République Algérienne Démocratique et Populaire
Ministère de l'enseignement Supérieur et de la Recherche Scientifique
Université A. MIRA - Bejaia

Faculté des Sciences et de la Nature et de la Vie
Département des Sciences Alimentaires
Filière : Sciences Biologique
Spécialité : Sciences Alimentaires
Option : Biotechnologie Agro-ressources technologie alimentaire

Réf :.....

Mémoire de Fin de Cycle
En vue de l'obtention du diplôme

MASTER

Thème

Etude comparative du séchage par étuve et micro- onde de la pelure d'aubergine

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Soutenu le : **18 Juin 2016**

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Année universitaire : 2015 / 2016

ACKNOWLEDGMENTS

FIRST AND FOREMOST, MY MOST EARNEST GRATITUDE TO OUR LORD, ALLAH, FOR BLESSING ME WITH THE ABILITY TO UNDERTAKE THIS STUDY AND GRANTING ME THE STRENGTH TO COMPLETE IT.

Foremost, we would like to express our sincere gratitude to our advisor

Dr. AchatSabiha *for the continuous support of our study and research, for her patience, motivation, enthusiasm, and immense knowledge. Her guidance helped us in all the time of research and writing of this thesis. We could not have imagined having a better advisor for our study.*

We would also like to thank all the members of my thesis committee for taking their valuable time to come and carefully evaluate my manuscript ***MrMoussi. KMmeIkhennache.F, MrMadani.K and MmeSmail.L***

We would like to thank the L3BS team and all of the wonderful doctorants ,teachers and all engineers, specially ***Mr.Remini .H***

We would also like to thank the laboratory of the dairy industry "DANONE DJURDJURA".

DEDICATION

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 forteaching me that I should never give up. Thanks for lending me your earon countless occasions when I needed to vent my frustrations …
To the memory of my dearest father

Thank you for your love and support.Without you, my life would fall apart.

To my sister Fatihaand her husbandAzdine.My brothers Slimane, and his wife Karima .Mustapha and his wife Faiza, et MouhendLahlou

To my angels Cylia, Imane,Rafik, Hamza.Hani,Ryad et Rym.

To my best friend who became my best teachersBenazzouz Leila and Sabiha Achat.

To my second family ho adopted me during my period of study have always responded when I lost this .Who feels about you and Ali Dada Nana Malika thank you

To my binomial and friend with which I have division a good moment Bellil Salima and her family

Taous

DEDICATION

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Daddy, you have always been there for me with encouraging words
Thank you for your love and support. Without you, my life would fall apart.

To my sisters Nassima and Ounissa who I love very much and I am lost without you. My brothers Salim , Mustapha , sofiane , Tarik and Abderrzak

To my binomial and friend with which I have division a good moment Souami Taous and her family

To all my friends and colleagues, specially Ouerdia and Lamia

Salima

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List of abbreviation

AED: Acoustic energy density

AHC: Ascending Hierarchical Classification

ANC: Anthocyanin compounds

ANOVA: Analysis Of Variance

CE: conventional extraction

CFU: Colony-forming unit

CGA: Chlorogenate acid

CGAE: Chlorogenate acid equivalent

CSE: Conventional-solvent extracted

DE: Dry extract

DGE: Delphinidin glucosid equivalent

DM: Dry Matter

DPPH: 2, 2-Diphenyl-1-picrylhydrazyl

DW: Dry weight

GAE: Gallic Acid Equivalent

HAD: Hot air

IR: Infrared

MAE: Microwave Assisted Extraction

MC: The moisture content

MW: Microwave

MWD: Microwave Drying

PCA: Principal Components Analysis

PREFMAP: Preference Mapping

RC: Reducing power

ROS: Reactive oxygen species

RSA: Radical Scavenging Activity

RtE: Rutin equivalent

SEM: Scanning electron microscopy

SY: Stirred yaourt

TAC: Total antioxidant capacity

TFC: Total Flavonoid compounds

TPC: Total Phenolic Compounds

UAE: Ultrasound assisted extraction

YTCg : Total chlorogenate yield

Introduction

Introduction

One of the higher-value options is food waste valorization, which over the past few years has gained a great attention as a potential alternative to the disposal of residues in landfill sites. Valorization of food processing residues is an intriguing concept, based on the recognition that this waste biomass is in fact an inexpensive and abundant source rich in bioactive phytochemicals, which could be used in the manufacturing of high value-added products, such as food additives, nutritional supplements, cosmetics and pharmaceuticals **(Galanakis 2012)**. In spite the diversity of biologically important constituents occurring in plant food wastes, particular emphasis has been given to polyphenolic compounds, which may possess a spectrum of beneficial properties, such as antioxidant, anti-inflammatory, cardio protective and anti- carcinogenic **(Babbar et al. 2015)**.

Eggplant (*Solanum melongena* L.) is an important market vegetable of both Asian and Mediterranean countries. Eggplants contain a variety of phytochemicals such as phenolics and flavonoids **(Akanitapichat et al.2010)**.They are ranked among the top ten vegetables in terms of antioxidant capacity due to the phenolic constituents **(Cao et al. 1996)**. The most cultivated variety in Algeria is the elongated ovoid in a dark purple skin **(Boulkbeche-Makhlouf et al. 2013)**.This fruit is primarily used as a cooking vegetable for various dishes all over the world **(Demir et al. 2002; Hanson et al. 2006).**

Eggplant peel is a less studied source in terms of bioactive compound extraction from industrial residues, although its high content of polyphenols is known **(Dranca et al. 2015).** Anthocyanins, an important group of naturally occurring pigments of red and/or purple colored fruits, are the main phenolic compounds in eggplant peel **(Mazza et al. 2004).** Different kind of anthocyanins have been extracted and identified from eggplant skin. Nasunin, a major component of anthocyanin pigment of eggplant, was isolated from the eggplant peels, and its antioxidant activity was evaluated **(Igarashi et al. 1993; Noda et al., 2000)**. However, eggplant peels have a very limited shelf life. Therefore, it is common to dry these byproducts to extend their shelf lives. Drying is among the methods for the purpose to produce high quality dried products, which can be consumed directly or used as ingredient for the preparation of chutneys, cakes, muesli and oat granola. 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 is often recommended to reduce long drying times and poor product quality (**Sumnu et al.**

2015). Microwave drying has been recently used for drying of fruits and vegetables. It offers advantages that have been employed prior to or with conventional drying in food processing technologies. Several researchers have provided strong evidence that microwave-assisted drying is ideal for fruits and vegetables which speed up drying process, increase mass transfer, and produce good quality products **(Prothon et al 2001; Abano et al. 2015*)*.**Therefore, the main objective of this study was to compare the effects of conventional oven drying (temperature and time) and microwave drying (power and time) on bioactive components and antioxidant activities of eggplant peels. The choice of this investigation is based on three criteria: first, to enhance the peel (byproduct) of eggplant, which is a good source of bioactive substances (anthocyanins) as long as the Algerian people do not consume it, then to evaluate several types of phytochemicals that are present in the different dried powders of peel eggplant: total monomeric anthocyanin (TMA), total phenolic (TPC), total flavonoid content (TFC) and total chlorogenate yield (YTCg). The second criterion is to select the drying procedure that led to the extracts with the highest amount of bioactive components and antioxidant capacity. Finally a formulation of fruity stirred yoghurt at laboratory scale was performed, in order to produce yoghurt fortified with natural antioxidants of eggplant peels.

Bibliography

I.1. Overview of eggplant

Eggplant (*Solanum melongena* L.), is in the 4th rank of vegetable crops **(Nielsen, Cohen et al. 1999).** It is of considerably economic importance in Asia, Africa, and subtropics (India, Central America), but is also grown in some warm temperate regions (Mediterranean area, South of the USA) **(Sihachakr, Chaput et al. 1993)**. In 1999, 1.3 million ha were cultivated in the world for a total production of 21.2 million t, of which 92.4% of the world productions were covered by Asia **(Nielsen, Cohen et al. 1999).** Although lower than that of tomato, eggplant nutritious value is comparable to other common vegetables **(Grubben, Tindall et al. 1977).**

Vernacular names

- English: Eggplant
- French : Aubergine
- Arabic : Al-bâdinjân
- Kabyle :Tabatelûant (ti-in)

I.1.1. Morphological description

Primitive eggplant characters are tall plants with large, spiny leaves, flowering in clusters with and romonoecy. Their fruits are small, green, and bitter in taste, with thick skin and hard flesh **(Fig.1)**. Fruit colour varies from light to dark purple, almost black, green, or white. Fruit length is between 4-45 cm, and thickness 2-35 cm, at different shapes and weight ranging between 15-1500 g. The fruits are set as single or in clusters, up to 5 fruits. Physiologically ripe fruits become brown, red or yellow **(Swarup 1995).**

Kingdom: Plantae
Division: Angiospermae
Class: Broadleaf
Order: Solanales
Family: Solanaceae
Genus: Solanum
Species: *Solanum melongena L*

Figure 1: Taxonomic classification of eggplant **(Swarup 1995).**

I.1.2. Chemical composition of eggplant

Eggplant presents a variety of chemical components; the fruits contain 4% total sugar, protein, lipid, organic acid, vitamins **(Table I)** and bioactive compounds such as phenolics and flavonoids, mainly anthocyanins **(Özcan, Hacıseferoğulları et al. 2005).**

Table I: Chemical properties and mineral contents of eggplant **(Özcan, Hacıseferoğulları et al. 2005).**

Fraction	Content	Element	Content (mg)
Moisture content (%)	92.7	Calcium	18.0
Carbohydrates (%)	4.0	Magnesium	16.0
Protein (g)	1.4	Phosphorus	47.0
Fat (g)	0.3	Iron	0.9
Fiber (g)	1.3	Sodium	3.0
Vitamin A (I.U.)	124.0	Copper	0.17
Vitamin C (mg)	12	Potassium	2.0
Oxalic acid (mg)	18	Sulphur	44.0
B-carotène (µg)	0.74	Chlorine	52.0

I.1.2.1. 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 constituent **(Salunkhe, Salunkhe et al. 1990).** Natural polyphenols range from simple molecules to highly polymerized compounds, the most important are: phenolic acids, anthocyanins, flavonoids and tannins **(Hmid 2013).**

I.1.2.1.1 Phenolic acids

There are two main classes of phenolic acids, the derivatives of benzoic acid (C1-C6) **(Guignard 1996)** and derivatives of cinnamic acid (C3-C6) (**Fig.2) (Ajibesin, Bala et al. 2012).** The concentration of the hydroxybenzoic acid is generally very low in edible vegetable. These derivatives are quite rare in the human diet by those against hydroxycinnamic acids which are very present **(Macheix, Fleuriet et al. 2005).**

R = R' = H; *p*-hydroxybenzoic acid
R = OH, R' = H; protocatechuic acid
R = OCH3, R' = H; vanillic acid
R = R' = OH; gallic acid
R = R' = OCH3; syringic acid

R = R' = H; *p*-coumaric acidR
R=OH, R'=H; caffeic acid
R=OCH_3, R'=H; ferulic acid
R= R'=OCH_3; Sinapic acid

Figure 2: Benzoic acid and cinnamic acid derivatives (**Guignard 1996)**

- The main phenolic acids found in eggplant are: chlorogenic acid, caffeic acid, *p*-coumaric acid **(Hanson, Yang et al. 2006); (Sakakibara, Honda et al. 2003).**

I.1.2.1.2. Flavonoids

The term flavonoids bring together a very wide range of natural compounds. Their main function seems to be the color of plants (beyond chlorophyll, carotenoids and betalains) **(Formica and Regelson 1995).** Flavonoids have a common biosynthetic origin and they all have the same basic skeleton (**Fig.3)** fifteen carbon atoms composed of two aromatic units, cycle C6 (A and B), linked by a chain C3 **(Bruneton 1999).** The various sub groups are flavones, flavonols, flavanols and anthocyanins witch are the major flavonoid of eggplant peel **(Chira, Suh et al. 2008).**

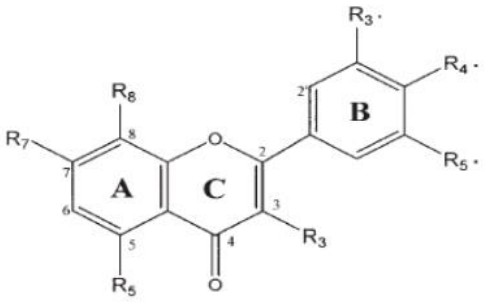
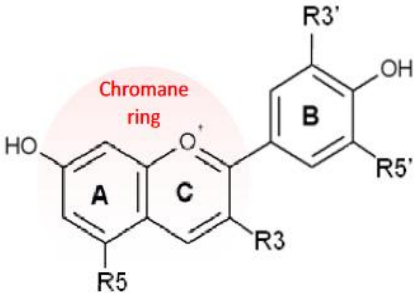


Figure 3: General structure of flavonoid in eggplant **(Laura, Alvarez-Parrilla et al. 2009)**

I.1.2.1.2.1. Anthocyanins

They are flavonoids due to the C6-C3-C6 carbon skeleton in their molecules, derivatives of the flavylium cation found in the oxo or carbonium forms, their huge diversity resulting from the many potential attachment sites for functional-methoxy and hydroxyl- groups in the cation ring (**Fig.4)**. In food, they are mainly found as anthocyanidin mono- di- and triglycosides **(Joshi and Goyal 2011)**. Anthocyanins are responsible for colours ranging from pale pink to red to purple and deep blue **(Dahmoune, Madani et al. 2013)**.



Anthocyanin	R3'	R5'	R3	R5
Pelargonidin 3-glucoside	H	H	Glc	OH
Pelargonidin 3,5-diglucoside	H	H	Glc	Glc
Cyanidin 3-glucoside	OH	H	Glc	OH
Cyanidin 3,5-diglucoside	OH	H	Glc	Glc
Delphinidin 3-glucoside	OH	OH	Glc	OH
Delphinidin 3,5-diglucoside	OH	OH	Glc	Glc

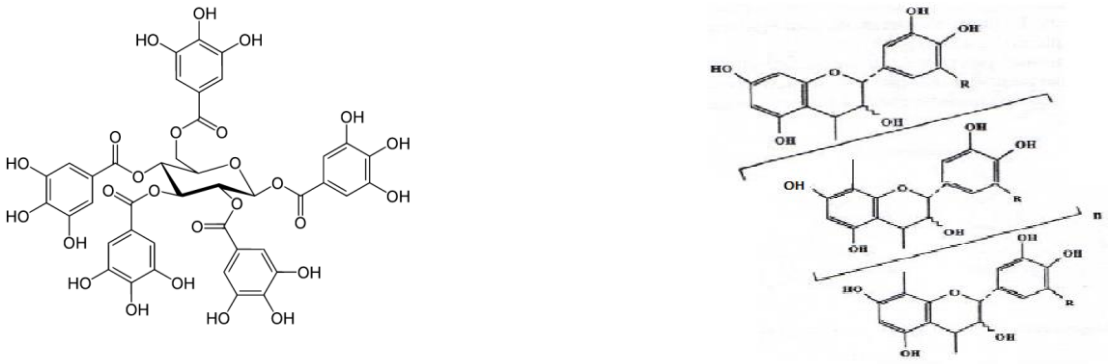
***Glc** : Glucose.*

Figure 4: Chemical structures of the anthocyanins. **(Joshi and Goyal 2011).**

The most abundant anthocyanins in *Solanum melongena* L, are nasunin and delphinidin conjugates (**Ichiyanagi, Rahman et al. 2007); (Braga, Scalzo et al. 2016)**, constituting 69,1 % 87,7% and 3-caffeoylrutinoside-5-glucoside, Delphinidin-3-glucosyl-rhamnoside and Petunidin wer reported **(Matsuzoe, Yamaguchi et al. 1999)**

I.1.2.1.3. 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) (**Fig.5)**. **(Makkar 2003); (Macheix, Fleuriet et al. 2005)**



a: Hydrolysable tannins. b: Condensed tannins.

Figure 05: Chemical structure of tannins **(Macheix, Fleuriet et al. 2005)**

Studies have shown that eggplant extracts contain tannins (5.37 to 413.7 mg tannic acid equivalent per 100 g dry matter (**Ref'at, Takruri et al. 2010); (Boulekbache-Makhlouf, Medouni et al. 2013).**

I.1.3. Biological activities

Studies have shown that eggplant has great nutritional values and numerous health benefits. The table II summarizes some of biological activities of this vegetable.

Table II: Effect of eggplant on biological targets, involved in some diseases.

Biological activities	Reference
Excellent remedy for those suffering from liver complaints	**(Chen, Ollis et al. 1999)**.
Inhibit oxidation of low-density protein (LDL).	**(Harborne and Williams 2000).**
Inhibit inflammation that can lead to atherosclerosis	**(Han, Tae et al. 2003).**
An hypotensive activitie	**(Suzuki, Gabrielson et al. 2002) ;(Watanabe, Houten et al. 2006).**
Suppress the development of blood vessels required for tumor growth and metastasis	**(Matsubara, Kaneyuki et al. 2005).**
Anti-obesity effect with improvement of lipid metabolism	**(Cho, Jeon et al. 2010).**
Exert selective anti-carcinogenic effects via induction of apoptosis in many human cancer cells, such as leukemia cells	**(TAO and Ming 2012).**
Cause delay in intestinal glucose absorption and inhibition of gluconeogenesis	**(Ong, Hsu et al. 2012).**

I.2. Drying techniques

Drying is the process of removing the moisture in the product up to certain threshold value by evaporation, due to simultaneous heat and mass transfer. **(Ozkan, Akbudak et al. 2007**). Thermal processing is one of the most important methods of food preservation, primarily intended to inactivate enzymes, deteriorative microorganisms and reduce water activity by dehydration. However, during processing, the food material may be exposed to temperatures that have an adverse effect on quality and making these products susceptible to colour deterioration, **(Barreiro, Milano et al. 1997; Avila and Silva 1999)**.

