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Réf :..........................

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

MASTER

Thème

Valorisation d'un déchet alimentaire : Séchage et principes actifs

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Mordjane

List of abbreviation

FA: Fat acid

HAD: Hot air drying

LMWC: Low molecular weight carbohydrate

MW: Microwave

MWD: Microwave drying

OMW: Oil mill wast

POE: Pleurotus ostreatus aqueous extract

PPs: Polyphenols

TPC: Total phenolic content

DF : Dietary fiber

JMP : John's Macintosh Project

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Introduction

INTRODUCTION

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

Waste biomass valorization is an intriguing concept of utilizing a renewable, inexpensive and abundant energy source, and most importantly, rich in bioactive phytochemicals that could be used in the manufacture of high value-added products, such as food additives, natural health products and pharmaceuticals **(Galanki ,2012).** Despite the diversity of biologically important constituents present in plant food wastes, particular attention has been given to phenolic compounds that may have antioxidant, anti-inflammatory, cardio protective, and anti-carcinogenic properties. **(Babbar and al.,2015).**

Eggplant (*Solanum melongena* L.) is an important commercial vegetable in Asian and Mediterranean countries, the latter contain a variety of phytochemicals such as phenolic compounds and flavonoids **(Akanitapichat and al.,2010).** They are ranked among the top ten vegetables in terms of antioxidant capacity due to their phenolic constituents **(Cao and al. 1996).** The most cultivated variety is the elongated ovoid with dark purple skin **(Boulekbache-Makhlouf and al., 2013)**. Eggplant skin is a less studied source in terms of extraction of bioactive compounds from industrial residues, although its high polyphenol content is known **(Dranca and al., 2017)**. Anthocyanins, an important group of natural pigmentsin red and/or purple fruits, are the main phenolic compounds in eggplant skin **(Mazza and al., 2004)**.

Most legumes are consumed after a simple industrial process in which the pod is and the seed are prepared as fresh or frozen food. The bean is widely consumed and grown worldwide **(Mateos-Aparicio and al .,2012)**. The Food and Agriculture Organization of the United Nations (FAO), the global production is about 3.6 million tons of beans that are produced by growers, 70% of which are by-products **(Abu-Reidah and al.,2017).** This by- product could also be an important source of functional ingredients such as natural antioxidants **(Mateos-Aparicio and al,.2012).**

Peas are known for their nutritional value and the significant amount of by-products (pods) they release, according to the Food and Agriculture Organization of the United Nations, the world production is 15.87 million tons, 67% of which are by-products, and Algeria occupies the fifth position with a production of 186348 tons **(FAO, 2013).**

Drying is one of the methods to produce high quality dried products, which can be consumed directly or used as an ingredient for different preparations. It is not considered only as a preservation process, but also as a method of increasing the added value of food and among food stuffs, special attention has been given to the drying of fruits and vegetables in order to obtain diversified products to include in breakfast cereals, soups and dairy products **(Ramos and al.,2003)**.

Fermented dairy products already have a positive image for health due to the beneficial action of viable bacteria **(Sendra and al., 2010)**, yogurt appears as a food of choice in a balanced diet. Indeed, it is rich in protein and provides a contribution of vitamins and trace elements, including calcium, while having a moderate protein intake. **(Yahia, 2012).**

The present study was conducted to optimize the preparation of stirred yoghurts, at the laboratory scale, fortified with the different dried by-profucts; eggplant peels, bean and pea pods, and to compare the effect of drying technique (oven and microwave) on physico-chemical properties ,microbioligical and sensory quality of the manufactured yoghurts.

Chapter I

Bibliographical Part

I- Overview of eggplant

Eggplant (*Solanum melongena* L.) also known as aubergine, brinjal, berenjena or Guinea is an agronomically and economically important non-tuberous species of the night shade Solanaceae family. Eggplant has been cultivated for centuries in Asia, Africa, Europe, and the Near East **(Bohs and Weese.,2010)**.Eggplant has undergone a constant increase in yield (2.7-fold) and total production (8.7-fold) in the last fifty years, although the largest increases have been recorded in the last decade **(FAOSTAT,2017).**

I-1 Morphological description

Primitive eggplant characters are tall plants with large, spiny leaves, flowering in cluster swith 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 and morphology of eggplant **(Swarup ,1995).**

I-2 Chemical composition of eggplant

Eggplant is becoming more and more popular due to its taste and the content of useful chemicals, such as vitamins of group B, C, potassium, calcium, phosphorus, magnesium and sodium **(Voytsekhovskiy and al .,2015).**

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

Table I: Chemical composition of eggplant **(Özcan and 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

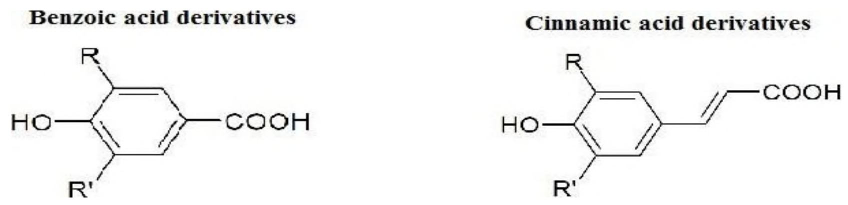
I-3 Phenolic composition

Phenolic compounds include a wide range of chemicals comprising at least one aromatic ring and one or more hydroxyl groups, in addition to other constituent **(Salunkhe and 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-3-1 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 and al.,2012).**The concentration of the hydroxyl benzoic acid is generally very low in edible vegetable. These derivatives are quite rare in the human diet by those against hydroxyl cinnamic acids which are very present **(Macheix and al.,2005).**

