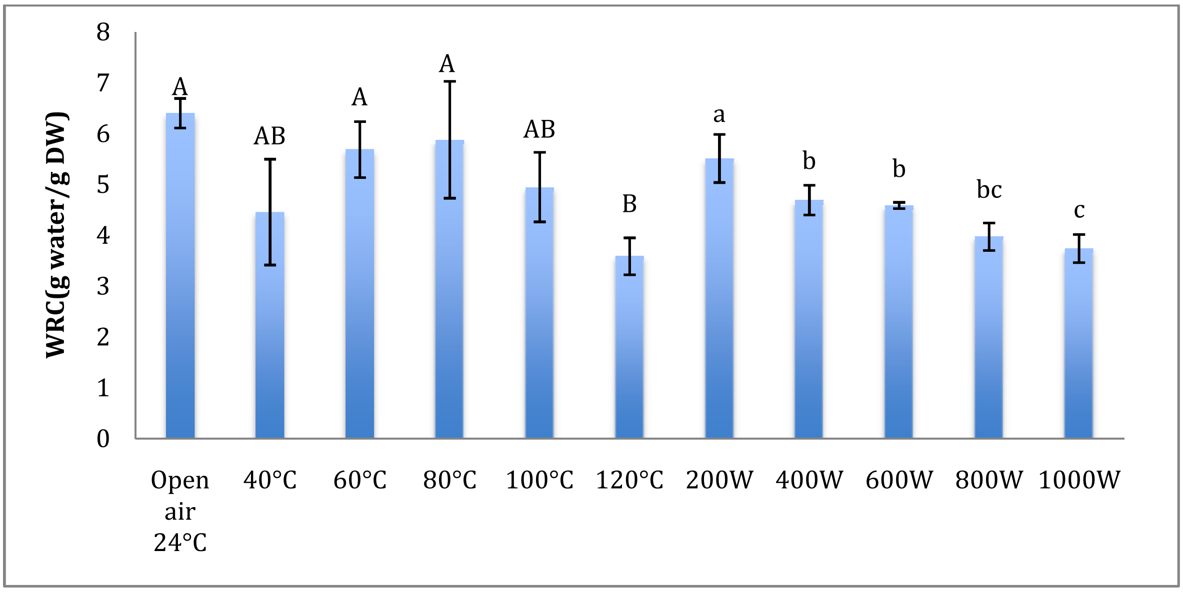


Figure 06: Effect of drying methods on water retention capacity (WRC) of the pea pod.

As it can be seen, the WRC of open air-drying, was the highest (6.403± 0.291g water/g DW) than WRC of other drying methods (oven and microwave). Microwave drying decreases the WRC of dried pea pod, the highest WRC (5.512± 0.472 g water/g DW)was obtained at the lower microwave power (200 W), and the lowest WRC (3.74± 0.277g water/g DW) was assigned to the high microwave power (1000W).However, in drying oven, the WRC shows fluctuations: a decrease of WRCwas observedat 40°C (4.458± 1.040g water/g DW), followed by an increasingof WRC at 60 °C and 80 °C, then WRC decreases also up to 3.589± 0.364 g water/ g DW at 120°C($p<0.05$).

Rehydration process depends on fiber processing, structural changes in vegetable tissues and cells of food material during drying, which produces shrinkage and collapse **(Kaymak-Ertekin. 2002).** Similar investigations reported that drying temperature is the main factor affecting the WRC **(Vega-Gálvez et al. 2008).** The authors showed that the decrease of WRC could be explained due to cellular structure damage resulting in modifications of osmotic properties of the cell as well as lower diffusion of water through the surface during rehydration **(Kaymak-Ertekin. 2002).**

III.3.3 Oil retention capacity

Fiber was closely compacted and formed many bundles of fiber matrix in might be due to the fiber–fiber interactions through hydrogen bonds, van der Waals forces, or Coulomb interactions.These fiber–fiber interactions could thus expose the hydrophobic surface to adsorb more oil**(Gouw et al. 2017).**

The mean values of ORC, recorded for the dried pea pod using open air, oven and microwave drying were shown in figure 09.

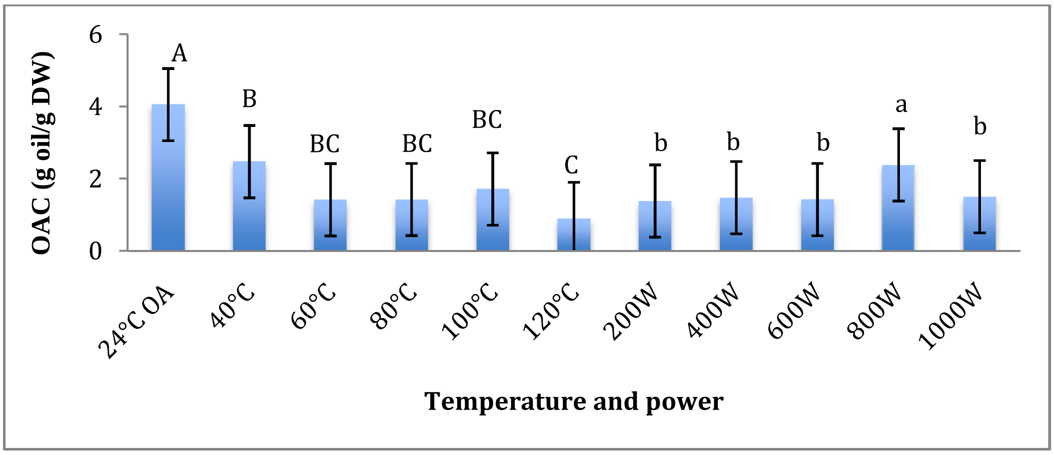


Figure 07: Effect of drying methods on oil retention capacity (ORC) of the pea pod.

Drying promoted a general decrease in the ORC of all temperatures and powers in comparison to ORC ofopen-air drying which present a higher ORC value (4.054 ± 0.129 g oil / g DW) at p<0.05. The drying process at 120 °C decreases significantly the ORC of pea pod up to0.908 ± 0.163g oil/g DW.Microwave drying shows less ORC than open air and whatever the used power for drying pea pods, there isno significant difference(p>0.05).

In fact, microwave drying affects the fibrous matrix modifying the structural characteristics and the chemical composition of the fiber (water affinity of its components) and promoting water retention to the detriment of oil retention. Similar trends were reported by **Ait Mohamed 2006.**

III.4. Total ash content

The ash contents of different powders obtained after drying with the three methods are illustrated in figure 10.