There are many drying applications; the most abundant are solar drying, oven drying and recently microwave drying.

I.2.1. Solar drying

Solar is one of the oldest applications of drying. It was used since the dawn of mankind mainly for food preservation but also for drying other useful materials as cloths, construction materials, etc. The first installation for drying by solar energy was found in South France and is dated at about 8000 BC. Solar heat was the only available energy source to mankind until the

discovery and use of wood and biomass. Until today in remote small communities, not only in the so-called third world regions, but also in the western countries, people take advantage of solar radiation to dry and preserve small amounts of food.

(Belessiotis, Delyannis 2011). Natural sun 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 equipments, to improve the quality of the final product. **(Ertekin and Yaldiz 2004)**

I.2.2. Conventional air drying

Conventional air drying or hot air drying is one of the most frequently used operation 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 is 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).**

I.2.3. 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 (HAD) time according to certain authors **(Maskan 2001**;**Therdthai and Zhou 2009)**.

MWD drying 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, Mohareb 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 MWD **(Maskan 2001**;**Zhang, Himmel et al. 2006; Bakirci, Ozyurt et al. 2011)**.

I.3. Yoghurt

I.3.1. Definition and Classification

Yogurt which is a product of Lactic acid fermentation of milk by addition of a starter culture containing *Streptococcus thermophilus and Lactobacillus delbrueckii subsp. Bulgaricus;* is one of the most traditional cultured milk. **(Amakoromo, Innocent-Adiele et al. 2012).** Typical composition of yoghurt is shown in table III.

Table III: Chemical composition of typical yoghurt **(Amakoromo, Innocent-Adiele et al. 2012).**

Constituent (per 100 g)	Standard yoghurt	Fruit yoghurt
Water (g)	81.9	77.0
Total solids (g)	18.1	23.0
Fat (g)	3.0	0.7
Protein (g)	5.7	4.1
Lactose (g)	7.8	-----
Calcuim (mg)	200	150
Phosphorus (mg)	170	120
Soduim (mg)	80	64
Potasium (mg)	280	210
Zinc (mg)	0.7	0.5

- Industrially, yoghurts can be largely divided into two types. A set-style yogurt is made in retail containers giving a continuous undisturbed gel structure in the final product. On the other hand, stirred yogurt has a delicate protein gel structure that develops during fermentation .In stirred yogurt manufacture, the gel is disrupted by stirring before mixing with fruit and then it is packaged. Stirred yogurts should have a smooth and viscous texture. In terms of rheology, stirred yogurt is a viscoelastic and pseudoplastic product. Yoghurts come in a variety of textures (e.g. liquid, set, and smooth), fat contents (e.g. luxury, low-liquid, virtually fat-free) and flavors (e.g. natural, fruit, cereal), can be consumed as a snack or part of a meal, as a sweet or savory food, and are available all year round. This versatility, together with their acceptance as a healthy and nutritious food, has led to their widespread popularity across all population subgroups **(Khraisheh, Cooper et al. 1997).**

I.3. 2. Health Benefits

Better growth and increased nutrient utilization are associated with yoghurt consumption, due to increased protein digestibility. Milk fat also becomes easily digestible due to certain predigestion reactions during fermentation. Yoghurt provides higher levels of protein,

carbohydrate, calcium and certain B vitamins than milk **(Amakoromo, Innocent-Adiele et al. 2012)**

- Yoghurt is not just seen as a diet food but also a health food because of its therapeutic value and it is consumed as both as a food and a thirst quenching beverage. Increasead yoghurt consumption enhances the intestinal environment and immune system due to the presence of yoghurt starter and probiotic bacteria which should be present at recommended concentration of log 6 to 8 CFU /g at the time of consumption **(Amakoromo, Innocent-Adiele et al. 2012)**

Health benefits of yoghurt are correlated with the presence of living microorganisms like lactic acid bacteria, streptococci, bifidobacteria or their combinations, which originate from the starter cultures and are recognized as functional ingredients. Yoghurt with added antioxidants from natural sources appears to be a convenient food format to satisfy consumer interest in original yoghurt nutrients, beneficial effects of starter cultures, and health benefits of added antioxidants. For this reason, several attempts to produce yoghurts fortified with natural antioxidant-rich extracts have been undertaken, including supplementation with polyphenol-rich wine extract **(Chouchouli, Kalogeropoulos et al. 2013).**

Materials and methods

II. Material and methods

II.1. Chemicals

All solvents and reagents used were of analytical grade. Sodium carbonate ($N_{a2}CO_3$), Folin ciocalteu's phenol reagent, aluminum chloride hexahydrate ($AlCl_3$-$6H_2O$) and 2, 2-diphenyl-1-picryl-hydrazil (DPPH) , trichloroacetic acid extra pure ($C_2HCl_3O_2$) were purchased from Sigma-Aldrich (Germany).Chlorogenic acid from Fluka India. Gallic acid, quercetin, citric acid ($C_6H_8O_7$ H_2O), sodium acetate anhydrous ($C_2H_3N_aO_2$ $3H_2O$) and potassium chloride (KCl) ,Iron (III) chloride hexahydrate ($Fecl_{3,}6H_2O$) were supplied from Biochem-chemopharma (UK), nitric acid (HNO_3) and ammonium molybdate tetrahydrate ($H_{24}Mo_7N_6O_{24}$, $4H_2O$) was purchased from Biochem-chemopharma(Canada) ,potassium ferricyanide [$K_3F_e(CN)_6$] was supplied from Biochem-chemopharma(USA). (UV-VIS Spectrophotometer UV-9200, Biothech Engineering Management CO, Ltd. UK).

II.2. Plant material preparation

Fresh eggplant (*Solanum melongena*) was purchased from local market, Bejaia city, Algeria in March 2016 **(Fig.6)** then washed by distilled water. Eggplant was peeled using a sharp knife (Todaro et al., 2009), and whole peel were dried by the oven and microwave methods

Figure 06. Photography of fresh eggplant

II.2.1. Drying Kinetics

II.2.1.1. Oven drying

The eggplant peels were air dried in a ventilated oven (ECOCELL), at different temperatures (40, 60, 80, 100 and 120 °C), until constant weight then ground using a grinder (IKA A11 BASIC, Germany) to granulometry (Sifter, RETCHE) lower than 250 µm prior to extraction. The water activity (aw) of powders was determined by HygroPalm AW. The fine powders were stored in air tight containers until use.

II.2.1.2. Microwave drying

Microwave drying experiments were performed in a domestic microwave oven (NN-S674MF. Samsung. Malaysia) with cavity dimensions of 22.5 cm × 37.5 cm × 38.6 cm and 2450 kHz working frequency was used. 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 eggplant peel, until constant weight, then ground and sieved to < 250 µm particle size. Then, the water activity was determined.

II.2.2. Evaluation of moisture content

Thermal drying method was used in the determination of moisture content of the sample. 10 g of sample were placed in an oven to dryness at 103±2°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 (%) =W_0/W_i x 100**, where W_0 correspond to the loss in weight (g) on drying and W_i correspond to the initial weight of sample (g) **(Doymaz 2004).**

II.2.3. Color assessment

Color of the samples was measured using a color reader (Minolta, CR10, Osaka, Japan) under white light at 90° angle. The colorimetric coordinates of the powders of eggplant 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. Data were the average of three measurements **(Achat, Tomao et al. 2012)**

II.2.4. Extraction procedure

II.2.4.1. Conventional extraction

A preliminary study was performed in order to select the solvent type for the rest of investigation. By fixing extraction time (3h) and solvent concentration (80/20, v/v), samples were extracted with ethanol, water, methanol, acetone and acidified ethanol at room temperature under stirring. Thus 1 g of dried powder of eggplant peels was macerated in 60 ml of the extracting solvent, and then the mixture was covered with parafilm and aluminum foil, to prevent light exposure. The solution was centrifuged for 10 min at 15000 rpm (25°C) and the supernatant

was used. After vacuum filtration the extract obtained was evaporated to dryness in a stove at 40 °C. The eggplant peels extracts were stored at 4°C and subsequently used for the determination of extraction yield and total anthocyanins compounds (ANC) .The extraction yield was obtained from this formula:

$$(W_2 - W_1 / W_0) \times 100$$

Where, W_2 is the weight of the extract and the container, W_1 is the weight of the container alone and W_0 is the weight of the initial dried sample.

- The best solvent type was selected according to the value of ANC, as mg Delphinidine -3-glucoside equivalents per dry matter (mg Del-3-glc /100g DM).

II.2.4.2. Ultrasound assisted extraction

The dried peel powder (60 mL/ g) was extracted, in a sonication bath (Elma P70, Singer, Germany), at fixed sonication conditions (power of 140 W, a frequency of 35 kHz, and an acoustic energy density (AED) of 35W L−1) for 90 min. The extractions were performed within a temperature 70 °C, according to the modified method of **(Philippi, Tsamandouras et al. 2016).** After the completion of the extraction, samples were centrifuged for 10 min at 15000 rpm. The clear centrifugate was filtered under vacuum, stored at 4°C. The obtained extracts were used for further analysis: determination of polyphenols (anthocyanins, total polyphenols, chlorogenic acid, flavonoids) and antioxidant assays.

II.2.4.3. Determination of polyphenols

II.2.4.3.1. Total phenolic content

The amount of total phenolic (TPC) in the extracts was determined using Folin-Ciocalteu method. 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 **(Lapornik, Prošek et al. 2005)**.Thus, a 2.5 mL sample of water-diluted Folin-Ciolcateu reagent (1/10) was added to the different extracts of *Solanum melongena*. 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 specific absorbance at 750 nm was immediately measured, using Uv-vis light spectrophotometer (SpectroScan 50, United Kingdom)**.** TPC concentration was calculated from a calibration curve, using gallic acid as a standard and the results were expressed as mg gallic acid equivalents per g of dry matter (GAE/ g DM). All determinations were carried out in triplicate.

II.2.4.3.2. Total anthocyanins content

Total monomeric anthocyanins (ANC) content of eggplant samples was monitored by the pH differential method as outlined by **(Lee, Durst et al. 2005).** Monomeric anthocyanin pigments reversibly change color wih a change in pH; the colored oxonium form exists at pH 1.0, and the colorless hemiketal form predominates at pH 4.5. The difference in the absorbance of the pigments at 520 nm is proportional to the pigment concentration. (**Fig.07**) **(Lee, Durst et al. 2005).**

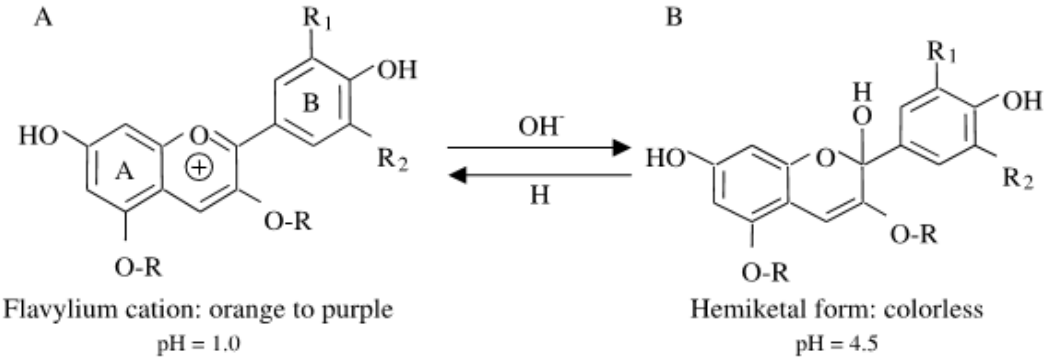


Figure 07: Structure of anthocyanins in pH 1.0 and 4.5 buffers, and the structures of the flavylium cation (A) and hemiketal forms (B). Glycosidic substituent. **(Lee, Durst et al. 2005).**

- After dilution of the extracts with potassium chloride buffer (0.025 M, pH = 1.0) and sodium acetate buffer (0.040 M; pH = 4.5) and allowed to equilibrate for 20 minutes. The absorbance of equilibrated eggplant samples was measured versus a blank cell (filled with distilled water) for pH 1.0 and 4.5 at maximum absorbance wavelengths ($\lambda_{visile\ max}$ =520 nm) and at 700 nm to correct for haze. Measurements were performed in triplicates using UV-visible spectrophotometer (UV-VIS Spectrophotometer UV-9200, Biothech Engineering Management CO.,Ltd. UK). Results are expressed as delphinidine -3-glucoside basis. Degraded anthocyanins in the polymeric form are resistant to color change regardless of pH and are not included in the measurements because they absorb at pH 4.5 as well as pH 1.0. Anthocyanin pigment concentration is calculated as follows:

$$\text{Anthocyanin pigment}\left(\text{delphinidine}-3-\text{glucoside equivalents},\frac{\text{mg}}{\text{L}}\right)=\frac{\text{A}\times\text{MW}\times\text{DF}\times(1000)}{\varepsilon\times\text{l}}$$

Where: A = ($A_{520nm} - A_{700nm}$) pH 1.0 – ($A_{520nm} - A_{700nm}$) pH 4.5;

MW (molecular weight) = 465 g/mol Delphinidine-3-glucoside (Del-3-glu);
DF = dilution factor;
l = pathlength in cm = 1;
ε = molar extinction coefficient = 29 000 $L.mol^{-1}.cm^{-1}$, for Del-3-glu;
10^3 = factor for conversion from g to mg.

II.2.4.3.3. Total chlorogenate yield

An aliquot of centrifuged, clear extract was diluted 1:10 with methanol, placed in a 1-cm quartz cell and the absorbance was obtained at 325 nm. The total chlorogenate yield (YTCg) was determined as chlorogenic acid equivalents (mg CGAE/ g DW) using as MW= 354 and ε =18,130 M^{-1} cm^{-1} **(Dao and Friedman 1992)**, as follows:

$$\text{YTCg mg CGAE /g DW} = \frac{19{,}53 * A * V}{m}$$

- Where V is the volume of the extraction medium (L) and m the dry weight of the plant material (g).

II.2.4.3.4. Total flavonoids content

The total flavonoid content (TFC) was determined according to the mostly applied colorimetry method based on the formation of aluminium- flavonoid complexes **(Fig.08)** and following the procedure of **(Bahorun et al. 1996).** Briefly, the extracts were diluted and 1.5 mL of 2% (w/v) aluminium chloride ($AlCl_3$) was added to 1.5 mL of diluted extracts or rutin (positive control) and then mixed using vortex mixer (EV-102, tehtnicazelezniki, Germany) for approximately 10 s. The mixture was allowed to stand for 15 min. Absorbance of the mixture was determined at 430 nm versus the prepared blank using Uv-vis light spectrophotometer (UV-VIS Spectrophotometer UV-9200, Biothech Engineering Management CO.,Ltd. UK). TCF was expressed as mg rutin equivalent per g of dry matter (RE/ g DM)). Samples were measured in triplicate.

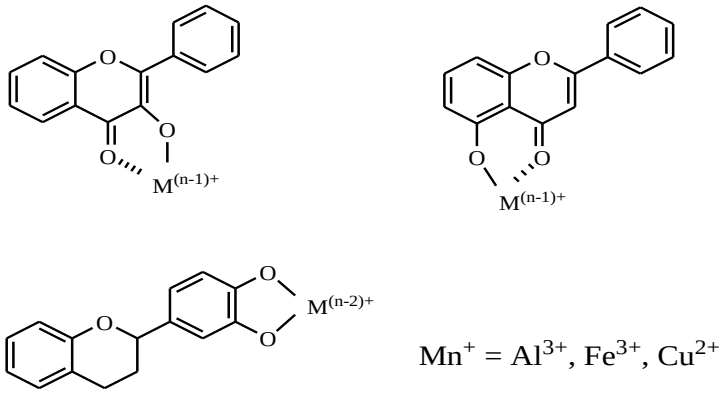


Figure 08: The chelation of metal ions by flavonoids **(Dangles 2006)**

II.2.4.4. Antioxidant assays

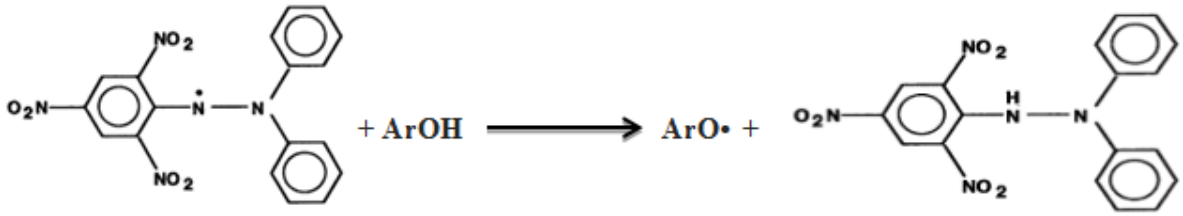
II.2.4.4.1. Radical-scavenging test

The radical-scavenging activity of samples was evaluated by the DPPH• assay. DPPH (2,2-diphenyl-1-picrylhydrazyl) is a stable highly colored free radical that can abstract labile hydrogen atoms from phenolic antioxidant (ArOH) with concomitant formation of a colorless hydrazine (DPPH-H), according to equation 1 and figure 09 **(Molyneux 2004)**. The free radical-scavenging activity (RSA) of an extract can be expressed as the percentage of DPPH reduced by a given amount of extract. The free radical-scavenging activity (RSA) was measured, following **(Achat, Tomao et al. 2012)** method. 1 ml of extract was added to 2 ml of DPPH solution (2.10^{-4} Mol/L in methanol) and the mixture was left in the dark at room temperature for 20 min. The total RSA of each extract was expressed as the percentage of DPPH reduced and was calculated by the following equation:

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

A_C: absorbance of DPPH solution without any antioxidant; A_S : absorbance of DPPH solution after reaction with the extract. All experiments were performed in triplicate.

$$\text{DPPH}^{\bullet} + \text{ArOH} \xrightarrow{k} \text{DPPH-H} + \text{ArO}\bullet \qquad \text{[Eq.1].}$$



Diphenylpicrylhydrazyl (free radical)

Diphenylpicrylhydrazine (non radical)

Figure09 : DPPH• radical reduction **(Molyneux 2004; Achat, Tomao et al. 2012)**

II.2.4.4.2. Reducing power assay

The reducing power was determined according to the method of **Oyaizu 1986**. Each sample (1–5 mg ml^{-1}) in ethanol (2.5 ml) was mixed with 2.5 ml of 200 mM sodium phosphate buffer (pH 6.6) and 2.5 ml of 1% potassium ferricyanide, and the mixture was incubated at 50 °C for 20 min. After incubation 2.5 ml of 10% trichloroacetic acid (w/v) were added, the mixture was centrifuged at 1500 g for 10 min. The upper layer (5 ml) was mixed with 5 ml of deionized water and 1 ml of 0.1% ferric chloride, and the absorbance was measured at 700 nm against a blank. A higher absorbance indicates a higher reducing power. RC_{50} (mg 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. All tests were carried out in triplicate.