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



R=R'=H; *p*-hydroxybenzoic acid
R=OH, R'=H; protocatechuic acid
R=OCH3, R’=H; vanillic acid
R=R'=OH; gallic acid
Sinapic 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’=$OCH_{3;}$

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

I-3-2 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, linkedby achain C3 **(Bruneton,1999).**The various subgroups are flavones,flavonols, flavanols and anthocyanins which are the major flavonoid of eggplant peel **(Chir and al.,2008).**

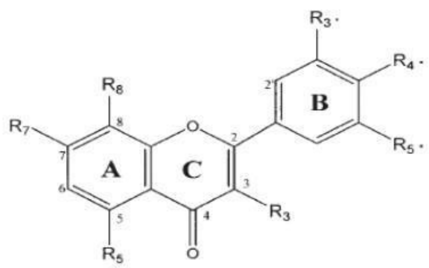
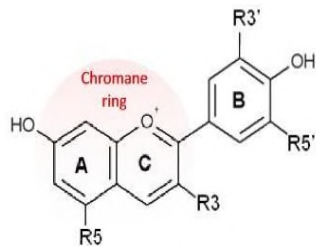


Figure 3: General structure of flavonoid **(Laura and al.,2009)**

I-3-3 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 fromthe many potential attachment sites for functional-methoxy and hydroxyl- groups in the cationring (**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 and al., 2013)**.



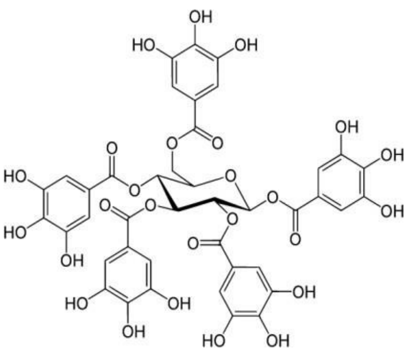
Anthocyanin	R3'	R5'	R3	R5
Pelargonidin 3-glucoside	H	H	Glc	OH
Pelargonidin 3,5-diglucoside	H	H	Glc	Glc
Cyanidin 3-glucoside	OH	H	Glc	OH
Cyanidin 3,5-diglucoside	OH	H	Glc	Glc
Delphinidin 3-glucoside	OH	OH	Glc	OH
Delphinidin 3,5-diglucoside	OH	OH	Glc	Glc

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

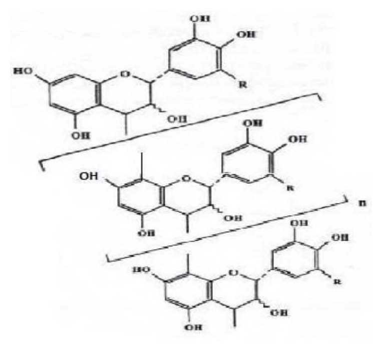
The most abundant anthocyanins in Solanum melongena L, are nasunin and delphinidin conjugates (**Ichiyanagi and al.,2007; Braga and al., 2016)**, constituting 69, 1 %, 87, 7% respectively and 3-caffeoyl rutinoside-5-glucoside, Delphinidin-3-glucosyl-rhamnoside and Petunidin were reported **(Matsuzoe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

I -3-4 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 and al., 2005)**



a: Hydrolysable tannins



.b: Condensed tannins

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

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

II- Overview of broad bean pod

Broad bean (*Vicia faba L.*), is a species of bean family; Fabaceae (*Leguminosae*), an ancient crop species that originated in the Near East1, is mainly grown in Europe, the Middle East and North Africa. It is an important leguminous crop worldwide because of its nutrient-rich seeds. It is extensively used as a legume, a vegetable, and as fodder **(Li and Yang .,2014)**. According to FAO estimates, world production of broad beans was estimated to be around 4 million tons. Curiously, harvesting this vegetable would yield around 2.8 million tons of broad bean by-products (~70% of the total production) **(Abu-Reidah and al.,2017)**.

II -1 Morphological description

V. faba is an annual herb with coarse and upright stems, unbranched 0.3 to 2 m tall, with 1 or hollowed stems from the base. The leaves are alternate, pinnate and consist of 2 to 6 leaf lets each up to 8 cm long. The plant flowers profusely but only a small proportion of the flowers produce pods. Flowers are large, white with dark purple markings; 1-4 pods develop from each flower cluster **(Singh and al.,2013)** .Pods are fruits fleshy which can be from 10 to 20 cm long according to the varieties and can contain a variable number of seeds (4 - 9). In the young state, pods are of green color then darken in the maturity **(Fig.6)**.

Kingdom: Plantae
Division: Angiospermae
Class: Broadleaf
Order: Fabales
Family: Fabaceae
Genus: Vicia
Species: V*icia faba.L*

Figure 06: Taxonomic classification and morphology of broad pean **(Mark and al.,2009)**

II-2 Chemical composition

Broad bean pod is a prized diet component since it contains considerable amounts of valuable nutrients: minerals **(Tab.II)**, and secondary metabolites namely phenolic compounds **(Abu-Reidah and al., 2017)** Broad bean pod generated from the agro-industrial practices are considered a key source of bioactive and functional components that can be used for their nutritional and added value properties **(Singh and al.,2013).**

Table II: Composition of broad bean pod: Low molecular weight carbohydrates (LMWC) and minerals (g/100 g dry matter) **(Mateos-Aparicio and al .,2010)**.