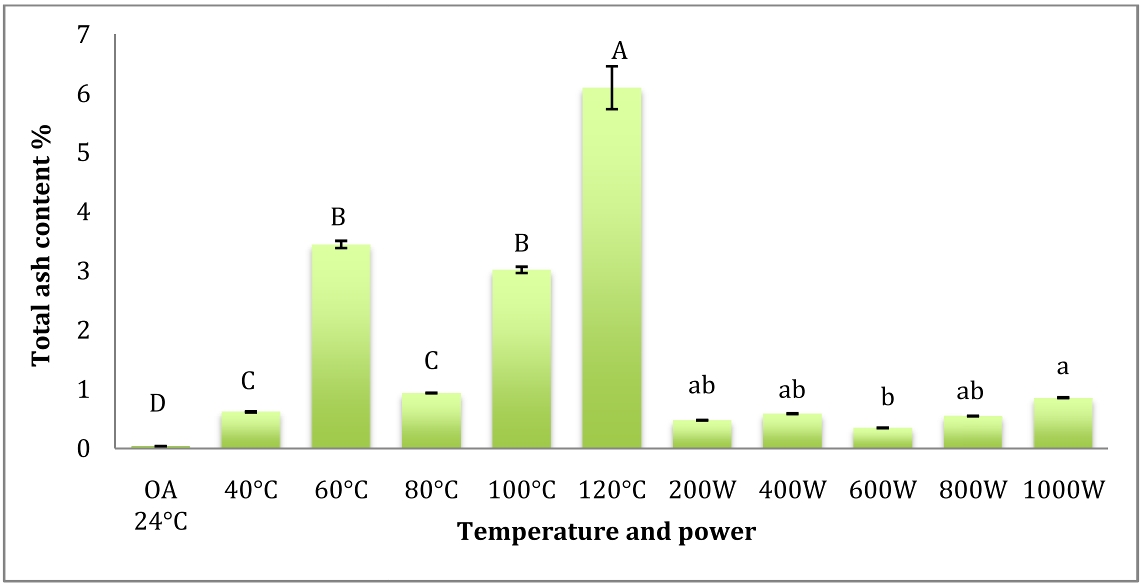


Figure 08: Total ash content of pea pod in differentdrying methods.

According to the results, the total ash content of the dried pea pod with oven ranged from 0.62±0.001% to6.1±0.363%, which represent the highest percentage at 120°C(p<0.05). However the open-air showedthe lowest ash content (0.04%±0.0004). For Microwave treatment, the maximal percentage of ashwas attributed to 1000 W (0.86±0.006%), but which remains very lower than oven drying.

These data are close compared to the results obtained by **Wadhwa et al. 2006,** for the same matrix with a value of 8.5%.

III.5. Determination of crude fiber

The results obtained during the determination of the crudfibers content (CFC) of the dried pea pods using open air, oven and microwave methods are shown in figure 11.

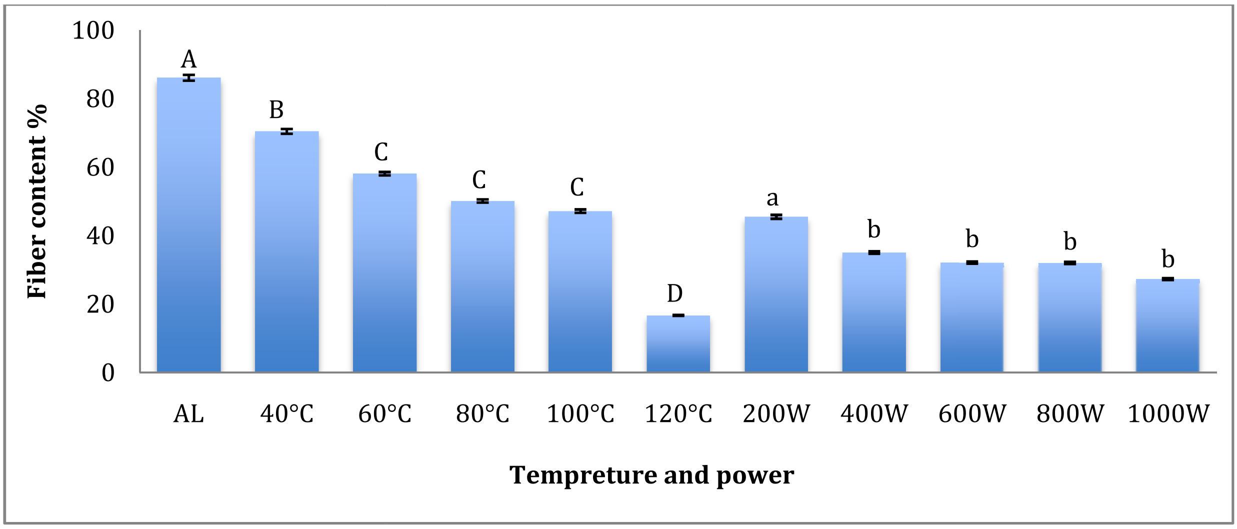


Figure 09: Crude fiber content of pea pod in different types of drying.

The reflection of the figure, all resultsare statistically different ($p< 0.05$), the CFC is inversely proportional to the temperature. In fact, the highest content is recorded in the open air, which is 86.19±0.840%, while the lowest is allocated at 120 ° C. with a yield of 16.73±0.165%. This trend was similar to the microwave drying, theCFC decreases with the increase of the irradiation power. The highest content is recorded at 200W (45.54±0.568%) and the lowest one at 1000 W (27.36±0.277%).

The comparison between the studied methods shows that open-air drying preserves fibers better than oven and microwave treatment. In deeded, heat treatment had an effect on dietary fiber content. (**Tanongkankit et al. 2012)**

The results of this work are higher than those found by **Mateos-Aparicio et al. 2012,** which is 58.6%, for the same variety using freeze-drying. This difference may be related to the drying method.

II.6. Determination of polyphenols

II.6.1. Total phenolic content

Figure 11 depicted the amount of TPC of pea pod, using different drying methods.The results obtained were statistically different ($p < 0.05$).

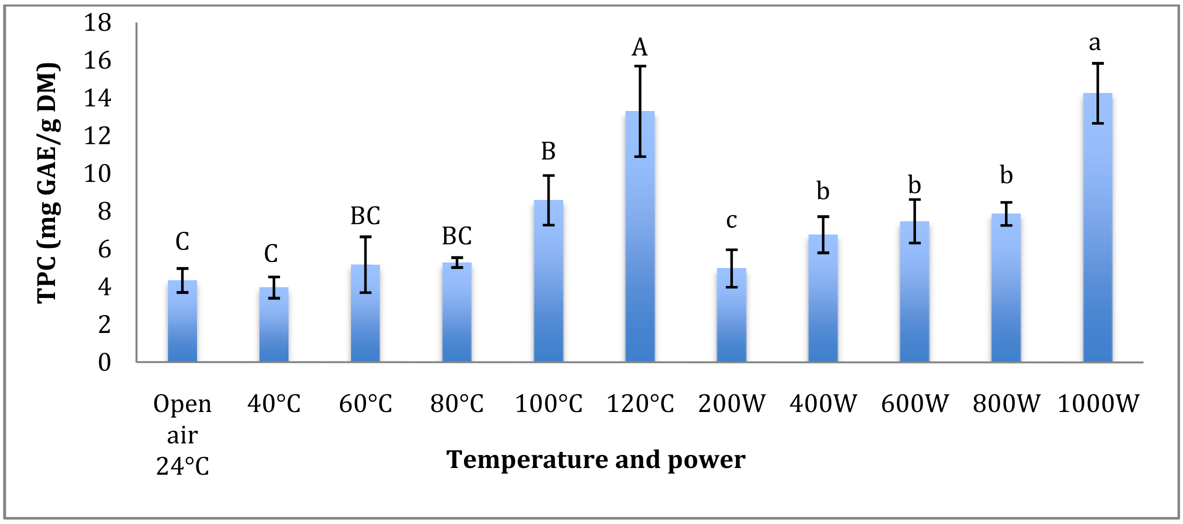


Figure 10: Total phenolic compounds of pea pod in different types of drying.