II.2.4.4.3. Total antioxidant activity

The total antioxidant activity of samples was evaluated by the green phosphomolybdenum complex formation according to the method of **Gokturk and Baydar et al.. 2007.** This method is based on the reduction of phosphomolybdic acid to phosphomolybdenum blue complex by sodium sulfide. The obtained phosphomolybdenum blue complex is oxidized by the addition of nitrite and this causes a reduction in intensity of the blue colour. Briefl y, a 0.1 mL of sample aliquot was mixed with 1 ml of reagent solution (0.6 M sulphuric acid, 28 mM sodium phosphate and 4 mM ammonium molybdate). The test tubes were capped and incubated in a water bath at 95°C for 90 min. After the samples had cooled to room temperature, the absorbance of the mixture was measured at 695 nm against a blank. The antioxidant activity was expressed as the absorbance of the sample.

II.2.4.5. Mineral content

For the analysis of minerals 5 g of dried ground sample (80°C and 100 W), were calcined in a Muffle furnace (Labco, India) at 450 °C for 2 h. Ash was moistened with distilled water and 2-3 drops of concentrated HNO_3(69%) was added. Crucibles were again kept in muffle furnace at 450 °C for 30 min to complete ashing. The ash was then dissolved in 5 ml of concentrated HCl (37%). The mixture was heated until the first vapors appeared and 10 ml of double distilled water was added immediately. Then the solutions were filtered through quantitative ashless filter paper and the final volume was made up to 100 mL with distilled water. The samples were analyzed using atomic absorption spectrometer **(Arivalagan, Bhardwaj et al. 2013).**

II.2.4.6. Scanning electron microscopy (SEM) analysis

For microstructural analysis, eggplant peels was observed under SEM (Quanta 200, FEI Company, France) for morphological characterization before and after the extraction and drying processes **(Lou et al. 2010)**. Seven samples of dried *Solanum melongena* (3: untreated and dried residues UAE and CSE samples; 4: dried peels at 80 °C and at 100 W, outside and inside part) were used for SEM analysis. Dried sample particles were fixed on a specific carbon film support, and their shape and surface characteristics were observed by using gaseous secondary electron detector GSED with environmental mode. Images of dried eggplants were taken at × 50 and × 100 magnification levels.

II.3. Formulation of fruity stirred yoghurt at laboratory scale

II.3.1. Manufacture of yoghurts

The preparation of yoghurt was made in the laboratory 3BS (University of Bejaia) respecting the diagram for making standard yoghurt with addition of eggplant peel. The adapted recipe is the one determined within the work which is included in our research laboratory project. Thus, four steamed yoghurts were manufactured; cow milk was homogenized and heated to 95 °C for 5 min then cooled to 40 °C. After then, traditional starter culture was added and the mixture was incubated until the gel structure was formed. The gel was stirred and stored at refrigerator (6±2°C), in this case a standard stirred yoghurt was obtained. The same experiment was done with the other yoghurts except that whereas dried eggplant peel were added

Table IV: Recipe of standard yoghurt and yoghurt flavored with the eggplant peel.

Recipe	Milk (L)	Sugar (g)	Eggplant	Lactic Ferment (%)
Standard yoghurt	1	80-100	0	0.02
Yoghurt with eggplant (100 W)	1	80-100	---	0.02
Yoghurt with eggplant (80 °C)	1	80-100	---	0.02

II.3.2. Physico-chemical properties of yoghurt

Physico-chemical properties of the manufactured yoghurts (standard yoghurt, yoghurt with dried eggplant at 80°C and 100 W) were determined namely, pH, dornic acidity, viscosity, the dry extract and fat contents (**Table V**). These tests were carried out at the laboratory of the dairy industry "DANONE DJURDJURA".

Table V: Physico-chemical properties of yoghurts

Measure	**Method**
pH	The pH value of yoghurt was measured at fixed temperature (9.5-10.5°C) with a calibrated pH electrode (HANNA HI 2210).
Viscosity (g)	Apparent viscosity of yoghurt was expressed using a viscometer "TAXT EXPRESS" during 45 S.
Dornic acidity (°D)	10 g of sample (adjusted with distilled water up to 60 g), was put in acidometer apparatus then the result was directly displayed.
Brix degree	The soluble solids content of the filtered yoghurt (whey) and was assessed by the refractometer, where sugar content value was given.

Total dry extract (%) Protein content (%) Fat contents (%)	50 g of yoghurt was placed in "Food scan" apparatus which give the values of total dry extract, protein and fat contents.

II.3.3. Microbiological analysis

Microbiological quality of prepared yoghurt was evaluated by enumerating total viable mesophilic micro-organisms. The micro-organisms enumerated include total flora, yeast, moulds, total coliforms and specific bacteria of yoghurt **(Table VI).**

Table VI: Microbiological analysis of manufactured yoghourts.

Micro-organisms	Selective mediums	Incubation temperature	Incubation time	Method
Total Coliforms	VRBL	30°C	24h	3g of the Yoghurt samples was spread plated in triplicates into prepared and dried petri-plates of suitable media for the enumeration of different organisms.
Total Flora	PCA	30°C	72 h	
Yeasts, moulds	YGC	25°C	5 days	
Streptococcus thermophilus	M17	37°C	48h	
Lactobacillus bulgaricus	MRS	37°C	72h	

VRBL: Violet Red Bile Agar
YGC: Yeast extract glucose chloramphenicol agar
M17: M17 agar
MRS: Rogoza and Sharpe agar.

II.3.4. Antioxidant acitivity and ANC of yoghurts

The anthocyanin content in yoghurts was determined by using the pH differential methods (Section II.2.3.2). The Radical scavenging capacity was also measured in prepared yogurts by the $DPPH^{\bullet}$ assay (Section II.2.4.4.1). Ethanolic solution containing citric acid 1g L^{-1} was used as extraction solvent

II.4. Sensory analysis

Evaluation of sensory properties of yoghurts (standard yoghurt, yoghurt with powder at 80°C and powder 100W was studied. The panel was constituted by ten trained panellists from the staff members of the Life and Nature Science (University of Bejaia). Panelists evaluated the color, taste, texture, flavor and odor of each sample, using a numerical scale 1–9 (1 = not acceptable, 9 = extremely good).

Statistical analysis

All experiments were conducted in triplicate and results are expressed as mean ± standard deviation (SD). The analysis of variance (*ANOVA*) was performed using XLSTAT Release 10

(Addinsoft, Paris, France). Tukey's multiple range test (HSD) was used to compare means of the determined parameters. Evaluations were based on the $p < 0.05$ significance level.

Results and discussions

III. Results and discussion

III.1. Drying kinetic of eggplant peels

The conventional drying (oven) and the innovative drying (microwave) are the most suitable procedures adopted in this study because of their ability to keep the bioactive components of the eggplant peels and compare their performance.

III.1.1. Oven drying kinetic

The weight loss depending on the time-temperature of ventilated oven (conventional) drying of eggplant peels was shown in figure 10.

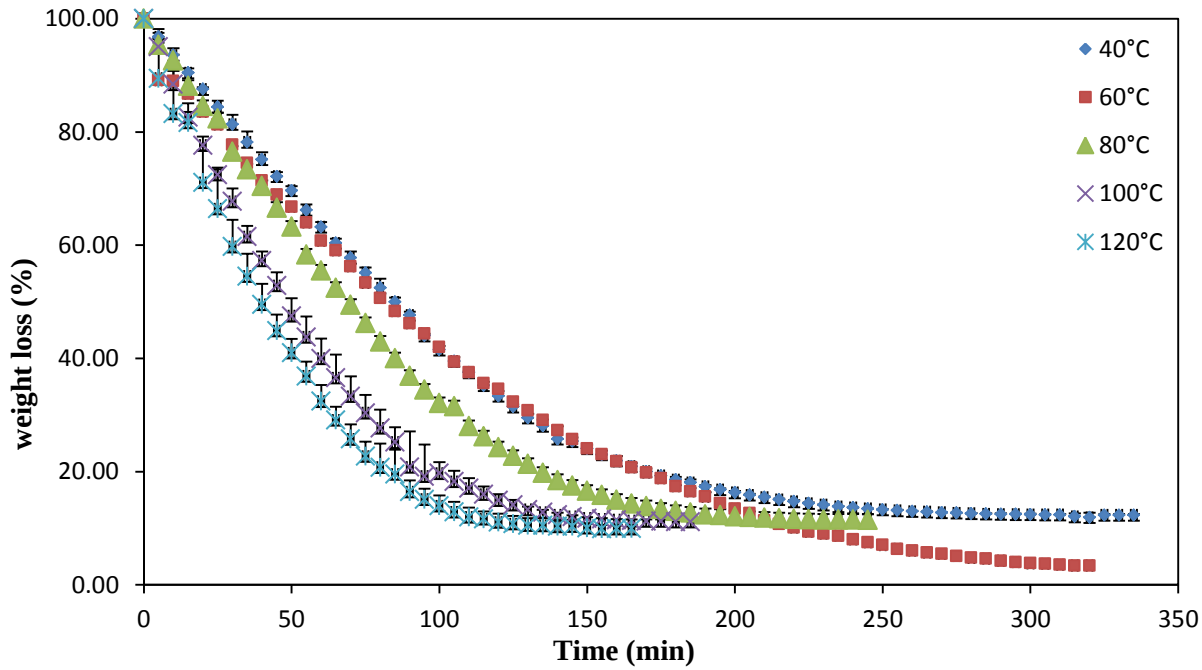


Figure 10: Weight loss evolution as a function of time oven drying of eggplant peels.

The graph shows the variation of the weight loss versus time and drying temperature. The weight of the sample decreases with time progression. The weight stability of the sample dried at 40 °C was reached after 5.47 ± 0.09 hours drying while the dried sample at 120 °C stabilizes after 1.15 ± 0.01 hours of drying. Indeed, at high temperature (100 to 120 °C), the water loss is much faster. The obtained results show that the drying time is inversely proportional to the applied temperature.

III.1.2. Microwave kinetic drying

Weight loss of eggplant peel according on time and temperature of drying in microwave is shown in the figure 11

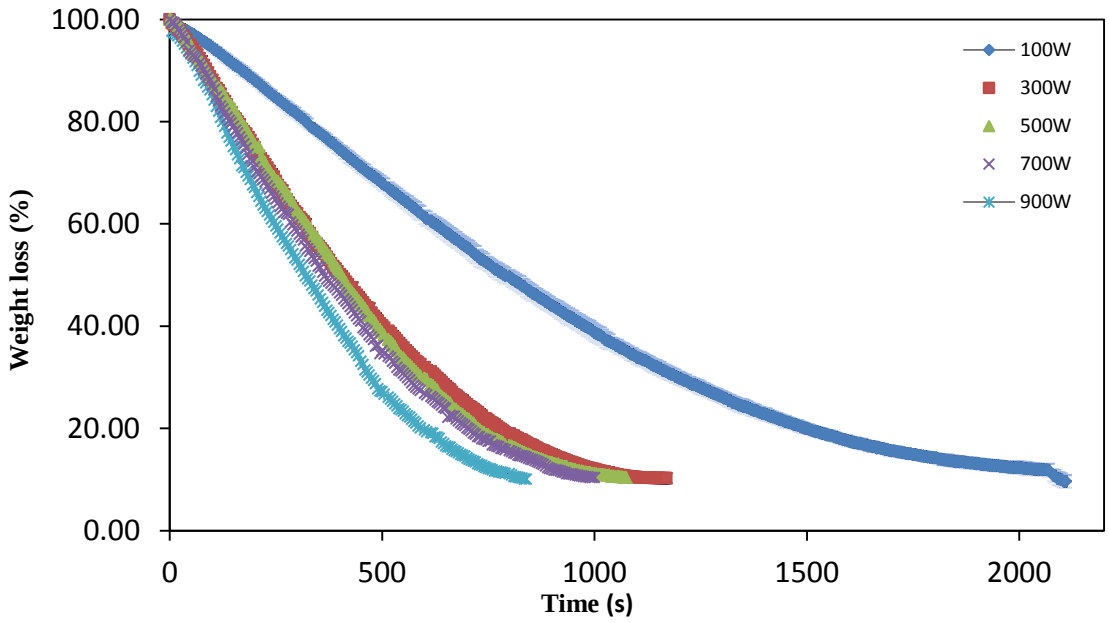


Figure 11: Weight loss evolution according to microwave drying time and power

The longer drying time is attributed to the power of 100 W, which is 55.66 ± 2.50 min. However, the shortest time is obtained when drying is at 900 W (the stability of the mass is reached at 15.43 ± 0.56 min). The obtained results show that the drying time is inversely proportional to the drying power, thus the higher power level; the greater drying time is reduced. The microwave drying efficiency can be explained by a high internal pressure, giving a concentration gradient which increases the evaporation of liquid through the product until weight loss stability **(Chemat, Lagha et al. 2004).** The same results are found by **Ghanem, Zollinger et al. 2012** on citrus peels.

The oven drying time is about 328.33 ± 5.47 min (40 °C) which is significantly higher than that of microwave power which is 15.43 ± 0.56 min **(Fig. 11).** Shorter drying time obtained for microwave can be explained by the rapid mass transfer within the food during microwave heating. Heat is generated within the food due to the absorption of microwave energy and it creates high internal pressure temperature and concentration gradients. Therefore , the flow rate of the liquid through the food is increased **(Sumnu, Sahin et al. 2005).** Similar results are obtained by different studies in which microwave drying time of fruits and vegetables is found to

be significantly shorter than that obtained for hot-air drying time **(Sumnu, Sahin et al. 2005**; **Sharma, Kumari et al. 2007) .** It is also found that the surface temperature of eggplants dried at 20 % IR (Infrared) power and 50% microwave power is 91 ± 2 °C which is significantly higher than that of hot-air-dried ones (47 ± 2 °C). This also explains why microwave-IR combination drying causes shorter drying time. This is due to the fact that the rate of mass transfer is higher at higher microwave powers. Similar results have been observed in literature for microwave drying of mango ginger **(Murthy, Manohar 2014)** and wheat **(Kahyaoglu, Sahin et al. 2012)**. The drying rates are higher in the beginning of the drying processes and gradually reduce through the end of the drying process. This is because more energy is absorbed by the water at the product surface initially, resulting in faster drying and with the product surface drying out subsequently, heat penetration through the dried layer decreases and thus retarding the drying rates **(Sharma, Kumari et al. 2007)**

III.2. Moistures Content

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 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. The moisture content (MC) and water activity of eggplant peels powder were shown in table VII.

Table VII: The moisture content and water activity of eggplant peels powder

40	0.34 ± 0.02	0.88 ± 0.00
60	0.34 ± 0.03	0.89 ± 0.09
80	0.32 ± 0.11	0. 88 ± 0.01
100	0.17 ± 0.06	0 89 ± 0.00
120	0.18 ± 0.00	0.90 ± 0.01
Power (W)		
100	0.17 ±0.02	0.89 ± 0.01
300	0.18 ± 0.04	0.90 ± 0.01
500	0.34 ± 0.08	0.87 ± 0.00
700	0.36 ± 0.00	0.90 ± 0.01
900	0.47 ± 0.21	0.89 ± 0.01

High water activity indicates more free 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 occur, it is induced by chemical reactions rather than by micro-organism **(Quek, Chok et al. 2007).** From the results, the water activities of the *Solanum melongena* powders were in the range of 0.17 – 0.47. This meant that the eggplant peels powders were relatively stable microbiologically. However, the storage conditions also played an important role in this matter in addition, the water content of eggplant peels was 92.30%.

III.3. Color assessment

Color of the dried eggplant peel was investigated by CIE scale: lightness (L*) and redness (a*) and yellowness (b*) values **(Table VIII).**

Table VIII: The color assessment of dried eggplant peels

Temperaturs (°C)	L * value	a*value	b*value
40	55.1 ± 0.70	2.95 ± 1.80	10,72 ± 1,71
60°C	55.45 ± 2.88	1.00 ± 0.64	7.47 ± 2.08
80°C	50.91±5.24	1.84±0.42	10.41±4.11
100°C	50.91±2.55	3.54±2.30	13.65±1.33
120°C	51.8±4.33	1.05±2.69	15.85±0.81

Power (watt)	L * value	a*value	b*value
100	51.94±2.89	1.05±1.62	11.07±2.34
300	50.82±1.80	2.88±1.31	15.84±3.86
500	49.34±2.32	3.27±0.93	18.21±4.25
700	47.62±1.94	4.11±1.14	19.88±0.82
900	49.79±1.82	5.21±1.29	15.04±1.51

Eggplants peel dried with microwave had lower L* values and higher a* values than eggplants dried with hot air. This could be explained by Maillard reactions taking place in microwave drying. **(Michaud, Martins et al. 2011)** stated that increased temperature caused an increase of the reactivity between the sugar and the amino group. Thus, the rate of Maillard reaction increases with temperature. **(Roncero-Ramos, Delgado-Andrade et al. 2013)** showed that Maillard reaction was accelerated at temperatures over 50 °C. Therefore, in microwave drying Maillard reaction rate was higher due to higher temperature. 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.4. Extraction procedure

III.4.1. Conventional extraction

The preliminary study carried out according to the protocol suggested by **Todaro, Cimino et al. 2009** which was adopted and modified for a conventional extraction study in order to confirm the chosen solvent efficiency. The mean values of yield extraction of eggplant peels are shown in figure 12.