Element	Content	Element	Content
Protein	13.6 ± 0.2	Potassium	2.29 ± 0.3
Fat	1.3 ± 0.5	Sodium	0.09 ± 00
LMWC	26.6 ± 0.5	Calcium	0.34 ± 00
Sucrose	6. 1 ± 0.2	Magnesium	0.12 ± 00
Glucose	13.3 ± 0.5		
Arabinose	1.3 ± 0.1	Iron	0.65± 0.1
Fructose	4.1 ± 0.3	Cupper	0.05± 00
Starch	11.7± 0.2	Manganese	0.13 ± 00
Dieatryfiber	40.1± 1.0	Zinc	0.14± 00
Insoluble DF	30.8 ± 1.2		
Soluble DF	9.3 ± 0.6		
Ash	6.3 ± 0.1		

LMWC**:** low molecular weight carbohydrate

II-3 Phenolic composition

Broad bean pod showed to contain polyphenols such as phenolic acids, flavonoids and tannins **(Mateos-Aparicio and al.,2010).**

- The structure of some characterized bioactive compounds in broad bean pod, are illustarted in **figure7.**

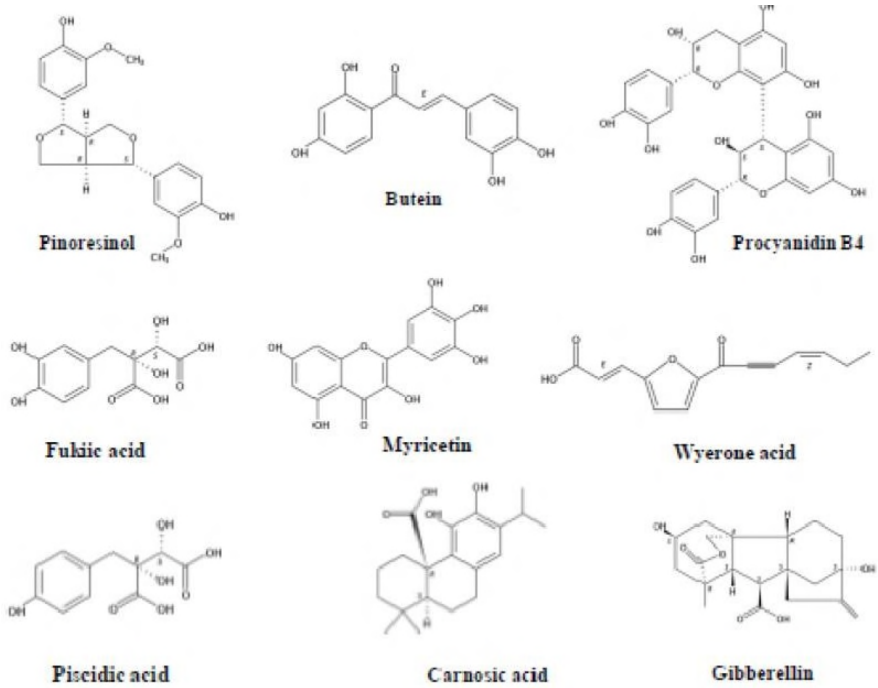


Figure 07: Structure of some phytochemicals characterized in broad bean pods **(Abu-Reidah and al.,2017)**

III- Overview of Pea pod

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

III-1 Morphological description

The pea pod is an oblong-oval dry fruit 3.5-15 cm ×1-2.5 cm, pendent **(Westphal and arora.,1989**), its color before maturity is generally green, is made up of a single carpel (unilocular) and opens at maturity by two dehiscence, one at the level of the placentas and the other at of midrib the carpel. The pod is divided into two valves, this property makes it possible to shell and collect the seed **(Fig.8**). The pea pod is provided with a parachment (a thin solid film), wich gives it a rigid appearance and allows its dehiscence (**Trebuchet and al., 1953**)

Kingdom: Plantae
Division: Angiospermae
Class: Magnoliopsida
Order: Fabales
Family: Fabaceae
Genus: pisum
Species: pisum sativum *.L*

Figure 8: Taxonomic classification and morphology of pea pod **(Mark and al.,2009)**

III-2 Chemical composition

Pea pods a prized diet component since it contains considerable amounts of valuable nutrients: fiber, sugar, protein, minerals **(Tab.III)**, and secondary metabolites namely phenolic compounds **(Mateos-aparicio and al.,2010**).The pea pods had 51% fiber, 28.2% carbohydrates, 14.2% crude protein, 4.5% lipids and 4.5% ash which consisted mainly of K, Mg, Ca, Na,Fe, Zn and Cu (in descending order). The fatty acid (FA) profile showed that linoleic, linolenic and palmitic acids were the main components **(Mejri ,2019).**

Table III: Chemical composition of pea pod (g/100g dry matter) **(Mateos Aparicio and al.,2010)**

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

III-3 Phenolic composition

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

VI- 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 and 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 color deterioration **(Barreiro et al.,1997; Avila and Silva 1999)**.