Among results obtained pea pod dried at 1000 W and 120 °C were the richest in phenolic compounds (14.253± 1.588 mg GAE/g DW; 13.298 ± 2.396mg GAE/g DW) respectively.Whereas the by-product dried at 40°C and at 200 W resulted in the weakest concentration of TPC (3.961 ± 0.562; 4.975mg ± 0.99mg GAE / g DW respectively).

According to **Arslan and Özcan. 2010,** the short time required for drying could have increased the phenolic content of the samples. The same authors have also reported that drying accelerates the release of bound phenolic compounds upon decomposition of cellular constituents.

It is noted that the total phenolic compounds in pea pods are not in agreement with to those found by **Mateos-Aparicio Cediel 2012:**4.2 ± 0.1 g kg^{-1}. This difference is probably due to the extraction method and drying process (freeze dried)

II.6.2. Total flavonoids content

The results of the determination of total flavonoids contentfor the various powders obtained after drying with the three methods are illustrated in figure 13.

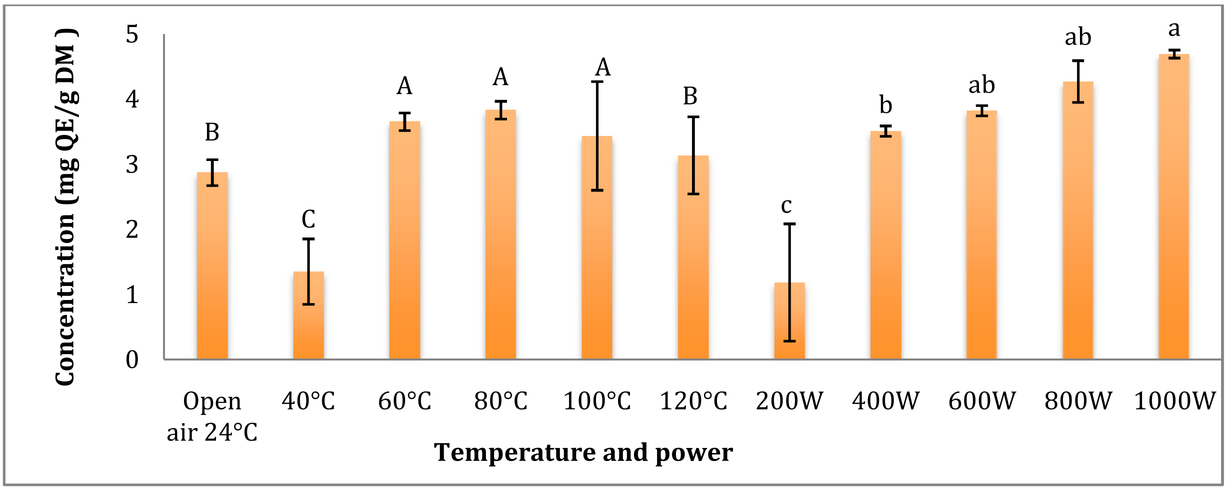


Figure 11: Total flavonoid content of pea pod using different types of drying

Microwave drying at 1000 W exhibited the highest flavonoid content (4.693 ± 0.061 mg QE / g DW), and the lowest yieldswere obtained at 200 W and at 40°C (1.185 ± 0.901; 1.352 ± 0.302 mg QE / g DW respectively) at (p<0.05).

The comparison between the three types of drying in terms of the flavonoid content, shows that the results obtained by microwaves are superior to those of the open-air and the oven.

Studies carried out on other vegetables and fruits have shown that heat treatment influences phenolic compounds, such as flavonoids and other bioactive compounds **(Williams et al. 2013).**

III.6.3. Total tannins content

The results of the determination of total tannins content for the various powders obtained after drying with the three methods are illustrated in figure 14.

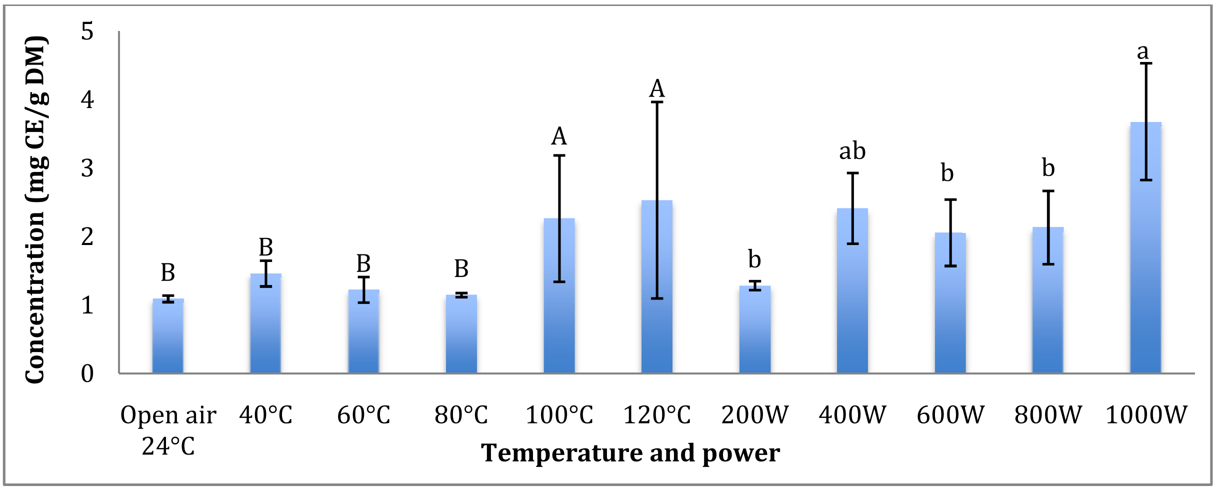


Figure 12: Total tannins content of pea pod in different types of drying

The highest level of total tannins of the dried powder extracts,has been detected in microwave at 1000 W (3.681 ± 0.853 mg CE/g DW), followed by oven drying at 120 °C(2.534 ± 1.436 mg CE / g DW). However the lowest content, was recorded in open-air drying (1.094±0.048 mg CE/g DM).

III.7. Antioxidant assays

III.7.1. Radical scavenging

The DPPH radical is usually used as a substrate to evaluate the antioxidative action of antioxidants by determining the free radical-scavenging ability of various samples (**Achat, Tomao et al. 2012***)*. Figure 15 shows the DPPH° radical scavenging activity of differentextract of dried pea pod, and the results are significantly different.