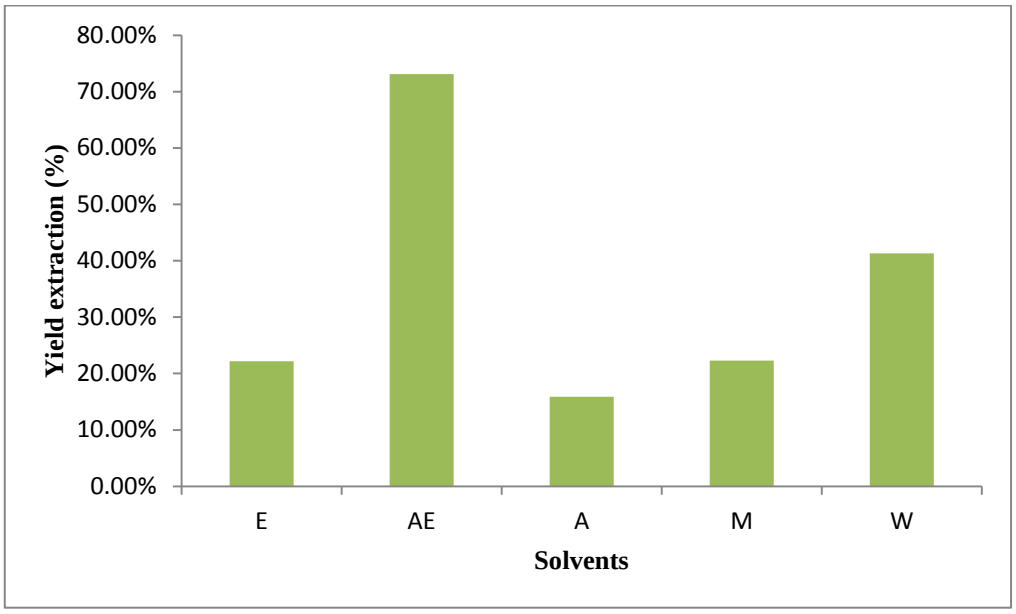


Figure 12: Yield extraction of crude extract from eggplant peels

(E: ethanol, AE: acidified ethanol, A: acetone, M: methanol and W: water)

The highest extraction yields were obtained with acidified ethanol (73.10), whereas the extraction yield with the rest of solvents extracted less material. The same results were reported for polyphenols compounds extraction, from dry eggplant peels. Solutions of organic acids used as alternative solvents showed good extraction yields (> 90% of total anthocyanins) **(Todaro, Cimino et al. 2009)**

III.4.1.1. Total polyphenols content

The figure 13 depicted the amount of total phenolic contents (TPC) of eggplant peels, using different extraction solvents.

Polyphenol contents presented significant differences according to solvent mixture used. Among extracts obtained, acidified ethanol (80 %), was the richest in phenolic compounds (247.22 ± 1.07 mg GAE/100 g DM), whereas ethanol (80%) and acetone (80%) resulted in the weakest concentration (17.67 ± 0.14 mg GAE/100 g DM).

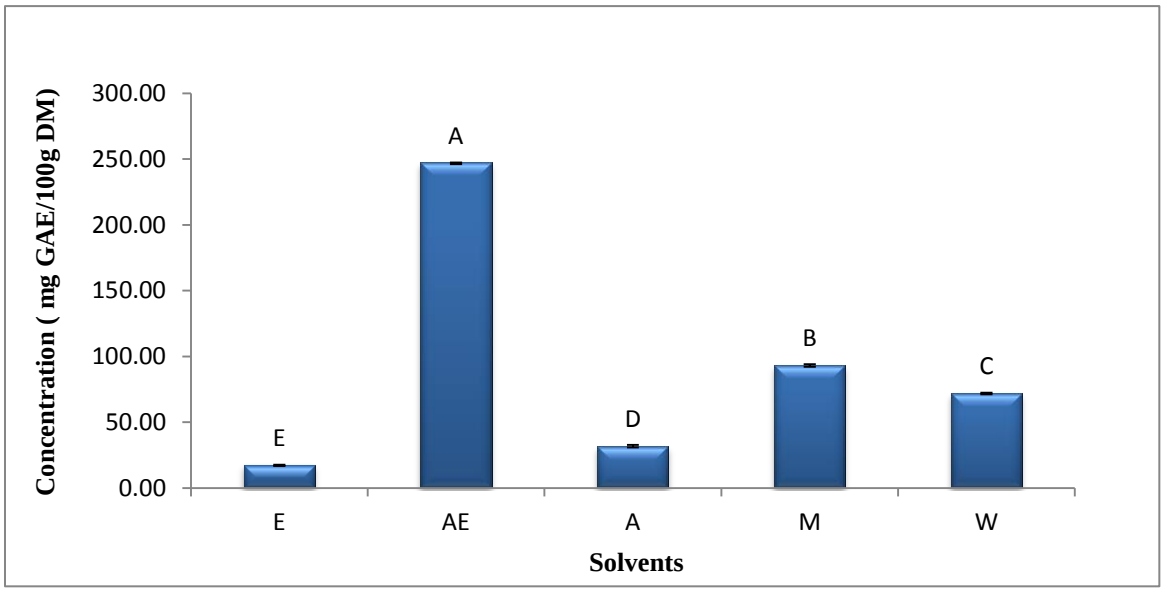


Figure 13: Total phenolic compounds of eggplant peels in different solvents

(E: ethanol, AE: acidified ethanol, A: acetone, M: Methanol and W: water)

A lot of studies have been performed on eggplant polyphenols **(Table IX)**, that revealed a high difference, but the result obtained by **Todaro, Cimino et al. 2009** is very close with our result. The difference of other amount might be due to the condition of the peeling fruit and extraction solvent

Table IX: Works about polyphenols content of eggplant peels

Extracts	Total phenolic content (mg GAE/ 100g DE)	Reference
Methanol	49.02 ± 1.4	**(Nisha, Nazar et al. 2009)**
Acidified ethanol (99%)	188.73 ± 73	**(Todaro, Cimino et al. 2009)**
Ethanol (70%)	55.19 ± 1.3	**(Jung, Bae et al. 2011)**
Ethanol (70%)	13.53 ± 0.6	**(Boulekbache-Makhlouf, Medouni et al. 2013)**
Ethanol (50%)	7.16 ± 0.2	**(Chatterjee, Jadhav et al. 2013)**

III.4.1.2. Anthocyanins content

Anthocyanins are the largest class with antioxidant activity in the peel eggplant **(Chen, Zhao et al. 2015)**.Therefore, it is necessary to extract them efficiently. There was a significant difference between flavonoids content of acetonic extract and the two other extracts ($p < 0.05$); but there is no difference between methanolic and aqueous extracts ($p < 0.05$).

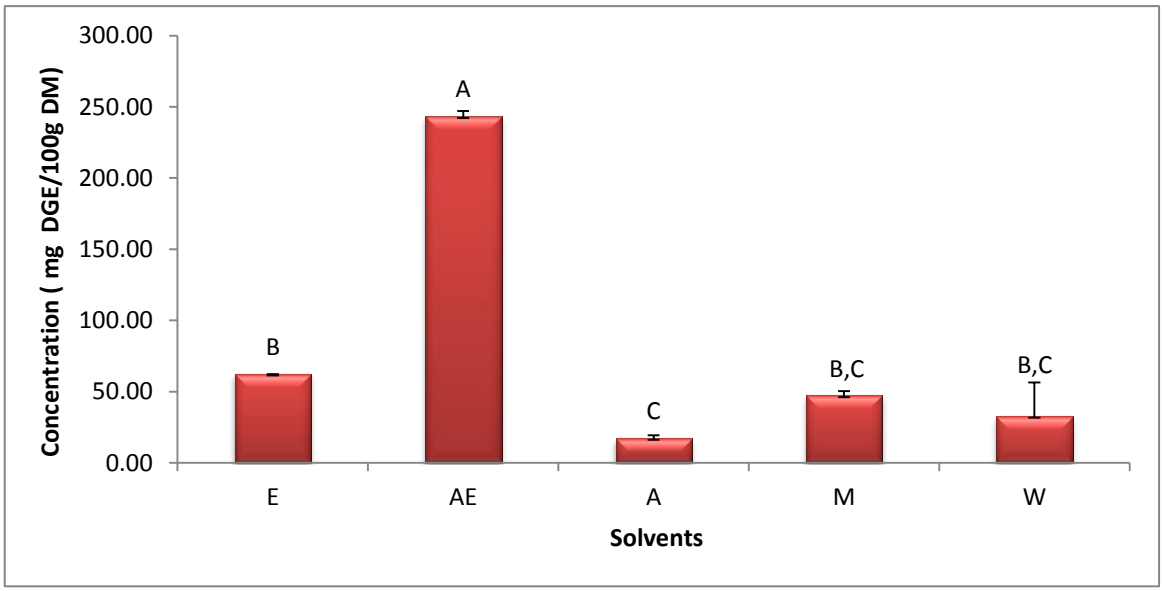


Figure 14: Anthocyanins content of eggplant peels in different solvents

(E: ethanol, AE: acidified ethanol, A: acetone, M: methanol and W: water)

Acidified ethanol extracts exhibited the highest ANC content than the other tested solvents, which was in accordance with previous studies **(Todaro, Cimino et al. 2009) (Table X).**

Table X: Works about ANC content of eggplant peels

Extracts	Anthocaynins (mg Del-3-glu / 100g DE)	Reference
Methanol (whole fruit)	0.53 ± 0.012	**(Nisha, Nazar et al. 2009)**
Acidified ethanol (fresh peel)	76.44 ± 3.82	**(Todaro, Cimino et al. 2009)**
Ethanol (70%) (fresh peel)	82. ± 1.3	**(Boulekbache-Makhlouf, Medouni et al. 2013)**

Those data confirms that anthocyanins are concentrated in the peel of the fruit.

III.4.1.3. Total chlorogenic acid content

Chlorogenic acid (5-*O*-caffeoylquinic acid), is the major eggplant phenolic compounds **(García-Salas, Gómez-Caravaca et al. 2014)**. There was a significant difference between total chlorogenate yield (YTCg) of acidified ethanol, water and ethanol extracts ($p < 0.05$). However, methanol and acetone were not statistically different **(Fig.15).**

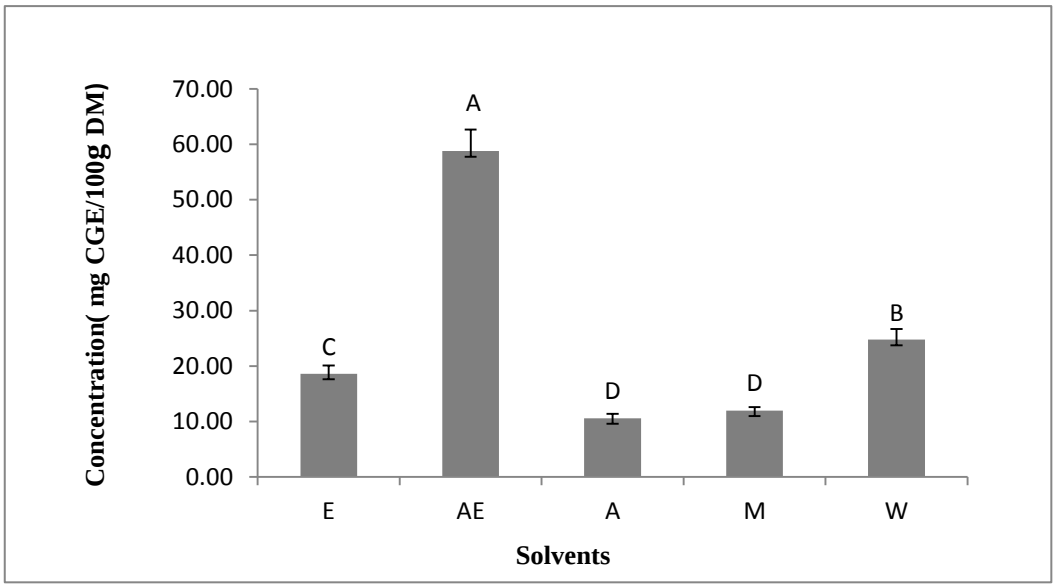


Figure 15: Total chlorogenic acid of eggplant peels in different solvents

(E: ethanol, AE: acidified ethanol, A: acetone, M: methanol and W: water)

The highest YTCg (58.77 ± 1.47 mg CGAE/g DW) was obtained in acidified ethanol extract and the lowest value (18.59 ± 0.80 CGAE/g DW) was recorded in the acetone extract. **Philippi, Tsamandouras et al. (2016)** reported the YTCg of 9.43 and 9.12 mg CGAE/g100 DW for water/ethanol and water/glycerol using ultrasound-assisted extraction, in dried eggplant peels. Eggplant presents a wide morphological and molecular diversity **(Prohens, Blanca et al. 2005; Hurtado, Vilanova et al. 2013)**, as well as a broad variation for composition traits, including total phenolics and YTCg content **(Stommel, Whitaker 2003**; **Arivalagan, Gangopadhyay et al. 2012).** Few studies have been performed in which the variation for YTCg content has been studied in a relevant number of eggplant accessions. The first and broadest study was performed by **Stommel and Whitaker 2003**, who found differences of up to 4.4-fold in the YTCg and a continuous range of variation in a collection of 97 accessions of cultivated eggplant.

III.4.1.4. Total flavonoids content

Flavonoids contents of different extracts are given in figure 16. The results suggested that nature of solvent, influence statistically ($p < 0.05$) the extraction efficiency of flavonoids

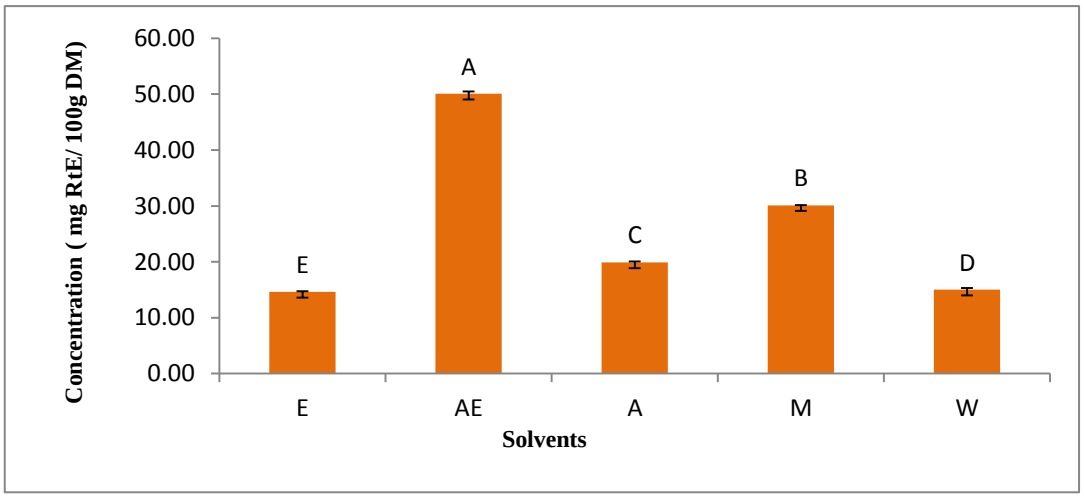


Figure 16: Total flavonoid content of eggplant peels in different solvents

(E: ethanol, AE: acidified ethanol, A: acetone, M: methanol and W: water)

The highest level has been detected in acidified ethanol extract (50.06 ± 0.43 mg RtE/100 g DM), followed by methanolic and acetone extracts (30.09 ± 0.07 and 19.87 ± 0.02 mg RtE/100 g DM. respectively). **Boulekbache-Makhlouf, Medouni et al.(2013)** have reported the same TFC of dried eggplant peels: 18.52 ± 0.07 and 16.26 ± 0.26 mg QE/100 g DE, in acetone and ethanol extracts respectively. However **Jung, Bae et al. 2011** have estimated the TFC in 70% ethanol extract of fresh peel eggplant, they found about 6.19 ± 0.28 mg catechin equivalent/100 g DE. **Pedastsaar, Vaher et al.(2014)** have recorded 660 mg RtE/100 g DE of TFC in ethanol (80%). In parallel **Salerno, Modica et al.(2014)** have reported 15.05 ± 0.15 and 34.02 ± 0.16 mg RtE/100g mg in ethanol (50%) and water extract. The difference among the values of reported TFC can be explained by the difference of the quantification methods used, the difference in the nature of the matrix (fresh or dried), the applied pre-treatments in each technique and finally the variety of eggplant studied.

III.4.1.5. Selection of solvent

The selection of extraction solvents is critical for the plant matrices as it will determine the amount and type of phenolic compounds being extracted. Aqueous alcohol particularly acetone, ethanol and methanol are most commonly employed in phenolic extraction from botanical materials **(Naczk, shahidi 2004)**. The best solvent type was selected according to the highest values of TPC, ANC, TFC and YTCg. Thus, acidified aqueous ethanol was chosen as the extraction solvent for the next experiments.