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

IV-1 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 food stuff **(Vasseur , 2009).**

IV- 2 Microwave drying

MWD is based on a unique volumetric heating mode facilitated by electromagnetic radiation at 915 or 2.450 MHz. The responses of a lossy food product to dielectric heating result in rapid energy coupling into the moisture and lead to fast heating and drying. A significant reduction in drying time in microwave drying is often accompanied by an improvement in product quality, making it a promising food dehydration technology **(Feng and al.,2012)**. 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)** and (**Therdthai and Zhou.,2009)**.MWD can be assigned as a “volumetric heating process”, Microwave electromagnetic energy being directly absorbed by water-containing materials and converted into heat by molecular agitation **(Khraisheh and al., 1997; Piyasena, Mohareb**

and al.,2003). A MWD process consists in three drying periods: (1) a heating-up period in which 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 usedfor moisture vaporization and transfer and (3) a reduced drying rate period during which the local moisture is reduced to a point that then ergy needed for moisture vaporization is lower than the thermal energy induced by MWD.**(Maskan 2001**;**Zhang and al.,2006;Bakirci and al., 2011)**.

V- Yogurt

V-1 Definition and classification

Yogurt has been a part of the human diet for several millennia and goes by many names throughout the world. The word “yogurt” is believed to have come from the Turkish word “yoğurmak,” which means to thicken, coagulate, or curdle. Yogurt (also spelled “yoghurt” or “yoghourt”) is considered by most regulatory agencies worldwide to be a fermented milk product that provides digested lactose and specifically defined, viable bacterial strains, typically *Streptococcus thermophilus* and *Lactobacillus bulgaricus* which must be simultaneously sowed and found alive in the product at the rate of at least 10^7 bacteria g^{-1} (**Fisberg and Machado. 2015).**The addition of additives (agent of texture, etc.) in yoghurt is authorized by the regulations of the majority of the European countries **(Kora, 2004).** It is a source of several essential nutrients, including protein, calcium, potassium, phosphorus, and vitamins B_2 and B_{12}, and serves as a vehicle for fortification (**Fisberg and Machado.,2015).**

V-2 Composition and production of yoghurt

The composition of yoghurt was given in table **IV**.

Table IV: Chemical composition of typical yoghurt **(Amakoromo and 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

- **Production diagram of yoghurt**

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 **(Fig.9)**.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 and al., 1997).**