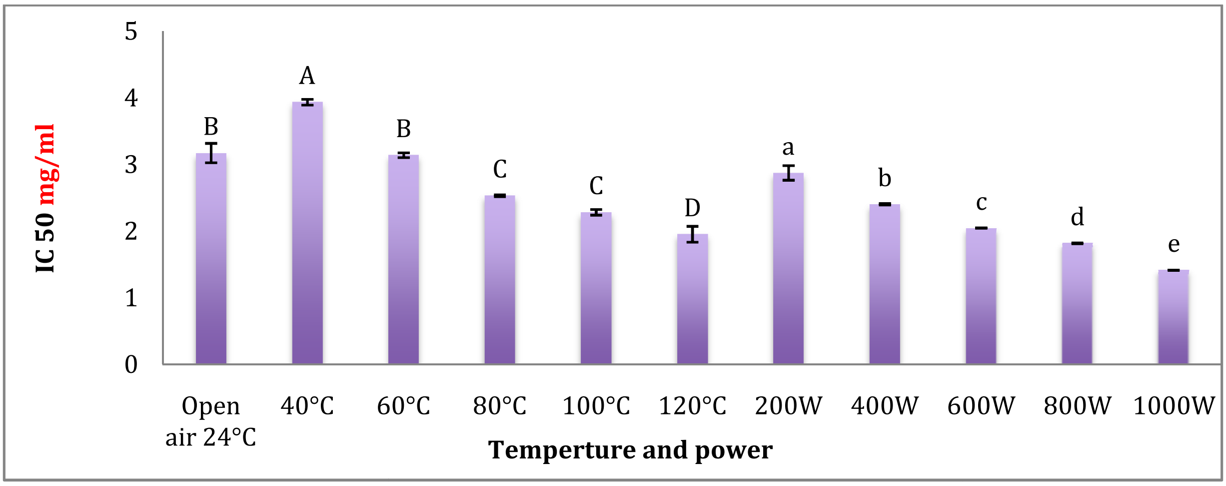


Figure 13: Antiradical activity (IC_{50}) of pea pod, dried in open-air, oven and microwave

The IC_{50} values (the concentration reducing 50% of DPPH) obtained for scavenging activities on DPPH° radical, were evaluated. The lower the IC_{50} value the greater the free radical-scavenging activity. Thus, the strongest activities ($p < 0.05$)were obtained in the case of drying method of microwave at 1000 W(1.418±0.002 mg/ml), followed by oven drying at 120°C (1.956±0.119mg/ml). However the sample of 40°C, 24°C and 200W possessed weaker antioxidant effects ($P < 0.05$): 3.938 ± 0.042; 0.753 ±0.145 and 2.876 ± 0.109 mg/ml respectively.

The antioxidant activity of pea pod dried in microwaveis greater than the scavenging activities obtained in open and oven drying.

In the presence of phenolic compounds which easily donates electrons to reduce **(Nisha et al. 2009).** Indeed, according to the Folin-Ciocalteu assay, flavonoid and tannins contents, it can be concluded that there is a positive correlation between the observed antioxidant power and the TPC content for these conditions.

The IC_{50}obtained in this study was very lower than those obtained by **I. Mateos-Aparicio. 2012,** for the same matrix (16.04 mg mL^{-1}). This difference can be explained by the difference of the drying technique (freeze), extraction method and climatic conditions of pea pod.

III.7.2. Reducing power

Fe (III) reduction is often used as an indicator of electron-donating activity, which is an important mechanism of antioxidant action, and can be strongly correlated with other antioxidant properties**(Dorman, Peltoketo et al. 2003)**. In this work, all samples **(Fig.16 and 17),**showed their abilities to reduce Fe^{3+} to Fe^{2+}. The increase in the absorbance at 700 nm of the reaction mixture caused by the tested extracts is indicative of their increased reducing power.

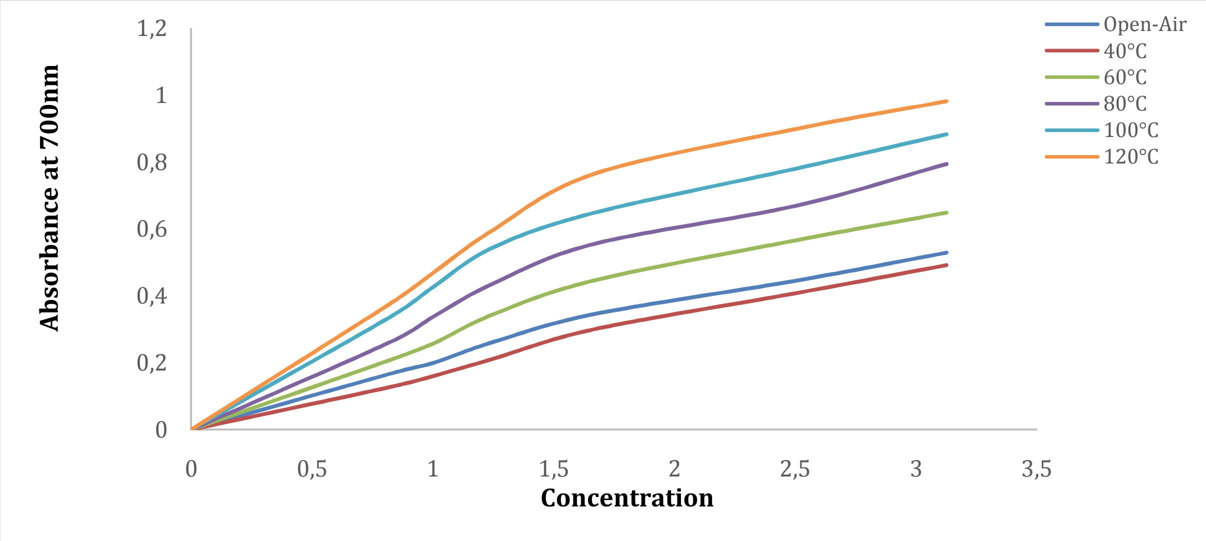


Figure 14: Reducing power of pea pod dried in oven

The reducing power of pea pod dried in oven exhibit the high absorbance at 120 °C extract (0.981), followed by the treatment at 100 °C and 80°C (A= 0.883; 0.794) respectively. At 40 °C and 24 °C, weaker absorbances were recorded (0.492 and 0.529 respectively).

The drying temperature increases the antioxidant compounds of the samples, which accelerates the release of bound physical compounds during decomposition of the cellular constituents(**Arslan and Özcan. 2010).**In line with these data, other authors have reported that some heat treatments result in an increase in total antioxidant activity of broccoli, green bean, pepper and spinach **(Turkmen et al. 2005).**

In the case of dried microwave samples, reducing power of pea pod showed the same order of the ability of sample to act as the donor of hydrogen atoms or electron: 1000 W>800 W>600 W > 400 W > 200W(0.919;0.879; 0.793; 0.688; 0.627 respectively)