III.4.2. Ultrasond-assisted extaction of eggplant peel

The use of bioactive compounds in different commercial sectors such as pharmaceutical, food and chemical industries signifies the need of the most appropriate and standard method to extract these active components from plant materials. Along with conventional methods, numerous new methods have been established namely microwave assisted extraction (MAE) and ultrasound assisted extraction (UAE). Thus, the development of "modern" sample preparation techniques with significant advantages over conventional methods for the extraction and analysis of these molecules is likely to play an important role in the overall effort of ensuring and providing high-quality products to consumers.

The results of UAE **(Fig.17)** revealed that there were significant differences with wide variability among the quantified polyphenols of eggplants peels, which were highest than values determined in conventional extraction (Section III.4.1).

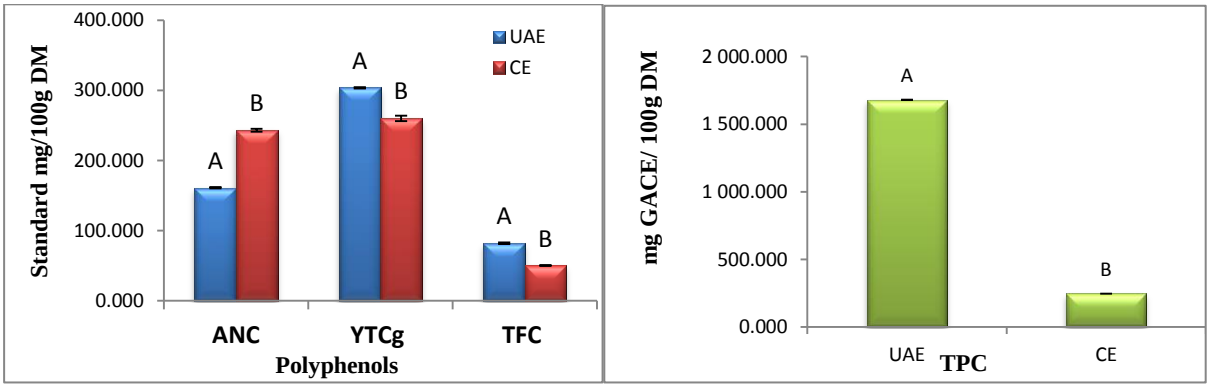


Figure 17: Polyphenols content (TPC, ANC, TFC and YTCg) of acidified ethanol and ultrasonic extracts from eggplant peels.

(UAE: ultrasound assisted extraction; CE: conventional extraction)

To evaluate the effect of drying, oven and microwave, on quality eggplant peels, the obtained acidified ethanol, ultrasonic extracts were analyzed for bioactive components (TPC, ANC, TFC and YTCg) and antioxidant activities (total antioxidant capacity, radical scavenging test and reducing power)

III.4.2.1. Total phenolic contents

The determination of total phenolic compounds for eggplants peels, dried with oven and microwave power are given in figure 18. The results obtained were statistically different ($p < 0.05$).

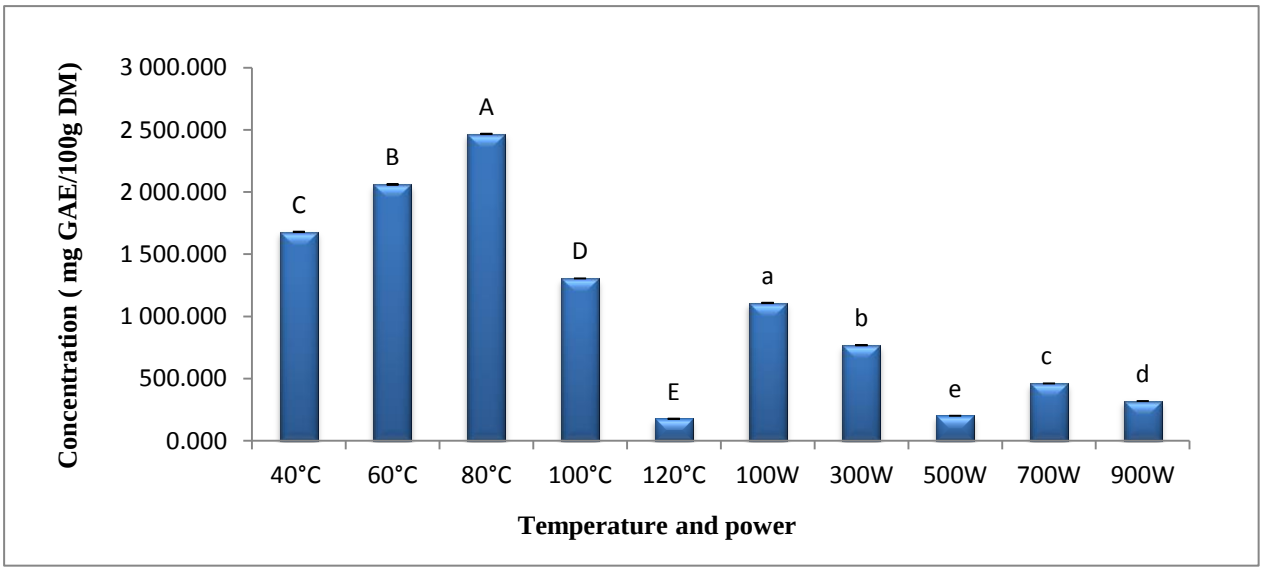


Figure 18: Contents of total polyphenol of the eggplant peels extracts, dried in oven and microwave

The drying oven indicated that the highest TPC was attributed to 80 °C and the lowest to 120°C (2468 ± 46 to 177.64 ± 0.07 mg GAE/100 g DM respectively) at $p < 0.05$. This may be due to the denaturation of polyphenols under temperature effect **(Klimczak, Małecka et al. 2007).** TPC of Eggplant peel obtained in this study was lower than previous data, 7842 mg GAE/100g DM, using UAE eggplant peels (2-propanol, 45 kHz, 60°C for 40 min) **(Dranca and Oroian 2015).** However, it was higher than the value recorded (10.03 mg GAE/g DM) using MAE of eggplant peel **(Salerno, Modica et al. 2014)**, and those reported by **Philippi, Tsamandouras et al. 2016** (13.51± 1.85 mg GAE/g DM, using UAE, water /glycerol mixture). These differences are probably due to the extraction solvent type, method and difference in varieties of eggplant studies.

TPC obtained in dried microwave samples varied from 1108.43 ± 0.28 to 202.56 ± 0.09 mg GAE/100 g DM, which assigned for 100 and 500 W powers respectively. This decrease can be explained by the degradation of these compounds by the strong radiation. The effects of the drying process by microwave on phenolic substances of food were been studied previously, some authors have reported that there is an effect on the phenolic compounds **(Akyıldız, Aksay et al. 2004)** and they have found that there is no significant change in their concentration of these compounds **(Dewanto, Wu et al. 2002).** It was also noticed that the TPC is very preserved, using drying oven at 80 °C (2468 ± 46 mg GAE/100g DM) after 130 min, while time is significantly reduced (15.83 min) when microwave drying is applied but with a lower amount of TPC at 100 W (1108.43 mg GAE/100g DM).

III.4.2.2. Total anthocyanins content

The mean values of ANC content of eggplant samples using oven and microwave drying are shown in figure 19

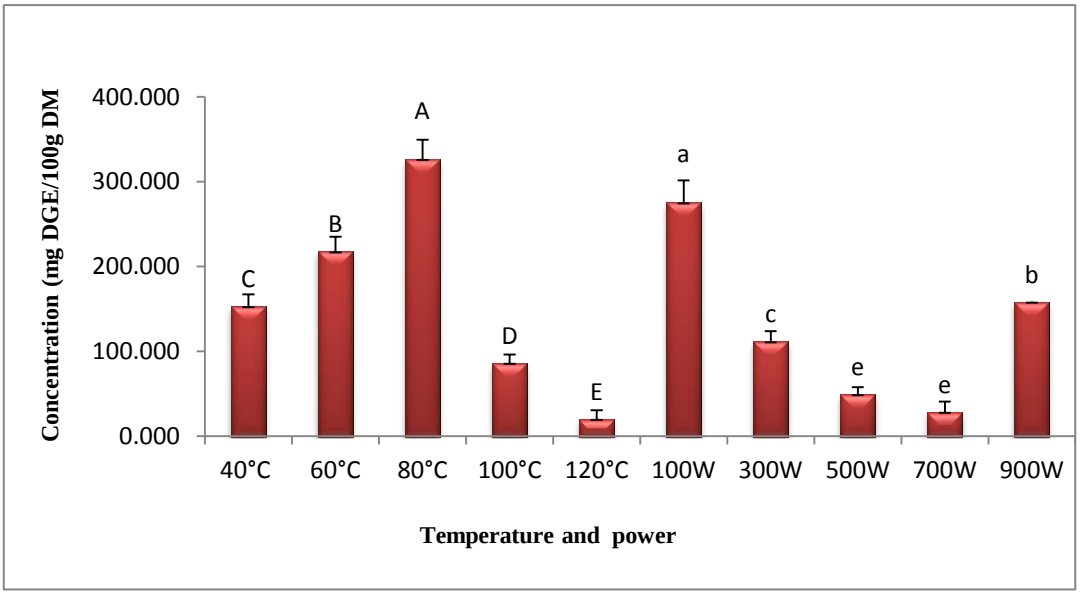


Figure 19: Anthocyanins contents in the extracts of eggplant peels, dried in oven and microwave.

Eggplants dried in ventilated oven had a highest value of ANC at 80 °C (339.31 ± 7.93 mg DGE / 100g DM) whereas the content obtained at 120 °C was much smaller ($P < 0.05$) (14.10 ± 0.043 mg DGE / 100g DM). However in microwave drying the power of 100 W give the greatest contents of ANC (260 ± 0.44 mg DGE / 100 g DM), which is close with ANC content at 80°C that obtained, from dried eggplant, during 42 min and 120 min respectively. Thus, it is interesting to note that microwave drying reduces drastically time of drying. This is also illustrated in the case of drying at 40 °C and 900 W that resulted in the same ANC contents (161.09 ± 2.4 and 160.89 ± 1.22 mg DGE/100 g DM respectively), but with only in a time of 0.35 h for 900 W and 5 h for the time of 40 °C.

III.4.2.3. Total chlorogenate and flavonoid contents

Figure 20 and 21 summarizes the total chlorogenate yield and total flavonoid contents in the different eggplant extracts, using dried powders in oven and microwave

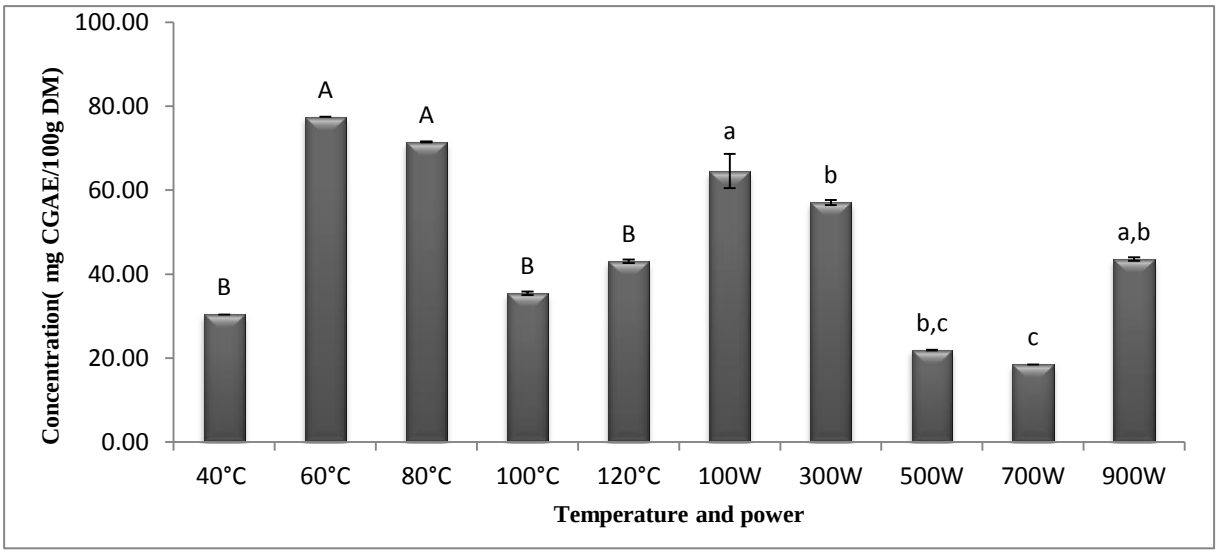


Figure 20: Total chlorogenic acid of eggplant peels, dried in oven and microwave.

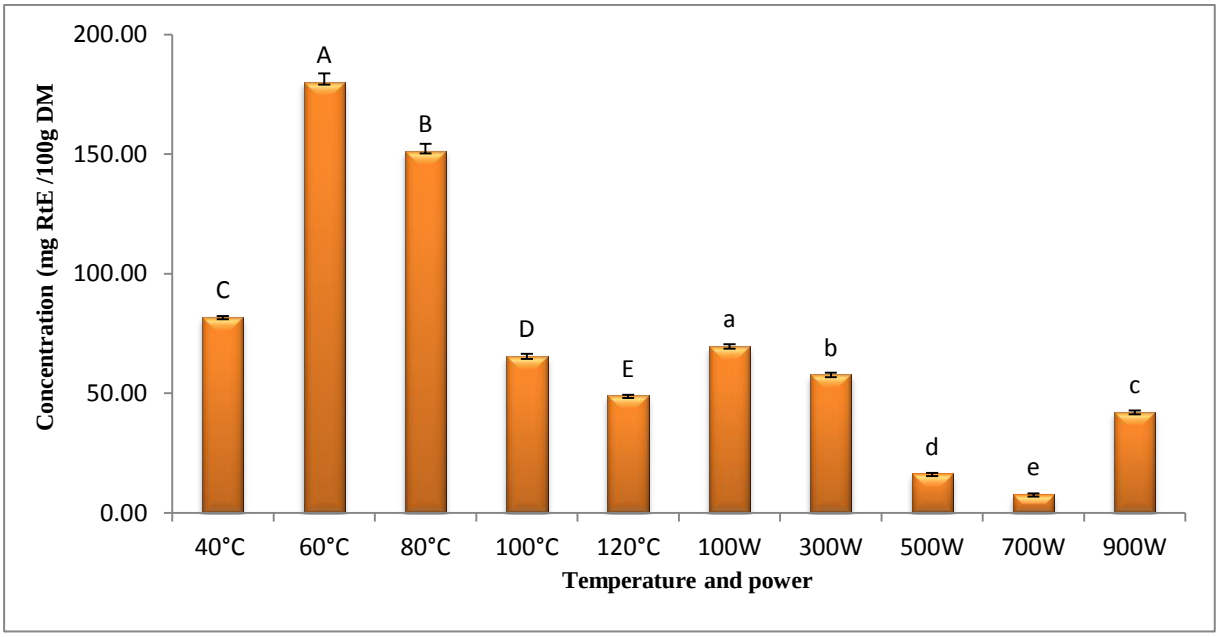


Figure 21: Total flavonoid content of eggplant peels dried in oven and microwave.

The greatest YTCg are attributed to the oven dried powder at 60 °C and 80 °C namely 77.17 ± 0.10 and 71.41 ± 0.10 mg CGAE/g DM. In the case of microwave the highest values was obtained with the lower powers 100 W and 300 W (67.44 ± 4.72 and 57.07 ± 0.61 mg CGAE/g DM. respectively). The power of 900 W revealed also a high YTCg. The TFC data **(Fig.21)** showed the same tendencies of the results obtained in the YTCg.

According these results, the stability (low degradation) of chlorogenic acid and flavonoid contents of eggplant peels can be assigned to high temperature/ short time. The

microwave reduces the drying time of 2 two times as fast for the same YTCg, in oven at 60°C, and 9 times to keep half of TFC contents.

III.4.3. Antioxidant assays

Several methods have been developed to measure the efficiency of dietary antioxidants. These methods are based on different kinds of defence systems: scavenging reactive oxygen species (ROS), hydroxyl radicals, reduction of lipid peroxyl radicals, inhibition of the lipid peroxidation and chelating of the metal ions **(Achat, Tomao et al. 2012)**

III.4.3.1. 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 22 shows the DPPH° radical scavenging activity of different extract of dried eggplant peels.