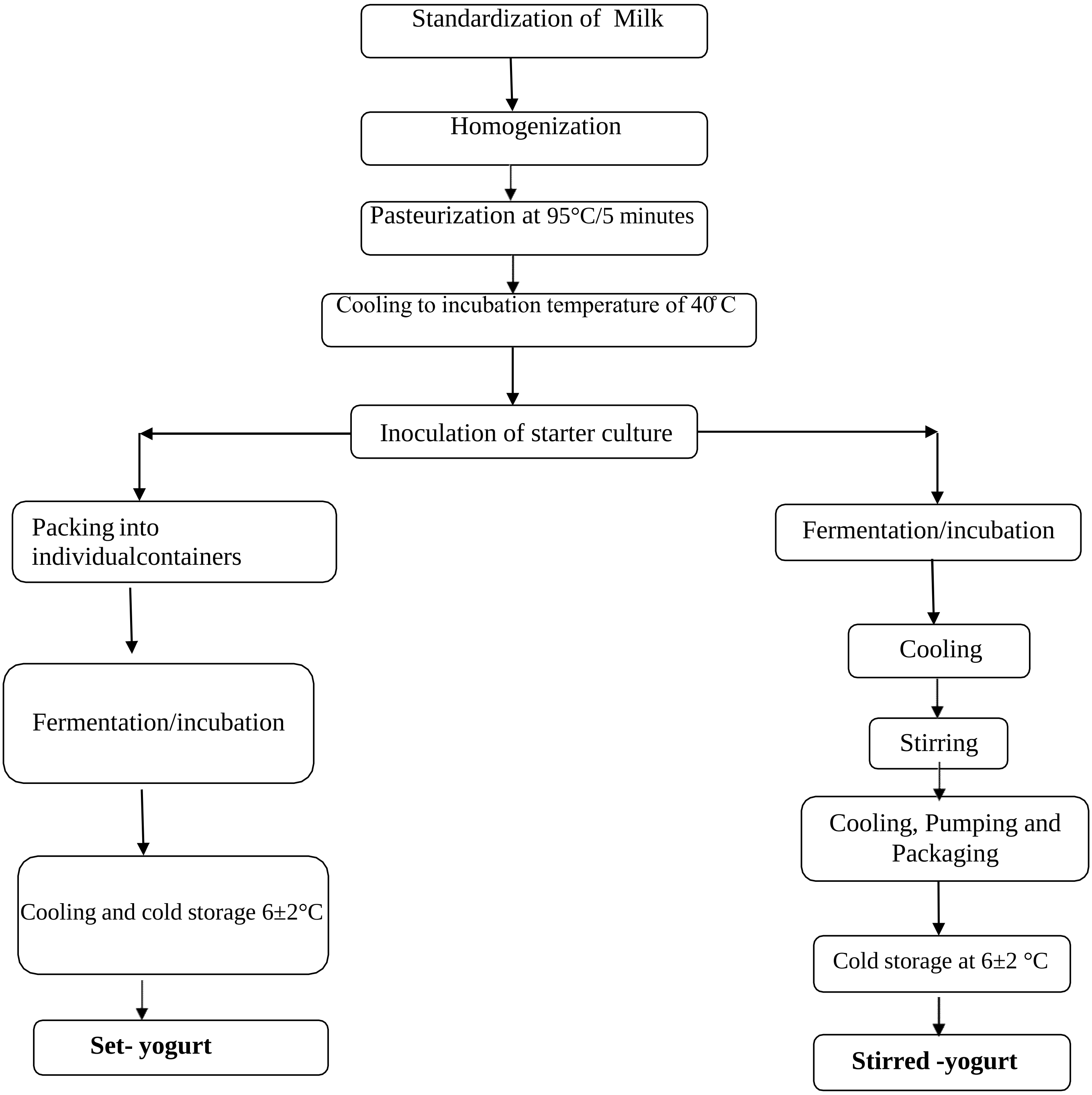


Figure 9: Manufacturing process of set-and stirred-yogurt **(Weerathilake and al.,2014)**

V-3 Health Benefits

There is a wealth of evidence about the relationship between dairy foods and health. Several studies showed that yoghurt consumption in particular is associated with benefits relating to bone health, cardiovascular health, diabetes and obesity **(Ruxton, 2015).**

- **Bone health:** Yoghurt provides many of the nutrients needed for optimal bone health such as calcium, protein, magnesium, zinc and phosphorus. The calcium presents in yoghurt is bioavailable as the low pH ionizes calcium, facilitating intestinal calcium uptake **(Williams and al., 2015).**
- **Cardiovascular:** Studies and meta-analyses have reported beneficial associations between yoghurt intake and cardiovascular disease risk factors. A high yoghurt intake was thought to support blood pressure control and may even help prevent hypertension **(Ralston and al.,2012)**.
- **Lactose intolerance:** Yoghurt naturally contains less lactose than milk (typically 3.4% compared with 6.0%), suggesting that it may be better tolerated than milk in people with lactose intolerance. An opinion by the European Food Safety Authority confirmed that live yoghurt can be included in the diets of people with lactose mal digestion because, within the gut, the cultures in live yoghurt improve the digestion of lactose **(Ruxton ,2015)**.
- **Improvement of the digestibility of proteins:** Bacterium lactic produces enzymes which hydrolyze partially proteins of the milk. Therefore, yoghurt contains more peptides and free amino acids than the milk. It is generally admitted that the prehydrolysis of casein improves the digestibility of proteins of the yoghurt. (**Achat and Brouk.,2017)**

V-4 Yogurt and bioactive compounds

Due to a growing demand for functional fermented dairy foods with improved nutritional qualities, the food processing industry has prompted to cut down on ingredients such as fat, sugar and additives, thereby necessitating some important changes in sensory qualities that influence consumer acceptance of fermented dairy products (**Stijepić and al. ,2012).** Although some bioactive substances have been added to yogurt in order to enhance the health outcomes of conventional yoghurt (**Georgiakouli and al.,2016)**.Dietary fibers have beneficial effects for human health. The recommended daily intake of fiber is about 38 g for men and 25 g for women. Dairy product as yoghurt can provide major opportunities for the development of fiber enriched foods. Their acceptability by the consumers is mainly based on satisfactory textural and sensory attributes **(Sendra and al.,2010)**. For this reason, several attempts to produce yoghurts fortified with natural antioxidant-rich extracts have been undertaken (**Tab.V)**

Table V: Enrichments of yoghurt with bioactive substances (antioxidants)

Yoghurt and matrix	Experimental conditions	References
-Yoghurt -Grape and callus extracts	At a concentration of 0.172 mg/kg in callus extract yogurts that made the novel bio fortified yogurt a goodsource of this health improving natural compound. The total amount of characterized and quantified phenoliccompounds from callus extract supplemented yogurts was 55.8 mg/L whereas FolineCiocalteu assay estimated the yogurt's total phenolic content as 77.23 mg/L at the first day of storage.	**Karaaslan and al.,2011**
-Yoghurt traditional Greek-type and European-type sheep'syoghurt -Olive mill wast (OMW)	In all cases the pH value of the yogurt in the initial incubation step dropped substantially faster when this was enriched by polyphenols, and additionally the added poly-phenols (5001000 ppm in concentration) excreted a protective effect against undesirable pH drop during yogurt storage (known as post-acidification).	**Petrotos and al.,2012**

- Full-fat and non-fat yoghurt - Grape seed extracts (GAE)	The fortification of yoghurts at 5-10 mg GAE/100 g did not affect yoghurts' pH, the viability of lactic acid bacteria, consistency, colour and flavour. Fortified yoghurts with seed extracts contained more polyphenols and exhibited higher antiradical and antioxidant activity than controls	**Chouchouli et al.,2013**