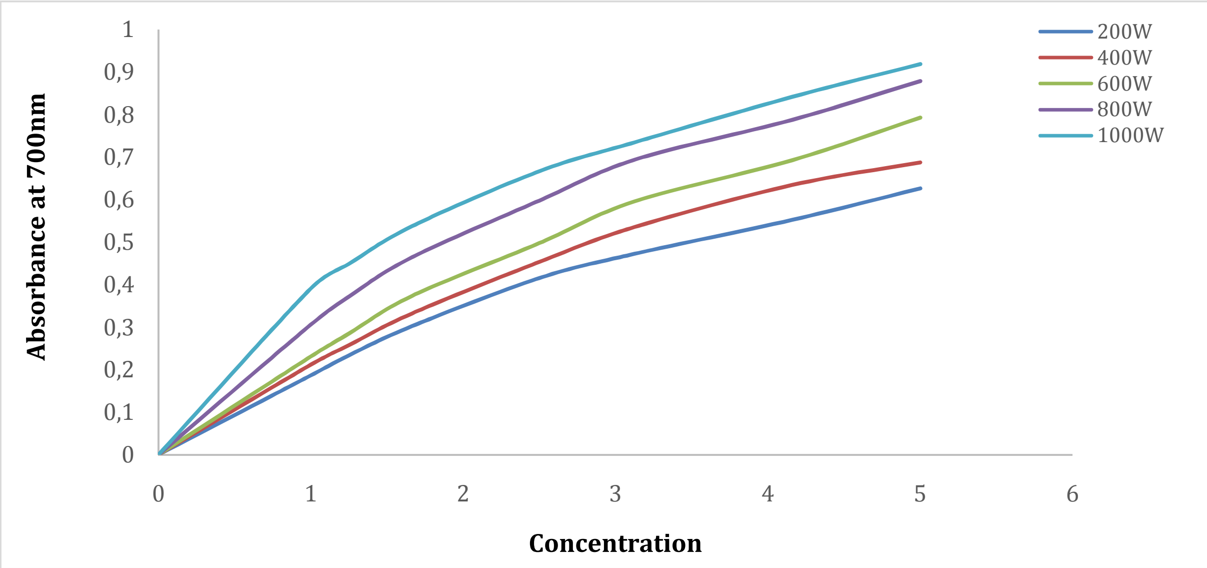


Figure 15: Reducing power of pea pod dried in microwave

III.8. Analysis of prepared soup

III.8.1. Physico-chemical analysis

Physico-chemical properties of the manufactured soup were shown in table 06.Results of this analysis revealed that the tested parameters were conform to norms.

Table 07: Physicochemical analysis of prepared soup.

	pH at 10%	Titrable acidity expressed at 10%	Water Activity (a_w)	Dry extract (%)	Humidity (%)	Dissolution (%)	Not dissolved (%)	Texture at 10 %
Enriched soup	6.65 %	0.17%	0.5723	93.36	6.64	73.00	27.00	Limpidviscous
Norms								

III.8.2. Microbiological analysis

Microbial quality of the manufactured soup was given in table 08.

Table 08: Microbiological analysis of formulated soup

	Aerobic germs	Coliforms	Fecal coliforms	*Staphylococcus aureus*	*Clostridium sulfito-reducer*	*Salmonella*
Sample of soup	$<3.10^5$	$<10^3$	$<10^2$	$<10^2$	Abs	Abs
Norms	3.10^5	10^3	10^2	10^2	30	Absence

Areobic germs, coliforms, fecal coliforms, *Staphylococcus aureus*, *Clostridium sulfite reducer and* Salmonella are the primary contaminants in food. These micro-organisms were not detected in soup sample. This illustrates the adequate hygienic preparation, under aseptic conditions, during processing and manufacturing of the soup.

III.8.3. Antioxidant activity

It was noticed from table 09 that antioxidant activity of different dehydrated soup measured by RSA revealed that the addition of pea pod, increased significantly the inhibitory activity against DPPH° radical compared with standard soup.

The pea pod contained total phenolic compounds; these compounds were present and significantly highest in enriched soup, providing a confirmation of supplementation

Table 09: Radical scavenging activity and total phenolic content of soups

	Radical scavenging activity (%)	TPC (mg GAE / g DW)
Soup before enrichment	$11,46 \pm 1,58^b$	$3,03 \pm 0,02^b$
Soup Enriched with polyphenols and dietary fiber	$36,82 \pm 2,72^a$	$3,65 \pm 0,05^a$

Polyphenols are the most abundant antioxidants in the diet **(Manach et al. 2004).**A large proportion of the polyphenols present in foods are associated with the insoluble fraction of dietary fiber, including condensed tannins.Indeed, according to the Folin-Ciocalteu assay, it can be concluded that there is a positive correlation between the observed antioxidant power and the TPC content for these conditions.

III.8.4. Total fiber content of soup

The results obtained during the determination of the crud fibers of the different soup are shown in figure 16.

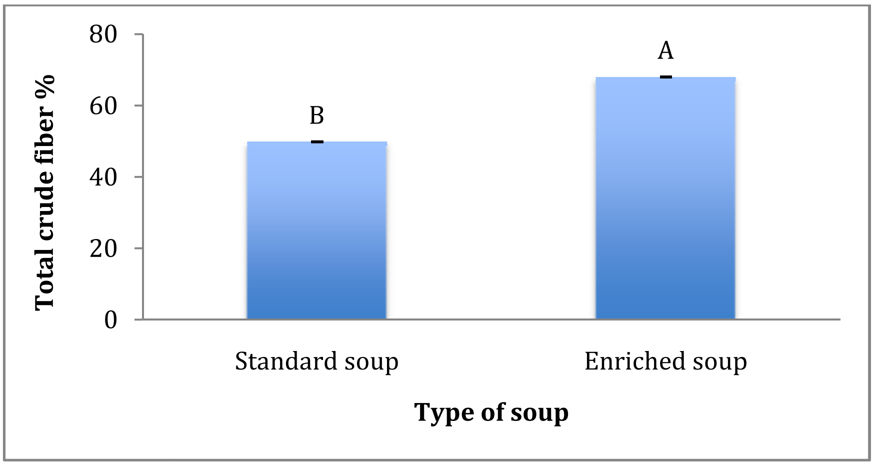


Figure 16: Total fiber content of standard and enriched soup.

The highest content of dietary fiber is recorded in the enriched soup (68.04%), while the lowest is assigned to the standard soup with a level of 49.89%.The statistical study showsasignificant difference (p<0.05).

The dietary fiber content increased after incorporation of the pea pod powder, which confirms the enrichment soup with dietary fiber.

Dietary fiber is the major compound in these by-products (more than 50%) **(I. Mateos-Aparicio et al. 2010)**, thus pea pod may be considered as a source of dietary fiber. So it is clearly evident that addition of this by-product gave the highest value.

General conclusion

Conclusion

This study examined the comparison of outdoor, oven and microwave drying methods and evaluated these processes on color, fiber content, ash, functional properties (swelling , Water) Water retention capacity and fat adsorption capacity), active ingredients (total polyphenols, flavonoids, tannins) and antioxidant activity; And on the other hand the formulation of a soup dehydrated with the powder obtained after drying of this by-product. Based on the results of this study, it can be concluded that the overall quality of pea pod powders was strictly dependent on the process and parameters applied during drying. The application of microwave power considerably reduced the drying time and revealed a low water activity which is 0.211 ± 0.034 to 1000W. And it is also important to learn that microwave drying of the pea pod at the same power (1000W) gave high levels of polyphenols, flavonoids and full tannins with scores of 14 253 ± 1.588 mg GAE / G DW, 4,693 ± 0.061 mg QE / G DW and 3881 ± 0.853 mg CE / g DW respectively. Even in antioxidant analyzes, 1000W extracts revealed better activities: DPPH radical sweep test (1468 ± 0.002 mg / ml), reducing power (absorbance = 0.919). This study indicates that the pea pod can be considered a good source of antioxidants. Analysis of functional properties and dietary fiber content, extracts of powders from dried pea pods by various methods showed that the high dietary fiber content (86.19 ± 0.840%) and the highest values of Water retention capacity (6.403 ± 0.292 g water / g DW), oil retention (4.054 ± 0.129 g oil / g DW) and swelling (10 ± 0.00 ml / g DW) are recorded Drying in the open air (24 ° C). This study therefore raises the possibility of considering these legume by-products as a biomass for the sustainable production of clean and affordable value-added ingredients.