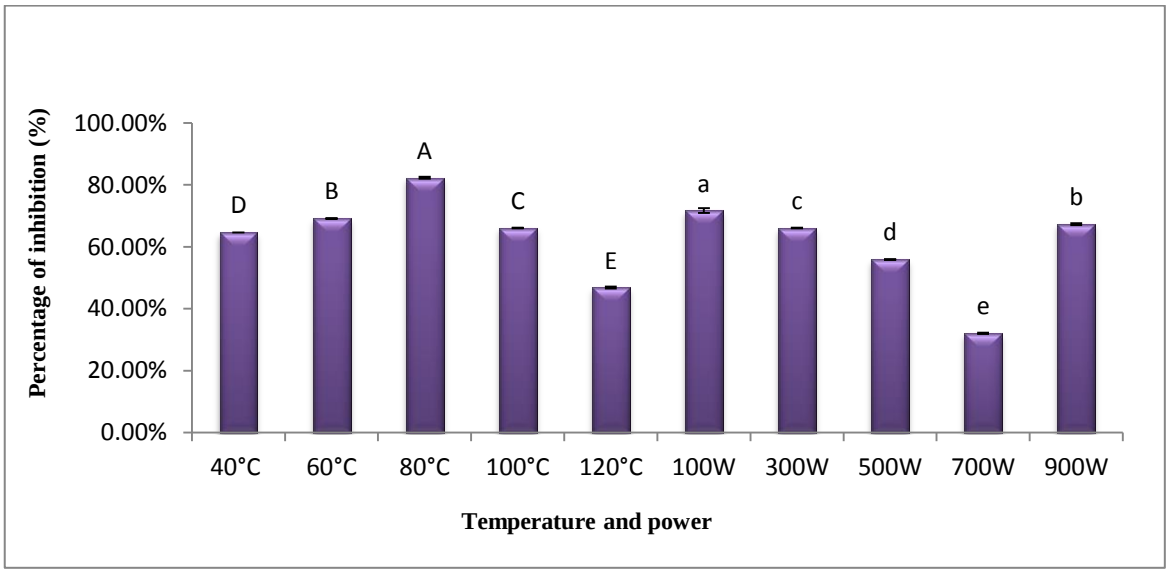


Figure 22: Antiradical activity (DPPH°) of eggplant peels, dried in oven and microwave

The DPPH radical scavenging activities of 80 °C extract exhibit the highest activity 82.30 ± 0.01 % compared to 100 W extract with 72 ± 0.01 %, whereas the lowest value are assigned to 120 °C and 700 W extract (46.82% and 32.06% respectively) at $P < 0.05$)

The IC_{50} values (the concentration reducing 50% of DPPH) obtained for scavenging activities on DPPH° radical, were evaluated **(Fig.23)**. The lower the IC_{50} value the greater the free radical-scavenging activity. Thus, the strongest activity ($P < 0.05$) was obtained in the case of drying method at 80 °C and 100 w (2.31 ± 0.05 and 3.02 ± 0.09 mg/ml respectively). However the sample of 120 °C and 700 W possessed weaker antioxidant effects ($P < 0.05$) (2.31 ± 0.05 and 3.02 ± 0.09 mg/ml respectively)

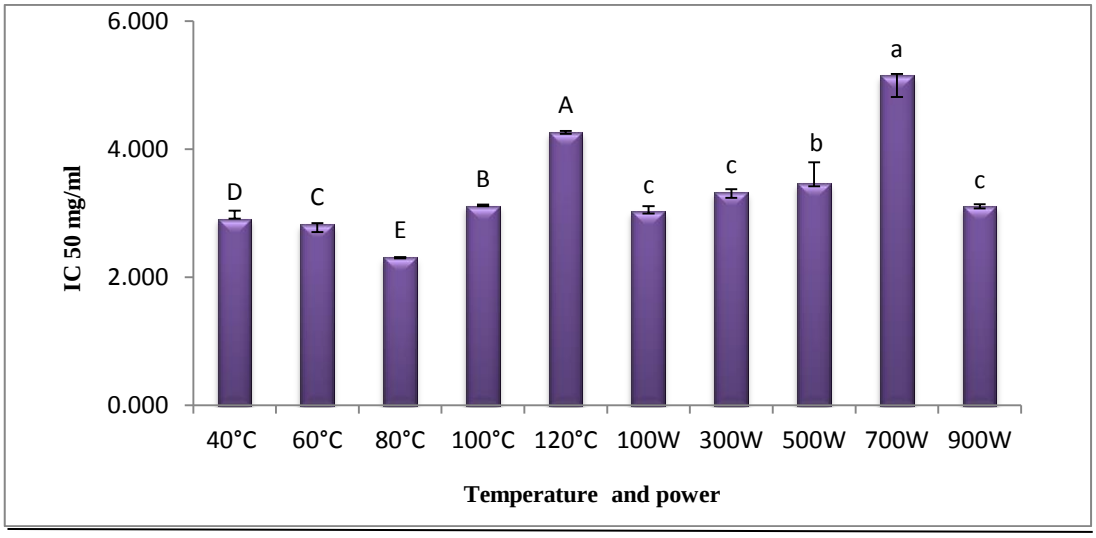


Figure 23: Antiradical activity (IC_{50}) of eggplant peels, dried in oven and microwave

In the presence of phenolic compounds which easily donates electrons to reduce **(Nisha et al. 2009).** 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. **Boulekbache-Makhlouf, Medouni et al. 2013** reported that the extract of dry peel have an antioxidant activity of 64.47% (IC_{50} of 3.32). **Jung, Bae et al. 2011 re**ported that the extract of fresh peel of *S. melongena* obtained an IC_{50} of 0.98 ± 0.33 mg/mL. These differences can be explained by the different states of the fruit (fresh or dried), the solvent and the extraction method.

III.4.3.2. 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.24 and 25),** 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. RC_{50} was also evaluated (mg ml^{-1}). This value is the effective concentration at which the absorbance was 0.5, for reducing power and was obtained by interpolation from linear regression analysis

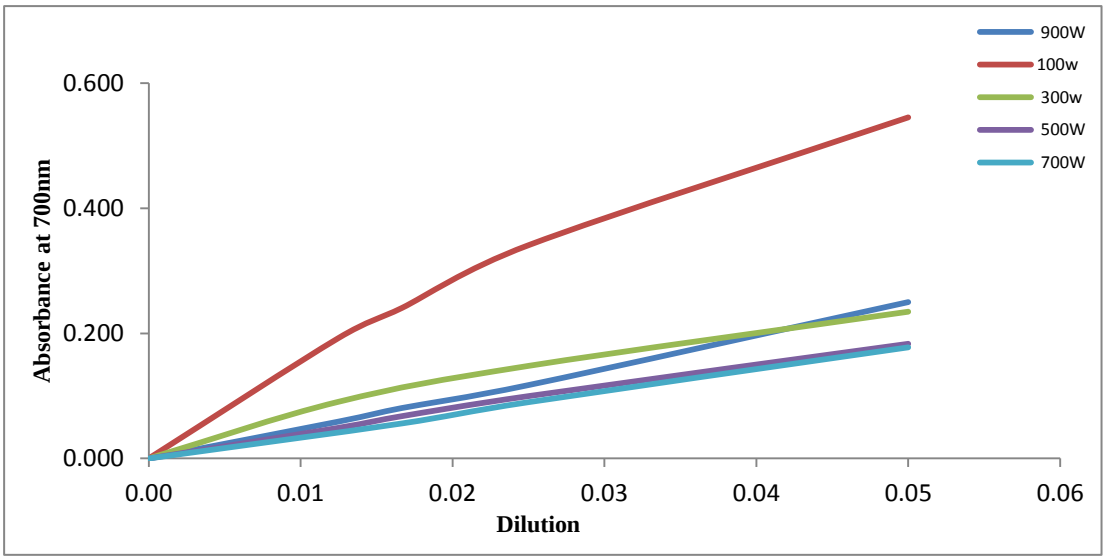


Figure 24: Reducing power of eggplant peels dried in microwave.

The reducing power eggplant peel dried in microwave exhibit the high absorbance at 100 W extract (0.545 ± 0.01) with the lowest RC_{50} (3.63 ±0.04 mg/ml), followed by the 300 W (A= 0.234 ± 0.002; RC_{50} = 8.17 ±1.18 mg/ml). At 700 W a weaker absorbance and a higher RC_{50} were recorded (0.176 ± 0.00 and 9.80 ± 0.17 mg/ml respectively). However the results given by the 900 W (0.250 ± 0.001; RC_{50} 7.25 ±1.96) made exception that were was higher than those of 300 W. This can be explained by the type of treatment (time / power) which allows to dry eggplant peels with less damage and bioavailability for bioactive substances. In the case of dried oven samples, reducing power of eggplant peels showed the same order of the ability of sample to act as the donor of hydrogen atoms or electron (80 °C > 60 °C > 40 °C > 100 °C > 120 °C).

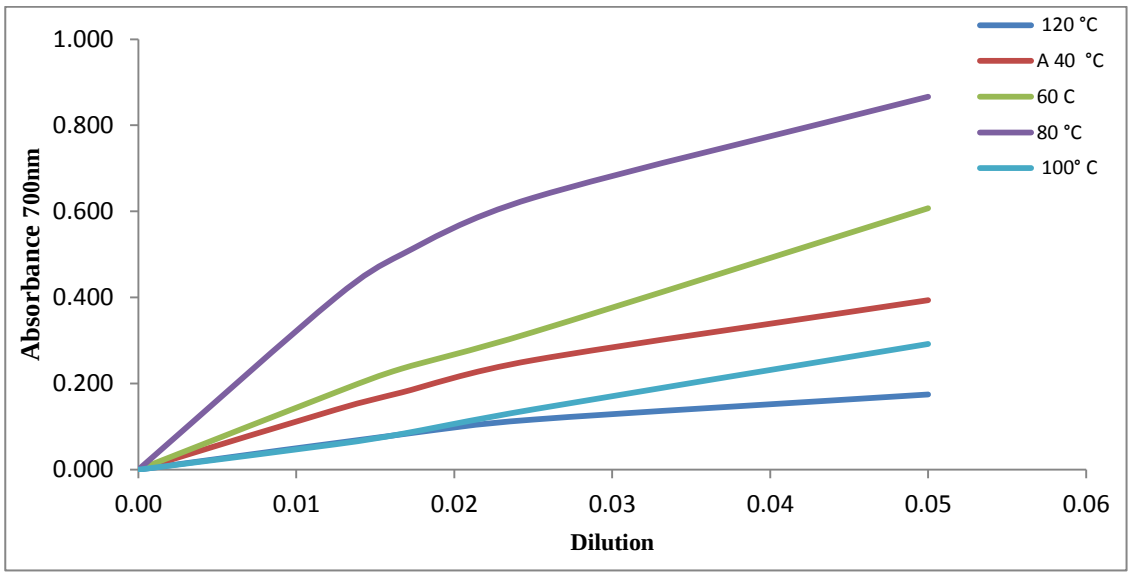


Figure 25: Reducing power of eggplant peels dried in oven.

The results obtained by reducing power are in good agreement with those obtained by the DPPH° test namely for the temperature of 80 °C, 60 °C and power of 100 W. These extracts showed the strongest radical scavenging activity, with the best reducing power. Indeed, the extracts rich on anthocyanins showed the best activity probably due to the high content of antioxidants (anthocyanins) which are the dominant class in the peel of eggplant **(Chen, Zhao et al. 2015).**

III.4.3.3. Total antioxidant capacity

Total antioxidant capacity (TAC) was based on the reduction of Mo(VI) to Mo(V) by the extract and subsequent formation of green phosphate/ Mo(V) complex at acid pH **(Prieto, Pineda et al. 1999).** It evaluates both water-soluble and fat-soluble antioxidants (total antioxidant capacity) **(Jayaprakasha and Patil, 2008)**. The high absorbance values indicated that the sample possessed significant antioxidant activity. The values of this assay (absorbance at 695 nm) at different extracts concentrations of eggplant peels were shown in figure 26 and 27. The results were found to be important and dose dependent.

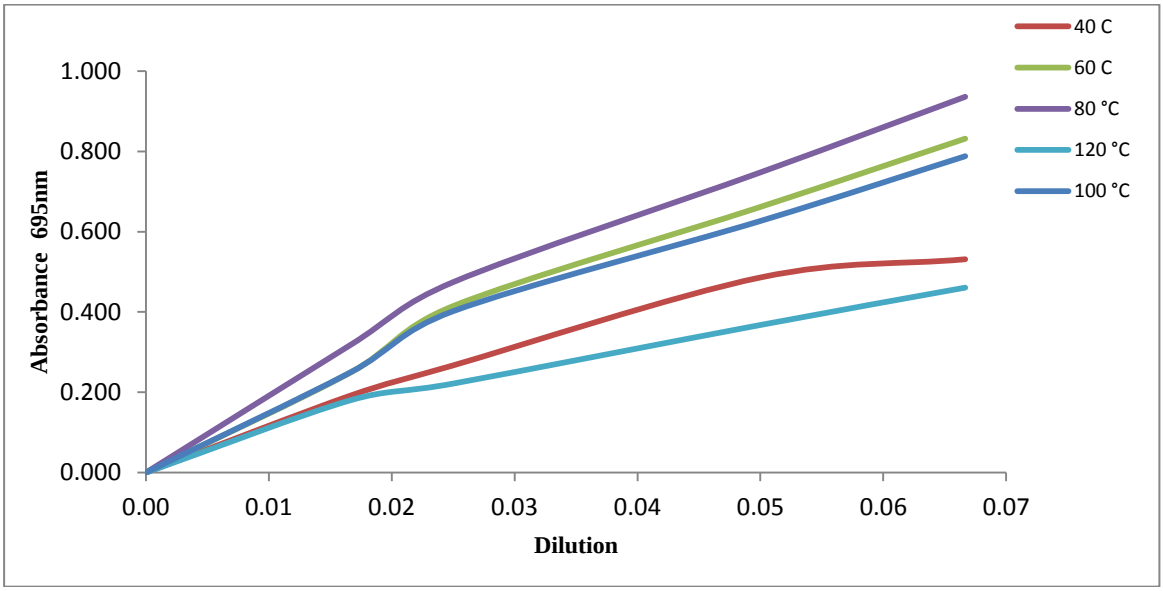


Figure 26: Total antioxidant activity of eggplant peels dried in oven.

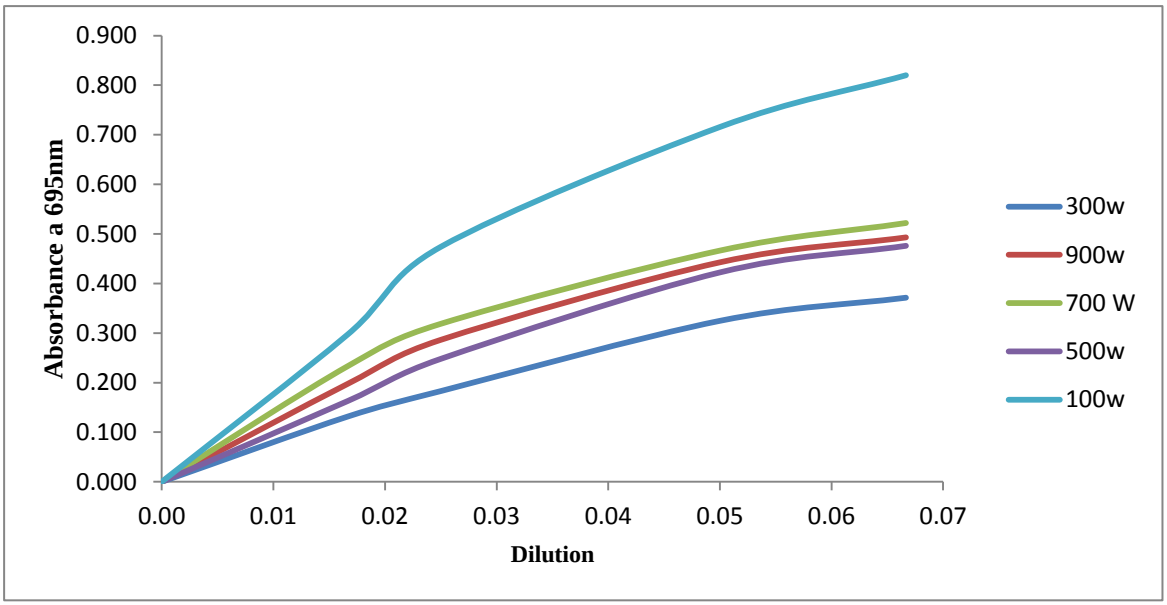


Figure 27: Total antioxidant activity of eggplant peels dried in microwave.

According to our knowledge, there is not an available literature on total antioxidant activity of eggplant peels.

III.5. Mineral content

The mineral analysis revealed that eggplant peel contained potassium, iron and zinc **(Table. XI)**, the dried eggplant by microwave showed the highest value of K. However the important quantity of iron and zinc was obtained in drying oven at 80°C.

Table XI: Mineral content of eggplant peels

Mineral	Dried eggplant	
	80°C (ppm)	100W (ppm)
K	1115260	2788961
Zn	0.77	0.20
Fe	1782	1455

Minerals are important constituents of human diet as they serve as co-factors for many physiological and metabolic processes. Potassium is the most abundant intracellular cation in the body and contributes to intracellular osmolality. Enzymes involved in glycolysis and oxidative phosphorylation are potassium-dependent. Adequate dietary intake of iron and zinc is essential to human health. Iron is an essential component of body systems involved in the utilization of

oxygen. Zinc is required for protein and carbohydrate metabolism, immune system, wound healing, growth and vision **(Arivalagan, Bhardwaj et al. 2013).**

III.6. Scanning electron microscopy (SEM)

III.6.1. Comparison of extraction methods

The residues of treated eggplant peels using UAE and CSE were examined for structural analyses by scanning electron microscopy and compared with the untreated control. It was observed that there was complete parenchyma without any significant destruction on cell walls but with slight ruptures on the surfaces of CSE sample **(Fig. 28 B)** compared to untreated one **(Fig. 28 A)**.