-Drinking yoghurt -Berry polyphenols extract (BPE)	Adding BPE before fermentation had resulted in PP metabolism to small phenolic molecules in the yoghurts and 3.5e 3.9 times the TPC value of yoghurts obtained by adding BPE after Fermentation. Adding PPs (in the form of BPE or Cyanidin) influenced the microbiological properties of the starter cultures (the appearance, survival and growth of lactic bacteria observed).	**SunWaterhouse and al.,2013**
-Low-fat yoghurt -Pleurotusostreatus aqueous extract (POE)	Viable counts of *S. thermophilus* and L. bulgaricus, pH, lactic acid production, changes in rheological and structural properties (syneresis, texture profile analyses, color and microstructure), antioxidant capacity and total phenolic were followed throughout 28 days of cold storage. Addition of POE increased lactic bacteria CFU counts.Thus,POE can be used to manufacture low fat yogurt with functional activity and at the same time modifies rheological properties.	**Vital and al., 2015**
-Probiotic yoghurt . -Green , white and black tea extract .	Green tea yogurt showed the highest phenolic content ($p < 0.05$) followed by white tea yogurt and black tea yogurt. LCMS/MS analysis revealed the absence of several phenolic compounds in tea yogurts, despite their presence in tea water extracts, as well as the presence of new phenolic compounds. All tea yogurts showed higher ($p < 0.05$) FRAP and FIC values than respective control during 21 days of storage.	**Muniandy and al., 2016**

-Yoghurt -Concentrated strawberry juice	The total lactic acid bacteria count remained higher than 10^8 CFU·mL^{-1}, during the storage time for all beverages studied. The viscosity of the yogurts decreased when the ratio of strawberry cryocon centrate was increased. The Power Law model was successfully applied to describe the flow of the yogurts, which had a thixotropic behaviour. The enrichment of natural yogurt with strawberry cryo concentrated pulp proved to be effective in the production of a beverage with higher nutritional characteristics.	**Henrique Jaster and al., 2018**

FRAP : Ferric reducing antioxidant power

TPC : Total phenolic content

Pps : polyphenol

Chapter II

Materials and Methods

II-1 Plant Materials

Fresh eggplant (*Solanum melongena*), fresh broad bean (*Vicia faba L.*) and fresh pea (*Pisum sativum*) were purchased from local market, Bejaia city (Algeria) in May 2021**,**then washed by distilled water. The eggplant was peeled using a sharp knife **(Todaro and al .,2009)** and the removal of broad bean and pea seeds from their pods was made manually. The whole peels and pods were dried by two different methods: oven and microwave technique**.** Before drying these samples were cut into squares (thin thickness).

II-2 Drying process

- **Oven drying**

Samples (peels and pods), were air dried in a ventilated oven (MEMMERT, UFB400), at temperatures already optimized in previous works : 80°C for the eggplant, 60°C for broad bean and 40 °C for pea until constant weight.

- **Microwave drying**

Microwave drying experiments were performed in a domestic microwave oven (Whirlpool) with cavity dimensions of 22.5 cm × 37.5 cm × 38.6 cm and 2450MHzworking frequency was used. The device was equipped with buttons to adjust the time and power of irradiation (linearly adjustable from 100 to1100 W).The microwave power of 100W (already optimized in previous works), was used in the drying of the eggplant peels, broad bean and pea pods until constant weight.

II-3 Grinding, sieving

The dried matrixes were ground using an electric coffee mill (KSW445 CB) and sieved to granulometry lower than 500µm particle size**.** The fine powders were stored in air tight containers until use.

II-4 Decontamination of the plant powders

Drying does not guarantee the microbiological safety of low moisture products, thus pasteurization technologies are needed **(Anderson,2018)**. Before the use of the eggplant peels, broad bean and pea pods powders in dairy products, three pasteurization techniques were used for these samples:

- Pasteurization in water bath 90°C/10 minutes and 95°C/5 minutes

- Pasteurization with the autoclave 120°C / 5 minutes
- Pasteurization with the pastor's oven 120°C / 15 minutes.

Microbiological analyses were carried out in order to verify the sterility of the powders and to compare the three methods.

II-5 Microbiological analysis

The microbiological quality of the powder was evaluated by enumeration of total viable organisms. The organisms enumerated include total flora, enterobacteria, yeasts and molds **(Tab.VI)**.

Table VI: Microbiological analysis of the powder

Micro-organisms	Selective Mediums	Incubation temperature	Incubation time	Method
Enterobacteria	VRBG	37°C	24h	In test tubes 1g of powder was put in 9 g of TS (trypto-salt) which is a diluent, well-sealed the tubes and mix them with a vortex then, seeding with the different culture media and incubate
Total Flora	PCA	30°C	72 h	
Yeasts, moulds	YGC	25°C	5 days	

VRBG: Violet Red Bile Glucose Agar
YGC: Yeast extract glucose Chloramphenicol agar
PCA: Plate Count Agar.

II-6 Formulation of stirred yoghurt at laboratory scale

The preparation of yoghurt was made in the laboratory of the dairy industry ***"DANONE DJURDJURA".***Thus 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 broad bean pod and eggplant peel were added **(Tab.VII)**

Table VII: Recipe of stirred yoghurts with eggplant, and broad bean pod.