Even analysis of the total color change has shown that drying in the open air decreases the discolouration of the pea pod. However, the best color-dried biological materials were obtained after using microwave drying at 200 W with a slight change in color that is. ΔE (14.55 ± 0.673). As a result, the color of the dried samples was affected by temperature and the development of the Maillard reaction, which occurs in conjunction with other events, could contribute to color change.

The use of the powders obtained after drying made it possible to obtain a dehydrated soup rich in dietary fiber (68.04%) and antioxidant (36.82 ± 2.72 mg / ml). And the results of the physicochemical and microbiological analyzes of the formulated soup show their perfect conformity with the norm.

In addition to this study, it should be supported by:

- Estimation of antioxidant activity by other methods and evaluation of biological activities.
- Determination of dietary fiber by enzymatic methods
- Characterization of the qualitative and quantitative composition of the pods by more efficient analytical techniques such as HPLC, NMR, etc.
- Characterization of minerals by atomic absorption spectrometry and determination of fibers by enzymes.
- Perform a sensory analysis of the soup.

References

-A-

Achat, S., V. Tomao, et al. (2012). "Direct enrichment of olive oil in oleuropein by ultrasound-assisted maceration at laboratory and pilot plant scale." Ultrasonics sonochemistry**19**(4): 777-786.

Ait Mohamed, L. (2006). "Etude physico-chimique de la qualité et de la conservation avant et après séchage solaire convectif de Gelidium sesquipedale (algue rouge) et du Citrus aurantium (orange amer)." These de 3e Cycle Faculté des Sciences Semlalia Marrakech, Maroc.

Alibas, I. (2007). "Microwave, air and combined microwave–air-drying parameters of pumpkin slices." LWT-Food Science and Technology**40**(8): 1445-1451.

Arslan, D. and M. M. Özcan (2008). "Evaluation of drying methods with respect to drying kinetics, mineral content and colour characteristics of rosemary leaves." Energy Conversion and Management**49**(5): 1258-1264.

-B-

Bakirci, K., O. Ozyurt, et al. (2011). "Energy analysis of a solar-ground source heat pump system with vertical closed-loop for heating applications." Energy**36**(5): 3224-3232.

Barreiro, J., M. Milano, et al. (1997). "Kinetics of colour change of double concentrated tomato paste during thermal treatment." Journal of food engineering**33**(3-4): 359-371.

Bimbenet, J.-J., A. Duquenoy, et al. (2002). Génie des procédés alimentaires: Des bases aux applications, Dunod.

Bimbenet, J. and C. Bonazzi (2003). "Séchage des produits alimentaires Principes." Techniques de l'ingénieur.

Bonazzi, C. and J.-J. Bimbenet (2008). "Séchage des produits alimentaires: Appareils et applications." Techniques de l'ingénieur. Agroalimentaire**2**(F3002).

Boulekbache-Makhlouf, L., L. Medouni, et al. (2013). "Effect of solvents extraction on phenolic content and antioxidant activity of the byproduct of eggplant." Industrial Crops and Products**49**: 668-674.

Bravo, L. and F. Saura-Calixto (1998). "Characterization of dietary fiber and the in vitro indigestible fraction of grape pomace." American Journal of Enology and Viticulture**49**(2): 135-141.

-C-

Chang, C.-C., M.-H. Yang, et al. (2002). "Estimation of total flavonoid content in propolis by two complementary colorimetric methods." Journal of food and drug analysis**10**(3).

Cherubini, F. and S. Ulgiati (2010). "Crop residues as raw materials for biorefinery systems–A LCA case study." Applied Energy**87**(1): 47-57.

-D-

Dahmoune, F., G. Spigno, et al. (2014). "Pistacia lentiscus leaves as a source of phenolic compounds: Microwave-assisted extraction optimized and compared with ultrasound-assisted and conventional solvent extraction." Industrial Crops and Products**61**: 31-40.

Dorman, H., A. Peltoketo, et al. (2003). "Characterisation of the antioxidant properties of de-odourised aqueous extracts from selected Lamiaceae herbs." Food chemistry**83**(2): 255-262.

Dukan, P. (1998). Dictionnaire de diététique et de nutrition, Le cherche midi Ed.

-E-

Ertekin, C. and O. Yaldiz (2004). "Drying of eggplant and selection of a suitable thin layer drying model." Journal of food engineering 63(3): 349-359.

-F-

Femenia, A., P. García-Pascual, et al. (2003). "Effects of heat treatment and dehydration on bioactive polysaccharide acemannan and cell wall polymers from Aloe barbadensis Miller." Carbohydrate polymers 51(4): 397-405.

Flink, J. (1980). "Dehydrated carrot slices: influence of osmotic concentration on drying behavior and product quality." Food process engineering 1: 412-418.

Forni, E., A. Sormani, et al. (1997). "The influence of sugar composition on the colour stability of osmodehydrofrozen intermediate moisture apricots." Food Research International 30(2): 87-94.

-G-

Galanakis, C. M. (2012). "Recovery of high added-value components from food wastes: conventional, emerging technologies and commercialized applications." Trends in Food Science & Technology**26**(2): 68-87.

Georgé, S., P. Brat, et al. (2005). "Rapid determination of polyphenols and vitamin C in plant-derived products." Journal of Agricultural and Food Chemistry**53**(5): 1370-1373.

Ghanem, N., D. Mihoubi, et al. (2012). "Microwave dehydration of three citrus peel cultivars: Effect on water and oil retention capacities, color, shrinkage and total phenols content." Industrial Crops and Products 40: 167-177.

Gouw, V. P., J. Jung, et al. (2017). "Functional properties, bioactive compounds, and in vitro gastrointestinal digestion study of dried fruit pomace powders as functional food ingredients." LWT-Food Science and Technology 80: 136-144.

Gowen, A., N. Abu-Ghannam, et al. (2008). "Modeling dehydration and rehydration of cooked soybeans subjected to combined microwave–hot-air drying." Innovative Food Science & Emerging Technologies**9**(1): 129-137.

-K-

Kaymak-Ertekin, F. (2002). "Drying and rehydrating kinetics of green and red peppers." Journal of Food Science 67(1): 168-175.

Khraisheh, M., T. Cooper, et al. (1997). "Microwave and air drying I. Fundamental considerations and assumptions for the simplified thermal calculations of volumetric power absorption." Journal of food engineering**33**(1-2): 207-219.

Krokida, M. and Z. Maroulis (2000). "Quality changes during drying of food materials." Drying technology in agriculture and food sciences: 61-106.

-L-

Laufenberg, G., B. Kunz, et al. (2003). "Transformation of vegetable waste into value added products::(A) the upgrading concept;(B) practical implementations." Bioresource Technology**87**(2): 167-198.

Lee, H. and G. Coates (1999). "Thermal pasteurization effects on color of red grapefruit juices." Journal of Food Science 64(4): 663-666.

Lozano, J. and A. Ibarz (1997). "Colour changes in concentrated fruit pulp during heating at high temperatures." Journal of food engineering **31**(3): 365-373.