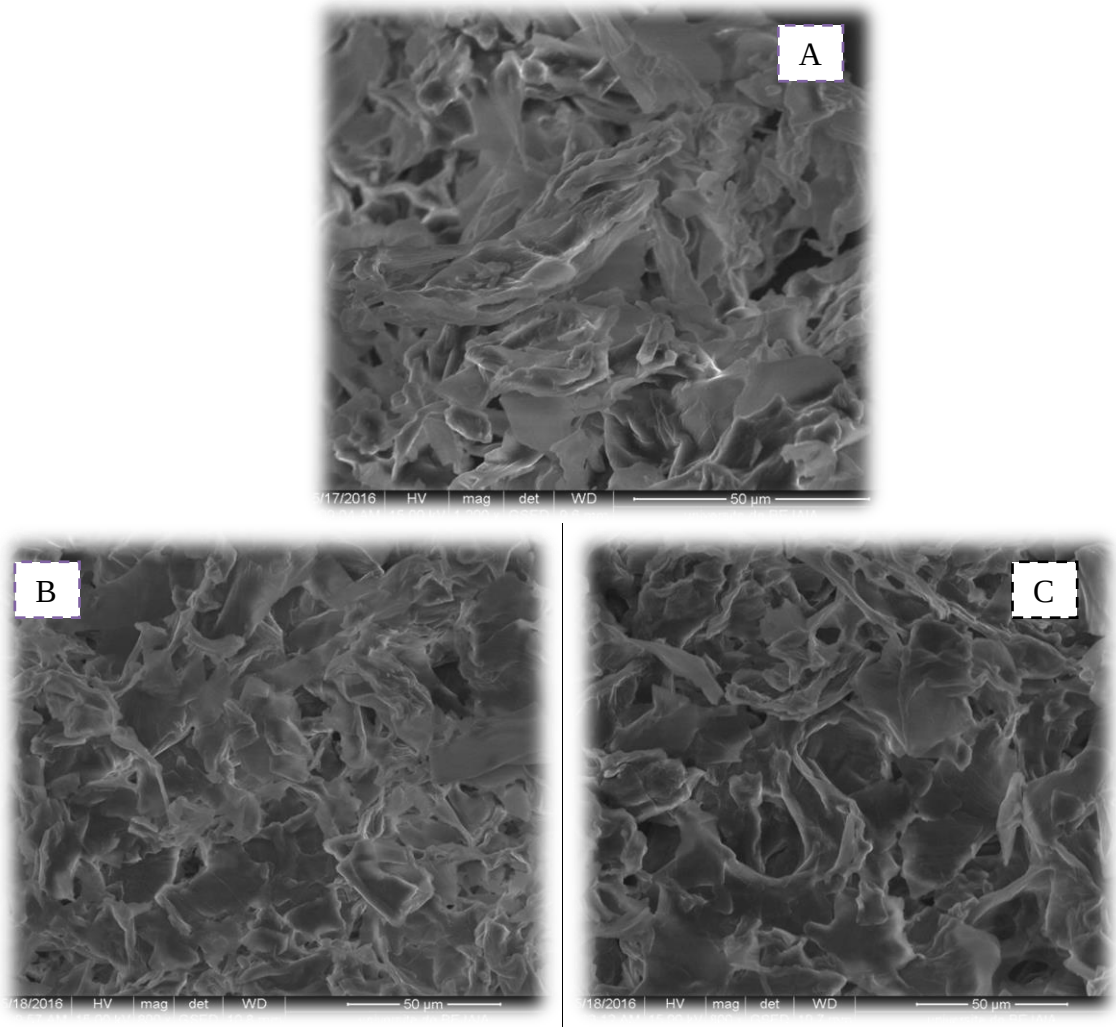


Figure 28:. Scanning electron microscopic images of residues in the extraction of untreated *Solanum melongena* peels (A). conventional-solvent extracted (CSE) peels (B). ultrasound-assisted extracted (UAE) peels (C).

During UAE, severe damage on cell walls was observed due to acoustic cavitation **(Fig. 28C)**. The UAE extraction allows the solvent to penetrate cell walls, and the bubbles produced by acoustic cavitation aid in the disruption of the cell wall which then releases active ingredients **(Achat, Tomao et al. 2012)**. Treatment of the eggplant peels with UAE likely initiated cell rupture and damage, which allowed more of the polyphenolic compounds from the powder to be extracted by the solvent. This process is quite different from CSE, which relies on the diffusion of the solvent into the solid matrix and extraction of the components by solubilization **(Dahmoune, Spigno et al. 2014)**. Therefore, the yield of total phenolics using CSE was lower than that UAE.

III.6.2. Drying process

Scanning electron microscopy (SEM) images of eggplants dried with microwave and oven are given in figure 29.

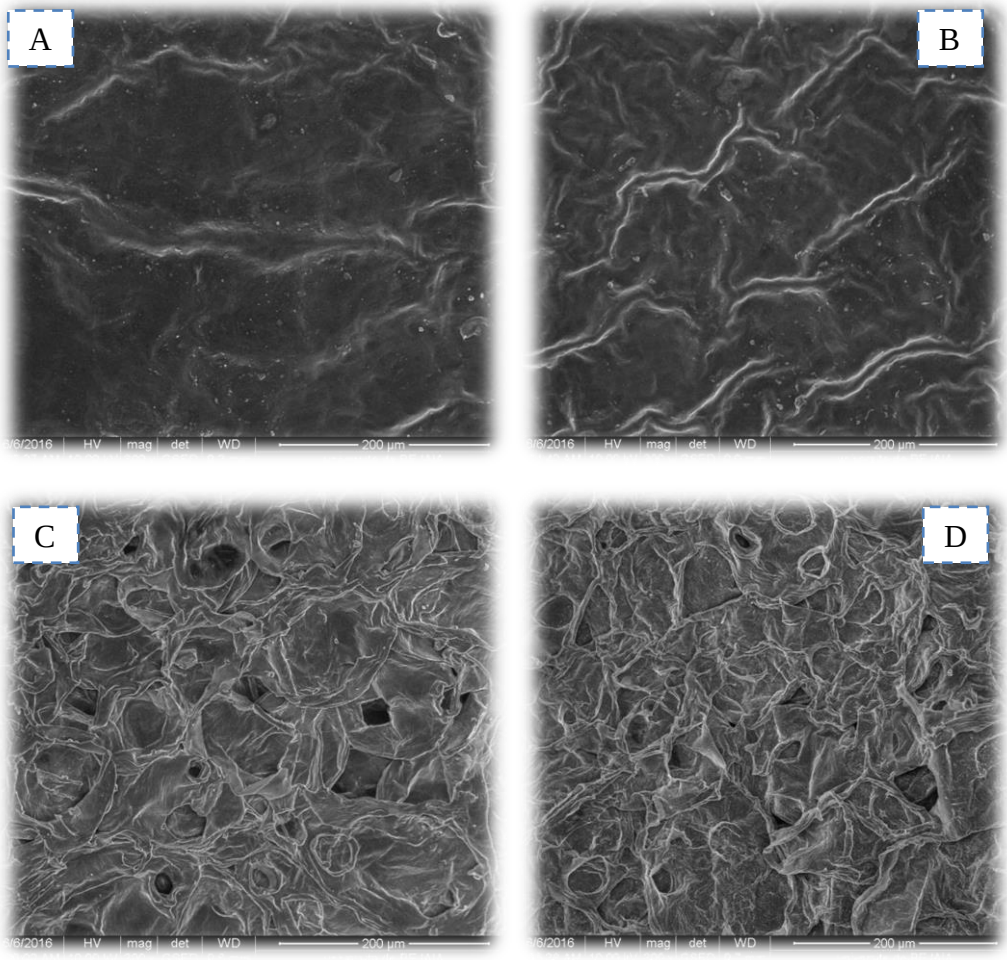


Figure 29:.SEM images of eggplants peels dried with oven at 80°C (A: outside of peel. C: inside of peel) and with microwave at 100 W (B: the outside peel. D the inside peel)

When the image for the conventionally dried eggplants was observed, some areas where the cells appeared to be collapsed could be seen **(Fig. 29 C)**. This showed that the structure was non-uniform in which both larger and smaller pores were observed. Moreover for the oven dried eggplant sample, there was less porous structure as compared to microwave dried samples **(Fig. 29 D)**. The pore development after microwave drying was probably due to tissue expansion as a result of the internal water vapor pressure. Higher shrinkage and case hardening due to the long drying time in conventional drying might lead to lower porosity and tissue damages. In literature, similar results were pointed out **(Aydogdu et al.2015).**

III.7. Analysis of prepared stirred yoghurt

III.7.1. Physico-chemical analysis of yoghurt

Physico-chemical properties of the manufactured stirred yoghurts (standard yoghurt. yoghurts with eggplant peels. dried at 100 W and 80 °C) were shown in table XII.

Table XII: Physicochemical analysis of stirred prepared yoghurts.

	pH	Acidity (°D)	°Brix	Viscosity (m pas)	Total dry extract (%)	Fat content (%)	Protein content (%)
Standard yoghurt	*4.36*	75	7.70	2896	19.74	3.7	3.12
Yogurt with eggplant (100 W)	4.43	76	8.02	3043	21.45	3.5	3.2
Yogurt with eggplant (80 °C)	4.52	78	7.99	3644	21.61	3.55	3.3
Norms	4.4-5.7	75-100			23.9-25.15	2.75-3.15	2.85-3.15

- Results of this analysis revealed that pH, soluble solids content, acidity and protein content determination were conform to norms. However an increase in total dry extract, fat content and viscosity were observed after addition of eggplant peels to standard yoghurt. On the one hand, this may be related to chemical composition of eggplant (protein: 1.4g; fat 0.3 g) **(Özcan, Hacıseferoğulları et al. 2005)**, on the other hand to its impact on the aggregation of casein network in yoghurts via electrostatic interaction and on the resistance for the yoghurt matrix to flow. Indeed the addition of plant extracts generally decreased the consistency of the products owning to reduced water-binding capacity of proteins **(El-Said et al. 2014)**

III.7.2. Microbiological analysis

Microbial quality of the manufactured stirred yoghurts was given in table XIII.

Table XIII: Microbiological analysis of formulated yoghurts

	Total coliforms at 37°C	Yeasts and moulds	*Enterobacteria at 37°C*	*Streptococcus thermophilus*	*Lactobacillus bulgaricus*
Standard yoghurt	*Absent*	Absent	Absent	1.6×10^8	1.2×10^5
Yoghurt with eggplant (100 W)	Absent	Absent	Absent	1.7×10^8	1.3×10^5
Yoghurt with Eggplant (80 °C)	Absent	Absent	Absent	1.7×10^8	1.4×10^5
Norms	< 10	< 30		$\geq 10^8$	$\geq 10^5$

Moulds, yeast and coliforms are the primary contaminants in yoghurt **(Amakoromo, Innocent-Adiele et al. 2012)**, were not detected in yoghurt samples (100 W, 80 °C and standard). This illustrates the adequate heating treatment of milk under strict aseptic conditions, during processing and manufacturing of the different stirred yoghurts.

Yoghurt enriched with eggplant presented a slight increase in viability of lactic acid bacteria Flora (*Streptococcus thermophilus* and *Lactobacillus bulgaricus*) when compared with control yoghurt, which could be related with the composition of proliferation media (sugar and lipid) of samples after addition of eggplant peels. The total viable numbers of lactic flora is an important parameter which contributes in the shelf life of yoghurt. This can be related to the chemical composition of the *S. melongena* peels: 1.4% protein, 1.3% fibre, 0.3% fat, 0.3% minerals and 4% various of carbohydrates and vitamins (A and C) **(Khan and Kasha 1979).**

III.7.3. Antioxidant activity and ANC content

It was noticed from table 11 that antioxidant activity of different stirred yoghurts measured by RSA revealed that the addition of eggplant peels, increased significantly the inhibitory activity against DPPH° radical compared with standard yoghurt prepared, being pronounced in yoghurt with eggplant dried at 80 °C (40.78 ± 0.51).

The eggplant contained total monomeric anthocyanin; these compounds were present and significantly highest in supplemented yoghurts, in the following order 80 °C > 100 W > SY, with the lowest value in the SY sample, providing a confirmation of supplementation

Table XIII: Radical scavenging activity and total monomeric content of steamed prepared yoghurts

	Radical scavenging activity (%)	**Total monomeric anthocyanin (mg DGE/100g DM)**
Standard yoghurt (SY)	14.45 ± 1.52^{c}	0.15 ± 0.07^{c}
Yoghurt with eggplant (100 W)	19.07 ± 0.83^{b}	1.43 ± 0.04^{b}
Yoghurt with eggplant (80 °C)	23.76 ± 0.05^{a}	1.80 ± 0.07^{a}

Eggplant peels is characterized by substantial amounts of phenolic compounds, including flavonoids namely anthocyanins **(Özcan, Hacıseferoğulları et al. 2005).** Therefore, ANC were well correlated and dominantly responsible for the antioxidant activity. The studied eggplant possess proton donating ability and in association with a number of hydroxyl groups in the ANC structures to stabilize free radicals it could due to their ability to quench hydroxyl radicals by transferring hydrogen atom to free radical **(El Said, Green et al. 2014)**. It is clear that addition of this vegetable gave the highest value, difference was statistically significant when $p < 0.05$ in the antiradical capacity, providing additional evidence of its antioxidant activity.

III.8. Sensory analysis

Three samples of yogurt A. B. C (reference. 80 °C and 100 W respectively), were sensory evaluated and scores were recorded.

1) Design of experiment

Designing an experiment is a fundamental step in order to verify if the collected data will be statistically valid **(Périnel and Pagès 2004)**. In our study, an optimal plan was validated.

Design evaluation

A-Efficacity	1.000
D-Efficacity	1.000

2) Product characterization

The figure 30 represents the characteristics ordered from the one having the lowest discriminating power to the one that has the highest discriminating power on the prepared Stirred yoghurts. As reported, texture and aroma are the highest discriminating powers, followed by flavor and odor. Sweet taste is the lowest discriminating power, followed by color, acidity and consistency.

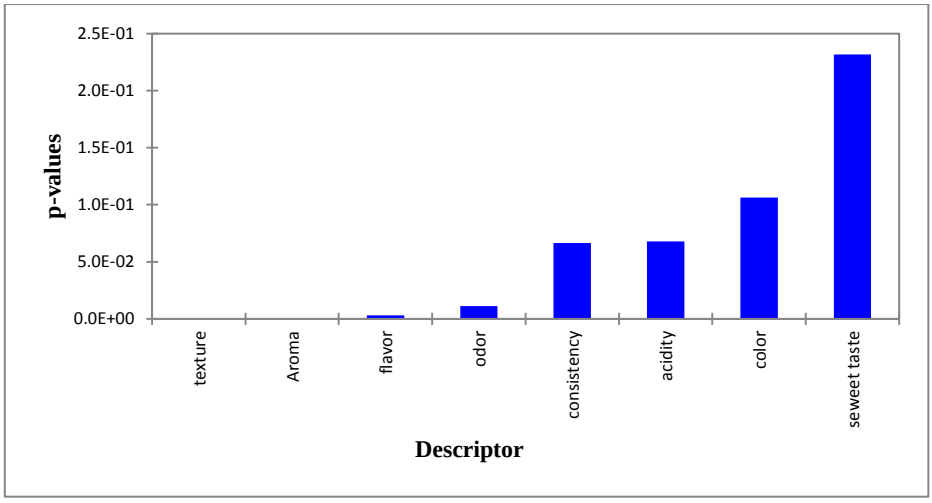
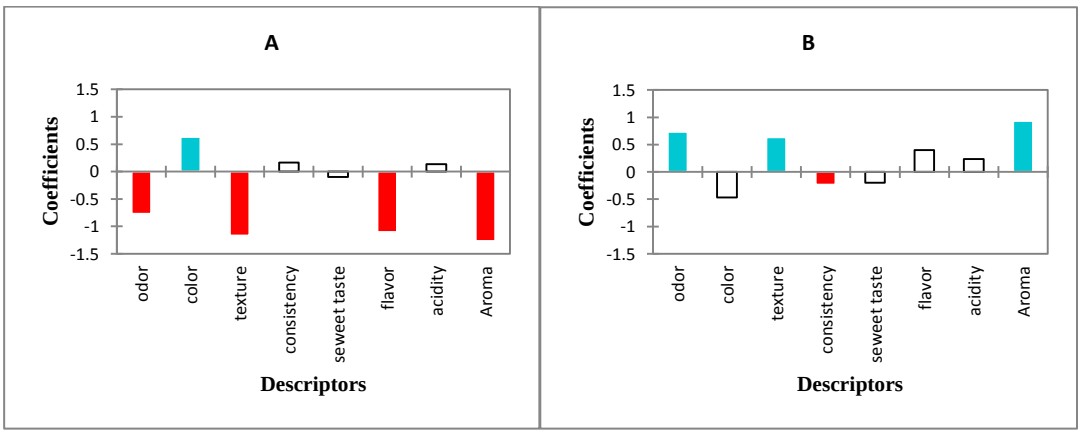


Figure 30: Discriminating power by descriptor.

- **Model coefficients**

The following graphics **(Fig.31)** are very helpful to define our products. The blue color is associated to coefficient that has a significant positive value; the red color is associated to coefficient that has a significant negative value and finely white is associated to insignificant value.



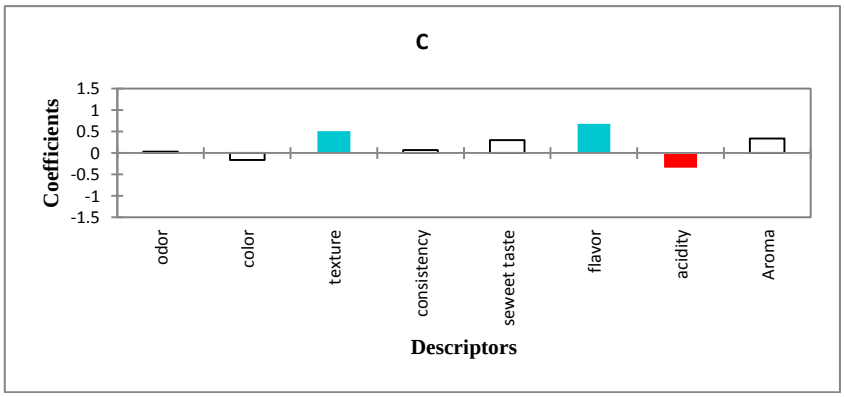


Figure 31: Model coefficients of yoghurts.

The figure above indicated that:

- Sample A had a good color but it had bad odor, texture, flavor and aroma
- Sample B had a bad consistency but it had good odor, texture and aroma
- Sample C is acid but it had good texture and flavor.

- **Adjusted product**

The purpose of this action is to define the adjusted calculated from the model for each combination product-descriptor (**Le and Husson 2008)**. In this sensory evaluation, results of table XV were obtained.