Recipe	Milk (L)	Sugar (%)	Pods (%)	Eggplant (%)	Lactic Ferment (%)
Standard Yoghurt	1	8	0	0	0.02
Yoghurt + eggplant (80 °C)	1	8	**(--)**	(--)	0.02
Yoghurt + eggplant (100 W)	1	8	**(--)**	(--)	0.02
Yoghurt + broad bean pod (60°C)	1	8	**(--)**	(--)	0.02
Yoghurt + broad bean pod(100W)	1	8	**(--)**	(--)	0.02

II-7 Physico-chemical properties of yoghurt

Physico-chemical properties of the manufactured yoghurts (standard yoghurt, yoghurt enriched with polyphenol and fiber) were determined namely, pH, viscosity, the dry extract and fat contents **(Tab.VIII)**. These tests were carried out at the laboratory of the dairy industry ***"DANONE DJURDJURA".***

Table VIII: Physico -chemical properties of yoghurt

Measure	Method
pH	The pH value of yoghurt was measured at fixed temperature (9.5-10.5°C) with acalibrated pH electrode (HANNAHI2210).
Viscosity (g)	Apparent viscosity of yoghurt was expressed using a viscometer "TAXT EXPRESS" during 45 S
Total dry extract (%)	3 g of yoghurt in the desiccators, spread the mass and start the drying process until the apparatus stops.
Fat content (%)	Manipulation under hood in a test tube we put sulfuric acid (H_2SO4) 1.82 ml and 11ml of yogurt and 10 ml of ISO amyl alcohol well saddle the tube then mix centrifugation for 10 minutes.

II-8 Experimental design methodology and application

II-8-1 Methodology of experimental design

The notion of the experimental designs was developed in the last decade in biology.Experimental design is a method of optimization trials of scientific research or industrial studies and provides the maximum amount of information with the minimum of experience. It also makes it possible to obtain the best possible precision on the modeling of the results. This method is based on strict mathematical rules; it requires a rigorous procedure on the part of the user **(Achat,2013)**.

II-8-2 Application of experimental design

The enrichment of the yogurt with the powder was obtained by response surface methodology (RSM), using '***STATISTICALS DISCOVRY FROM SAS JMP'***. The design was used to assess the relevance and interaction of the two controlled factors namely storage time (S) and powder concentration (C). The central composite design (CCD) application consists of a two-level full factorial design full two-level factorial (coded ±1), overlaid by central points (coded 0) **(Achat and al.,2012).** Thus**,** RSM was used to optimize the production of stirred yogurt enriched with vegetable powders, namely (eggplant peels, broad bean pod and pea pod) under the effect of independent variables such as storage time (X_1) and matrix powder concentration (X_2) at three different level scoded as : low (-1), medium (0) and high (+1).These levels were chosen by performing preliminary experiments, which indicated that plant powder concentrations of 0.1 to 0.5% and storage times of 1 to 28 days resulted in sufficiently palatable yoghurts (**Tab.IX**).

A total of 13 experiments, including five replicas of the central point, each designated by the coded value 0,randomized according to a CCD configuration for two factors, to avoid extraneous variable effects.The selected optimization parameters were pH (Y1), viscosity (Y2), fat content (Y3), total dry extract (Y4). The surface responses of the obtained data were analyzed with ANOVA and presented by a Standardized Pareto Chart **(Achat and al,. 2012)**. Thus 13 experiments will be carried out in order to estimate the mathematical model of the response investigated. The RSM will make it possible to model the answers studied in the form of a polynomial equation of the second degree.

Table IX: Experiments matrix

/	Configuration	Storage time	Powder concentration
1	00	14.5	0.3
2	-+	1	0.5
3	00	14.5	0.3
4	A0	1	0.3
5	0a	14.5	0.1
6	+-	28	0.1
7	00	14.5	0.3
8	00	14.5	0.3
9	A0	28	0.3
10	++	28	0.5
11	--	1	0.1
12	00	14.5	0.3
13	0A	14.5	0.5

II-9 Sensory analysis

The evaluation of the sensory properties of yoghurts (yoghurt with eggplant powder 80°C, 100 W and with bean powder 60°C, 100 W) was studied. The panel was constituted by 08 panelists of ***'DANONE DJURDJURA'***. The panelists evaluated the color, taste, texture, flavor, sweetness, acidity and smell of each sample, using a numerical scale.12 samples of yoghurt were presented and coded for each expert A1 A2 A3, B1 B2 B3, C1 C2 C3 and D1 D2 D3.

Chapter III

Results

and

Discussion

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, broad bean pod and compare their performance.

III-1 Microbiol decontamination

Moulds, yeast and coliforms are the primary contaminants in yoghurt **(Amakorom and al., 2012)**.There are many processes that utilize dry heat, moist heat or energy-based treatments that can pasteurize low moisture foods. Process humidity is an important parameter to consider when validating thermal pasteurization processes for low-moisture foods **(Zhang and al.,2017; Jeong and al.,2017)**

The microbial quality of the plant powder was assessed, using different pasteurization technique. The **Table X**, **XI**, **XII** and **XIII** showed the evolution of the counts of microorganisms*:* against enterobacteria, total flora and yeasts and molds in powder samples.

Table X: Microbial quality of powder samples, after pasteurization in a water bath at **90°C** for **10 minutes**

/		Enterobacteria	Total flora	Molds and yeast
Eggplant peels powder	(100W)	-	-	+2green yeast and white molds
	(80°C)	-	-	-
Bean pods powder	(100W)	-	+	+ 2 whites Molds
	(60°C)	-	-	-
Pea pods powder	(100W)	-	+	-
	(40°C)	-	+	-

+: Presence; -: Absence

These results revealed the absence of entebacteria in all samples but a presence of total flora in the bean powder (100 W), and the pea powder (40°C and 100 W) as well as the presence of yeasts and molds in the eggplant powder (100 W)**.** However, there was a growth of two green and white molds, in the bean and eggplant powder (100 W).