-M-

Macheix, J. J., Fleuriet, A., Jay-Allemand, C., & des VØgØtaux, L. C. P. (2005). Presses Polytechniques et Universitaires Romandes.

Mafart, P. (1991). "Génie industriel alimentaire(Tome I, Les procédés physiques de conservation)."

Manach, C., A. Scalbert, et al. (2004). "Polyphenols: food sources and bioavailability." The American journal of clinical nutrition **79**(5): 727-747.

Martins, S. I. and M. A. Van Boekel (2005). "A kinetic model for the glucose/glycine Maillard reaction pathways." Food chemistry **90**(1): 257-269.

Maskan, M. (2001). "Kinetics of colour change of kiwifruits during hot air and microwave drying." Journal of food engineering **48**(2): 169-175.

Mateos-Aparicio Cediel, I. (2009). Aprovechamiento de subproductos de leguminosas para la obtención de ingredientes funcionales: comparación de metodologías para la caracterización de la fibra alimentaria, Universidad Complutense de Madrid, Servicio de Publicaciones.

Mateos-Aparicio, I., A. Redondo-Cuenca, et al. (2010). "Pea pod, broad bean pod and okara, potential sources of functional compounds." LWT-Food Science and Technology **43**(9): 1467-1470.

Mateos-Aparicio, I., A. Redondo-Cuenca, et al. (2012). "Broad bean and pea by-products as sources of fibre-rich ingredients: potential antioxidant activity measured in vitro." Journal of the Science of Food and Agriculture **92**(3): 697-703.

Molyneux, P. (2004). "The use of the stable free radical diphenylpicrylhydrazyl (DPPH) for estimating antioxidant activity." Songklanakarin J. Sci. Technol **26**(2): 211-219.

-N-

Nethravathi, C., T. Nisha, et al. (2009). "Graphene–nanocrystalline metal sulphide composites produced by a one-pot reaction starting from graphite oxide." Carbon**47**(8): 2054-2059.

-O-

O'Neill, M. A. and W. S. York (2003). "The composition and structure of plant primary cell walls." The plant cell wall: 1-54.

Oreopoulou, V. and W. Russ (2007). Utilization of by-products and treatment of waste in the food industry, Springer.

Oyaizu, M. (1986). "Studies on products of browning reaction." The Japanese Journal of Nutrition and Dietetics**44**(6): 307-315.

-P-

Piyasena, P., E. Mohareb, et al. (2003). "Inactivation of microbes using ultrasound: a review." International journal of food microbiology**87**(3): 207-216.

-Q-

Quek, S. Y., N. K. Chok, et al. (2007). "The physicochemical properties of spray-dried watermelon powders." Chemical Engineering and Processing: Process Intensification**46**(5): 386-392.

-R-

Russ, W. and R. Meyer-Pittroff (2004). "Utilizing waste products from the food production and processing industries." Critical reviews in food science and nutrition**44**(1): 57-62.

Russ, W. and M. Schnappinger (2007). Waste related to the food industry: a challenge in material loops. Utilization of by-products and treatment of waste in the food industry, Springer**:** 1-13.

-S-

Scalbert, A., C. Manach, et al. (2005). "Dietary polyphenols and the prevention of diseases." Critical reviews in food science and nutrition**45**(4): 287-306.

Schieber, A., F. Stintzing, et al. (2001). "By-products of plant food processing as a source of functional compounds—recent developments." Trends in Food Science & Technology**12**(11): 401-413.

Sumnu, G., S. Sahin, et al. (2005). "Microwave, infrared and infrared-microwave combination baking of cakes." Journal of food engineering**71**(2): 150-155.

-T-

Tanongkankit, Y., N. Chiewchan, et al. (2012). "Physicochemical property changes of cabbage outer leaves upon preparation into functional dietary fiber powder." Food and Bioproducts Processing**90**(3): 541-548.

Tiwari, B. K., A. Gowen, et al. (2011). Pulse foods: Processing, quality and nutraceutical applications, Academic Press.

Tomás-Barberán, F. A. and J. C. Espin (2001). "Phenolic compounds and related enzymes as determinants of quality in fruits and vegetables." Journal of the Science of Food and Agriculture**81**(9): 853-876.

Trebuchet, G., Chopinet, R., Drouzy, J., 1953. Contribution a l'Étude des Variétés de Pois Potager Cultivees en France.

Treche, S. (1986). "Influence d'apports moderes d'engrais azote sur la valeur nutritionelle de tubercules de dioscqrea zotundata."

Tsao, R. (2010). Chemistry and biochemistry of dietary polyphenols. *Nutrients*,***2***(12), 1231-1246.

Turkmen, N., F. Sari, et al. (2005). "The effect of cooking methods on total phenolics and antioxidant activity of selected green vegetables." Food chemistry**93**(4): 713-718.

-V-

Vasseur, J., 2009. Séchage: principes et calcul d'appareils: Séchage convectif par air chaud (partie 1). Techniques de l'ingénieur. Génie des procédés.

Vega-Gálvez, A., R. Lemus-Mondaca, et al. (2008). "Effect of air drying temperature on the quality of rehydrated dried red bell pepper (var. Lamuyo)." Journal of food engineering**85**(1): 42-50.

-W-

Wadhwa, M., S. Kaushal, et al. (2006). "Nutritive evaluation of vegetable wastes as completefeed for goat bucks." Small Ruminant Research**64**(3): 279-284.

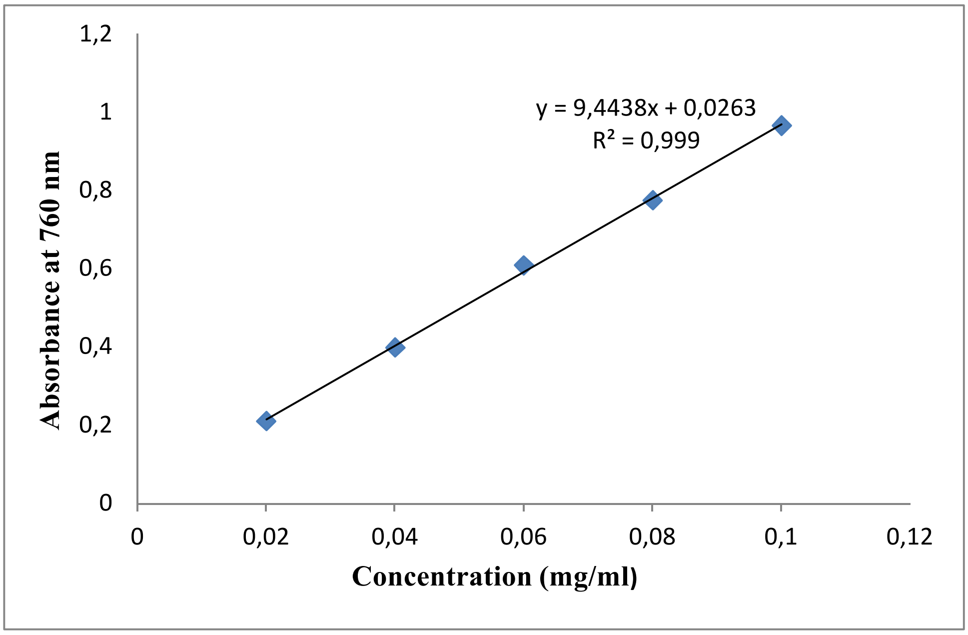
Westphal, E., Arora, R., 1989. Plant Resources of South-East Asia: Pulses. Pudoc.