Table XV: Corresponds to the adjusted averages calculated from the model for each combination product-descriptor

	Aroma	texture	odor	flavor	seweet taste	acidity	consistency	color
B	3.6000	3.4000	4.0000	2.9000	2.7000	2.5000	2.2000	2.8000
C	3.0000	3.3000	3.3000	3.2000	3.2000	1.9000	2.5000	3.1000
A	1.4000	1.6000	2.5000	1.4000	2.8000	2.4000	2.6000	3.9000

This table shows that yogurt B had a good aroma, texture and odor; followed by the yogurt C characterized by a good texture and a good flavor. Finally, the reference yogurt characterized by a good color.

3) Principal Components Analysis (PCA)

The following map **(Fig.32)** is used to represent the correlations between the variables and factors:

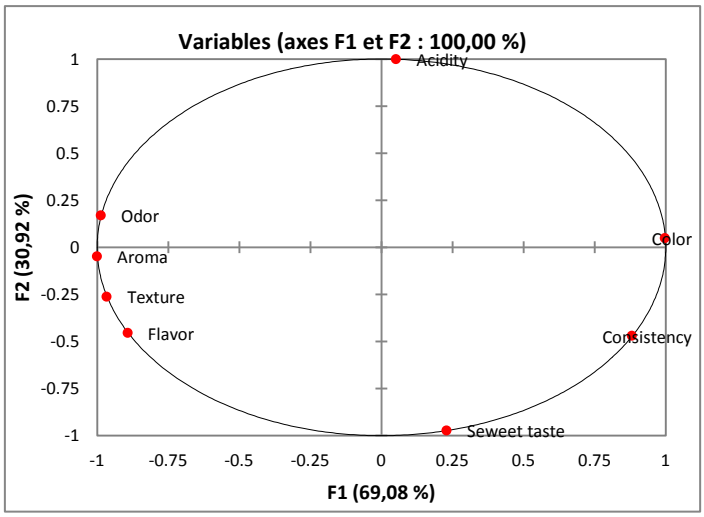


Figure 32: Correlations between variables and factors.

The quality of this map is good, as it used to represent 100% of the variability, indicated that the products were perceived by experts as different. As the figure shows,that all the descriptors are presented on the circle.

4) Ascending Hierarchical Classification (AHC)

Successive groupings produce a binary tree classification (Dendrogram), whose root is the class containing all individuals. This dendrogram **(Fig.33)** represents a hierarchy of partitions. This allows choosing partition by truncating the shaft at a given level, the level is dependent constraints the user (the user knows how many classes he wants to get) or more objective criteria **(Everitt, Dickinson et al. 2001).**

The following graph is used to represent the profile of the classes:

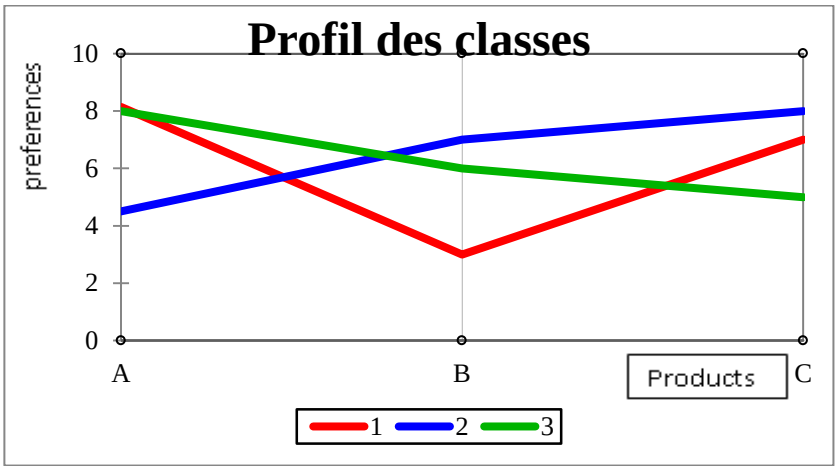


Figure 33: Classes Profil

Figure 33 allows to visually comparing the averages of different classes created, so that we can distinguish the preferred yogurt for each class: For the first class of experts (red), yogurt A and C are preferred. While the second class (blue) preferred C then B. Products A then B are preferred by the third class (green).

5) Preference Mapping (PREFMAP)

The PREFMAP shows the percentage of satisfied judges for each product: 67% for yogurts (A and C) and 33% for yogurt B.

The figure 34 defines the curve levels and the preferences map:

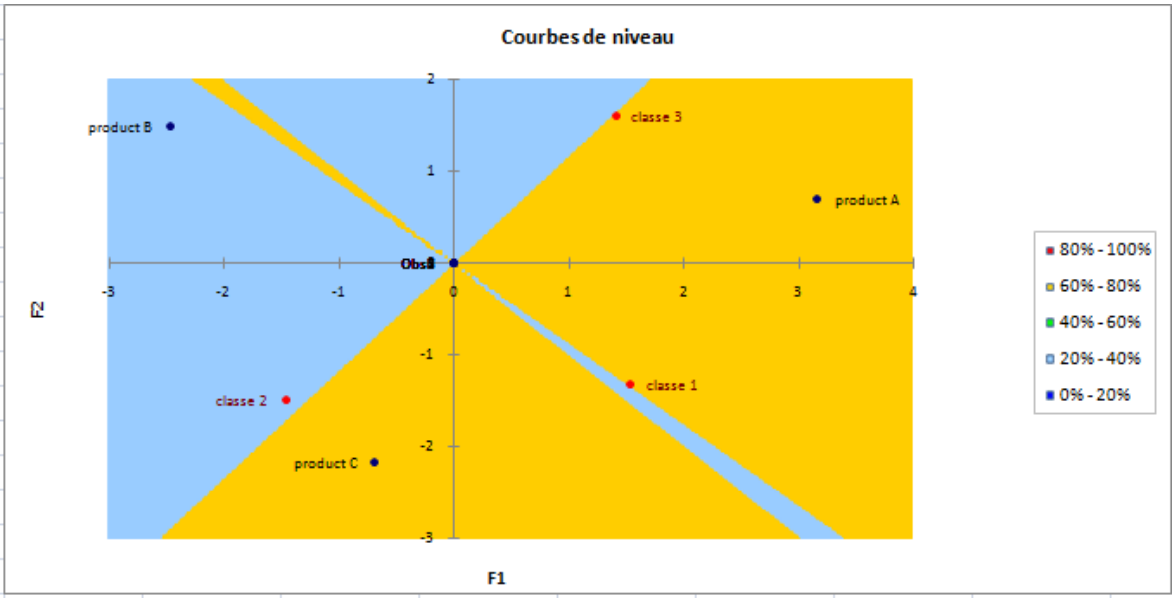


Figure 34: Curve levels and the preferences map.

According to the results, the group of Class 1 and 3 likes yogurt A and C (60-80%). The group of class 2 likes yogurt B (20-40%).

Conclusion

Conclusion

This study indicates that microwave drying time decreased, which was significantly shorter than conventional drying of eggplant peels. The moisture loss of samples time using oven at 40 °C was approximately twenty times higher (328.33 ± 5.47 min) than drying time in microwave at 900 W (15.43 ± 0.56 min) and six times higher at 100 W (55.66 ± 2.56 min). The reduction in the drying time was linked to the improvement in both the mass transfer coefficient and the effective moisture diffusivity. The results of the water activities of the *Solanum melongena* powders were in the range of 0.17–0.47, so relatively stable microbiologically using the both method of drying (oven and microwave). The color (L*a*b*, values) of eggplant peel powders was different: drying at 100 W revealed optimum color values, however at 120 °C (oven drying) and at 900 W (microwave drying) developed the least acceptable color values, due to the effect of high temperature.

In the present work extraction of bioactive compounds was also evaluated. Acidified ethanol was the solvent suitable for TPC, ANC, TFC and YTCg of eggplant peels using conventional extraction, while ultrasound assisted extraction allowed higher and better yields of polyphenols (1680.33±0.05mg GAE/100gDM, 161.09±2.41mg DGE/100gDM, 30.36 ±0.01mg CGAE/100gDM, 50.06 ±0.43 mg Rt/100gDM TPC, ANC, YTCg and TFC. The results of these bioactive components determination for eggplants peels, dried with oven and microwave, were statistically different ($p < 0.05$). In oven drying, the temperature of 80 °C provides a highest recovery of polyphenols: 2468±0.28 mg GAE/100gDM of TPC, 339.31±7.93 mg DGE/100 mg DM of ANC, 71.48 ±0.10 mg CGAE/100g DM of YTCg and 151.33 ±3.14 mg Rt/mg DM of TFC. Even in the antioxidant assays 80 °C extracts revealed better activities: radical scavenging test DPPH• (82.30±0.01 %, IC_{50}= 2.316±0.005 mg/ml), reducing power (RC_{50} = 2.26 ±0.18 mg/ml) and total antioxidant activity (A= 0.820 ±0.005). However with the microwave drying technique, powder extract obtained at 100 W was the best power in terms extraction of phenolic compounds but lower than conventional oven drying: TPC of 1108.43±0.28 mg GAE/100g DM, ANC of 69.62 ±0.44 mg DGE/100mg DM, YTCg of 67.44±4.72 CGAE/100g DM and TFC of 69.62 ±0.92 mg RtE/mg DM. The data of assessment of antioxidant activities of 100 W showed the same tendencies of the results obtained in 80 °C.

The mineral analysis revealed that eggplant peel contained potassium, iron and zinc and the microwave showed the highest value of K, however the important quantity of iron and zinc was obtained in drying oven at 80°C. According to microscopic analysis, oven-dried eggplants had less porous structure than the ones dried in microwave. The addition of *Solanum melongena* peels in the manufacture of fruity stirred yoghurt, could offer practical and economic sources of anthocyanins in dairy industry, with higher antioxidant activity.

Consumption of eggplant may have a potential therapeutic use. Our study confirms that eggplant peels are rich on polyphenols and present high antioxidant activity effects. Consequently, suggesting the use as an ingredient in different kinds of meals, instant soups, and sauces.

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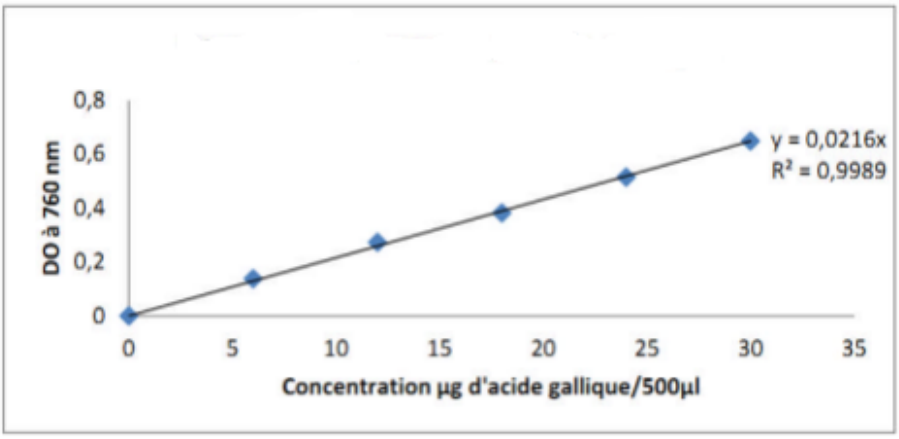
Appendix

Appendix 01

- Calibration courbe of gallic acid



Appendix 02

Questionnaire d'évaluation sensorielle de quatre échantillons du yaourt

Sexe: F ou H, Profession……..

Date : 05 juin 2016

Trois échantillons de yaourt brassé codés **A**, **B, et C** vous sont présentés, il vous est demandé d'évaluer différentes caractéristiques et d'attribuer une note de 1 à 5 pour chaque Echantillon sur l'échelle suivante :

1. Couleur *:*

1 : Non appréciée

2 : Peu appréciée

3 : Moyennement appréciée

4 : Bien appréciée

5 : Très appréciée

Echantillon A	Echantillon B	Echantillon C

Attribuez une note de 1à 9 pour chaque échantillon selon votre préférence par rapport à

La couleur :

A ☐ B ☐ C ☐

2. Odeur :

1 : Très faiblement intense

2 : Faiblement intense

3 : Moyennement intense

4 : Fortement intense

5 : Très fortement intense

Echantillon A	Echantillon B	Echantillon C

Attribuez une note de 1à 9 pour chaque échantillon selon votre préférence par rapport à

l'odeur :

A ☐ B ☐ C ☐

3. Consistance :

1 : Liquide

2 : Trop mou

3 : Mou

4 : Ferme

5 : Très ferme

Echantillon A	Echantillon B	Echantillon C

Attribuez une note de 1à 9 pour chaque échantillon selon votre préférence par rapport à

La consistance :

A ☐ B ☐ C ☐

4. Sensation en bouche :

A. Saveur

• Saveur sucré :

1 : Absent

2 : Faible

3 : Moyen

4 : Fort

5 : Trop fort

Echantillon A	Echantillon B	Echantillon C

Attribuez une note de 1à 9 pour chaque échantillon selon votre préférence par rapport à

la saveur sucrée :

A ☐ B ☐ C ☐

 Saveur acide:

1 : Absente

2 : Faible

3 : Moyenne

4: Forte

5 : Très forte

Echantillon A	Echantillon B	Echantillon C

Attribuez une note de 1à 9 pour chaque échantillon selon votre préférence par rapport à

la saveur acide :

A ☐ B ☐ C ☐

 Attribution de la saveur

1. Aucune
2. grenade
3. Aubergine
4. fruits des bois
5. Myrtille

Echantillon A	Echantillon B	Echantillon C

Attribuez une note de 1à 9 pour chaque échantillon selon votre préférence par rapport à

L'attribution de la saveur :

A ☐ B ☐ C ☐

 Arôme : (note)

1 : Absent

2 : Faible

3 : Moyen

4 : Fort

5 : Très fort

Echantillon A	Echantillon B	Echantillon C

Attribuez une note de 1à 9 pour chaque échantillon selon votre préférence par rapport à

l' arome :

A ☐ B ☐ C ☐

B. Texture

1 : Très lisse

2 : Lisse

3 : Moyenne

4 : Granuleuse

5 : Très granuleuse

Echantillon A	Echantillon B	Echantillon C

Attribuez une note de 1à 9 pour chaque échantillon selon votre préférence par rapport à

la texture :

A ☐ B ☐ C ☐

5. Classez selon d'ordre de préférence les échantillons (A, B, C ou D) en leur attribuant une note de 1 à 9 :

	Echantillon A	Echantillon B	Echantillon C
Classement			
Note			

6. Quels sont les caractéristiques qui ont motivé votre préférence ?

1 : La couleur

2 : L'odeur

3 : La texture

4 : Le gout

5 : La consistance

Autre…….....

*** Merci pour votre coopération ***

Résumé

L'aubergine est l'une des légumes communs les plus consommés dans le monde entier. L'objectif de ce travail est l'étude de l'effet de séchage des sous-produits (pelure) de l'aubergine (*Solanum melongena*), en utilisant deux méthodes de séchage: micro-onde (100, 300, 500, 700 et 900 W) et étuve (40, 60, 80, 100 et 120 ° C). Ainsi, la cinétique du séchage a été effectuée conformément à la perte de masse de la pelure d'aubergine. Pour chaque technique, l'analyse physico-chimique (teneur en humidité, test de couleur, la détermination des composés phénoliques et de l'activité anti-oxydante) des poudres a été évaluée. Micro-onde a réduit significativement les temps de séchage comparativement au séchage conventionnel de l'étuve. Les résultats de la détermination des composants bioactifs de la pelure d'aubergine, séchée à l'étuve et au micro-onde, ont été statistiquement différents (p <0,05). Dans le séchage à l'étuve, la température de 80 °C a donné le taux le plus élevé en polyphénols, mais avec la technique micro-onde, l'extrait de poudre obtenue à 100 W a enregistré la meilleure puissance en terme d'extraction de composés phénoliques, mais qui reste inférieur au séchage de l'étuve. Les données d'activité antioxydante des échantillons séchés à 100 W et 80 ° C, ont montré les mêmes tendances qu'aux résultats des teneurs en polyphénols. Les pelures d'aubergines séchées au micro-onde, ont présenté des structures plus poreuses que celles séchées à l'étuve. L'analyse minérale a révélé que ce sous-produit contient du potassium, du fer et du zinc. Yaourt avec des pelures d'aubergine, a augmenté de manière significative l'activité inhibitrice du radical DPPH° et la teneur en anthocyanes par rapport au yaourt standard.

Mots clés: Micro-onde, étuve, séchage, pelures d'aubergine, Polyphenols, Tests d'antioxydants, Yaourt.

Abstract

Eggplant is one of most common vegetables consumed all around the world. The objective of this study was to investigate the drying effect of byproduct (peel) of eggplant (*Solanum melongena*), using two drying methods: microwave (100, 300, 500, 700 and 900 W) and ventilated oven (40, 60, 80, 100 and 120 °C). Thus, kinetic drying was performed according to the mass loss of eggplant peel. For each technique, the physico-chemical analysis (moisture content, color test, determination of phenolic compounds and the antioxidant activity) of the powders were evaluated. Microwave provided significantly shorter drying time than conventional oven drying. The results of bioactive components determination for eggplants peels, dried with oven and microwave, were statistically different (p < 0.05). In oven drying, the temperature of 80 °C provides a highest recovery of polyphenols, however with the microwave technique, powder extract obtained at 100 W was the best power in terms extraction of phenolic compounds but lower than oven drying. The data of antioxidant activities of dried samples at 100 W and 80 °C showed the same tendencies of the results obtained in polyphenols. Microwave-dried eggplant peels had more porous structure than oven-dried ones. The mineral analysis revealed that this byproduct contained potassium, iron and zinc. Yoghurt with added eggplant peels increased significantly the inhibitory activity against DPPH° radical and anthocyanins contents compared with standard yoghurt.

Keywords: Microwave, Oven, Drying, Eggplant peels, Polyphenols, Antioxidant assays, Yoghurt