Williams, D. J., D. Edwards, et al. (2013). "Vegetables containing phytochemicals with potential anti-obesity properties: A review." Food Research International **52**(1): 323-333.

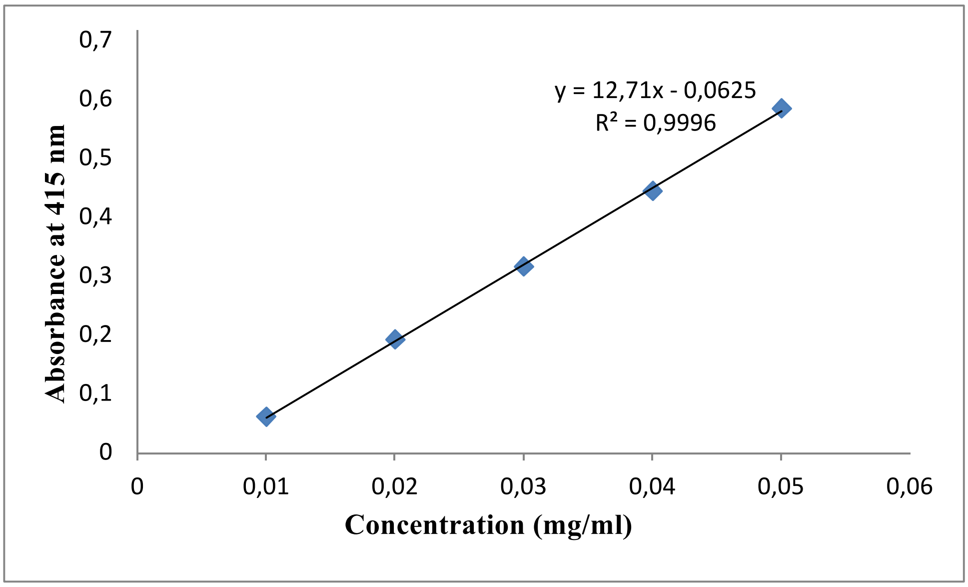
-Z-

Zhang, Y.-H. P., M. E. Himmel, et al. (2006). "Outlook for cellulase improvement: screening and selection strategies." Biotechnology advances **24**(5): 452-481.

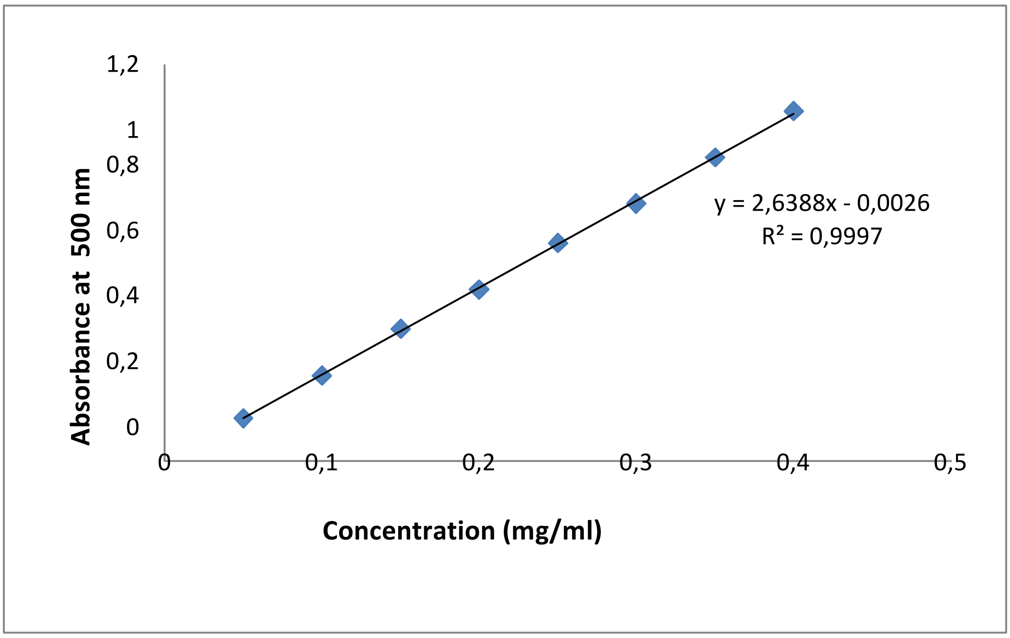
Appendix



Appendix 01 : Calibration courbe of gallic acid



Appendix 02 : Calibration courbe of quercitine



Appendix 03 : Calibration courbe of catéchi

Résumé

Le travailaccompli consiste à étudier l'effet de trois techniques de séchage : air libre, étuve et microonde,sur la qualité des substances bioactives et fibres alimentaires contenues dans la cosse de petit pois ***(Pisumsativum L.)***.

Des analyses ont été effectuées pour l'évaluation de la composition physico-chimique,des extractions par ultra-sons et différents dosages ont été réalisés pour la détermination de l'activité anti-oxydantede la poudre séchée obtenue après broyage et tamisage.Le séchage à l'air libre présente une teneur élevée en fibres alimentaires avec une valeur de 86.19 ± 0.840% et la teneur maximale en TPC (13.298 ± 2.396mg GAE / g DW) est obtenue par microonde à 1000W.

Cette cosse de petit pois a été valorisée par la formulation d'une soupe déshydratée enrichie à partir des poudres séchées à 1000 W et à l'air libre, qui sont très abondantes en polyphénols et en fibres alimentaires. Cette soupe a été soumise à des dosages révélant une activité anti-oxydante meilleure, avec une teneur en fibres élevée.Des analyses physicochimiques et microbiologiques confirment une qualité organoleptique, sanitaire, hygiénique favorableet satisfaisante.

Mots clés : Cosse de petit pois ***(Pisumsativum L.)***, séchage, polyphénols, fibres alimentaires, soupe déshydratée, activité antioxydante.

Abstract

The accomplished work consists of studying the effects of three drying techniques: open-air, oven and microwave, on the quality of bioactive substances and dietary fibers obtained from pea pods ***(Pisum Sativum L.)***.

Analysis have been conducted to evaluate the physico-chemical composition ofextracts by ultra-sound and different dosages have been achieved to determine the anti-oxidant activity of the dried powder obtained after grinding and sieving. Open-air drying presents an important content in dietary fibers with a value of 86.19 ± 0.840% and maximum content of TPC(13.298 ± 2.396mg GAE / g DW) is obtained by microwave at 1000 W.

This pea pod has been valorized by the formulation of an enriched dehydrated soup from powders dried at 1000 W and in open-air, which are very rich in polyphenols and dietary fibers. This soup has been subject to dosages revealing a better anti-oxidant activity, with an important content in fibers. Physiochemical microbiological analysis confirmed organoleptic, sanitary and hygienic favourable and satisfactory qualities.

Keywords*:* Pea pod***(Pisumsativum L.)***, drying, polyphenols, dietary fibers, dehydrated soup, anti-oxidant activity.