The observed counts reflect the original microorganism bioburden and growth (**Dababneh, 2013).**

The data showed in **table XI** that enterobacteria , total flora, molds and yeast were not detected in all the analyzed samples. Thes same tendency was observed in **table XII**.Thus, the no microbial proliferation indicates the effectiveness of the heat treatment (120°C for 5 min and 15 min)

Table XI: Microbial quality of powder samples, after pasteurization in a water bath at **120**˚C for **5 minutes**

/		Enterobacteria	Total flora	Molds and yeast
Eggplant peels powder	(100W)	-	-	-
	(80°C)	-	-	-
Bean pods powder	(100W)	-	-	-
	(60°C)	-	-	-
Pea pods powder	(100W)	-	-	-
	(40°C)	-	-	-

+ : Presence; -: Absence

Table XII: Microbial quality of powder samples, after pasteurization in a water bath at **120C** for **15 minutes**

/		**E**nterobacteria	Total flora	Molds and yeast
Eggplant peels powder	(100W)	-	-	-
	(80°C)	-	-	-
Bean pods powder	(100W)	-	-	-
	(60°C)	-	-	-
Pea pods powder	(100W)	-	-	-
	(40°C)	-	-	-

+: Presence; -: Absence

- According to the results of table XIII, we observe the presence of enterobacteria in both of peas peel powder (100W) and (40): 230 CFU/ml and uncountable respectively. The other micro-organisms were not detected in all tested samples.

Table XIII: Microbial quality of powder samples, after pasteurization in a water bath at **95°C** for **5 minutes**

/		**E**nterobacteria	Total flora	Molds and yeast
Eggplant peels powder	(100W)	-	-	-
	(80°C)	-	-	-
Bean pods powder	(100W)	-	-	-
	(60°C)	-	-	-
Pea pods powder	(100W)	+ of 230 CFU/ml of enterobacteria	-	-
	(40°C)	Uncountable	-	-

+ : Presence; -: Absence

This absence demonstrates the adequate heating treatment of different peel powders under strict aseptic conditions during processing and manufacturing of the different stirred yoghurts. But unfortunately, the pea pod powder contains enterobacteria even after heat treatment at 95°C for 5 minutes, for this reason the pea pod was eliminated and put it aside to avoid contaminating our yogurt and at the same time the consumers and harming their health. After several trials of heat treatments, the pasteurization at 95°C during 5 min was selected, because it is the only treatment which allowed us to have a good microbiological quality while keeping the nutritional aspect of the powder in particular their coloring and their pigments as well as their flavor **(Fig.10)**

Figure 10: Colors of powders preserved after treatment in water bath 95° during 5 minutes

III-2 Analysis of prepared stirred yoghurt

III-2-1 Physico-chemical analysis of yoghurt

Physico-chemical properties of the manufactured stirred yoghurts (standard yoghurt, yoghurts with eggplant peel and broad bean pod (dried at 100 W,80 °C and 60°C) were shown in table XIV, XV, XVI, XVII, XVIII and XIX during storage (day 1, 14 and 28).

Table XIV: Physico-chemical carceteristics yoghurt with eggplant peels at **day 1**

	Concentration	**pH**	**Viscosity (g)**	**Total dry extract (%)**	**Fat content (%)**
Standard Yoghurt		**4.45**	**24.6**	**23.6**	**2.75**
Yoghurt with eggplant (100W)	0.1%	4.43	28.9	23.24	2.3
	0.3%	4.50	22.1	23.63	2
	0.5%	4.42	29.50	23	2
Yoghurt with eggplant (80°C)	0.1%	4.43	28.3	22.96	2.4
	0.3%	4.41	27.8	21.56	2.4
	0.5 %	4.46	23.1	22.50	2.3
Norms		**4.4 - 5.7**		**23.9 -25.15**	**2.75 -3.15**

Table XV: Physico-chemical carceteristics yoghurt with eggplant peels at day **+14**

	Concentration	pH	Viscosity (g)	Total dry extract (%)	Fatcontent (%)
Standard Yoghurt		**4.45**	**24.6**	**23.6**	**2.75**
Yoghurt with eggplant (100 W)	0.1%	4.36	48.8	19.56	2.3
	0.3%	4.36	26.2	22.90	2.4
	0.3%	4.33	29.7	22.33	2.4
	0.3%	4.35	29.1	21.30	2.5
	0.3%	4.33	27.5	21.26	2.4
	0.3%	4.36	28.6	22.33	2.3
	0.5%	4.34	27	23.97	2.5
Yoghurt with eggplant (80°C)	0.1%	4.36	34.2	23.59	2.4
	0.3%	4.37	32.4	22.17	2.3
	0.3%	4.38	29.9	23.03	2.5
	0.3%	4.36	28.6	22.19	2.4
	0.3%	4.39	27.6	23.04	2.3
	0.3%	4.35	30.2	22.35	2.5
	0.5 %	4.36	32.4	21.98	2.5
Norms		**4.4 - 5.7**		**23.9 -25.15**	**2.75 – 3.15**

Table XVI: Physico-chemical carceteristics yoghurt with eggplant peels at day **28**

	Concentration	pH	Viscosity (g)	Total dry extract (%)	Fatcontent (%)
Standard Yoghurt		**4.45**	**24.6**	**23.6**	**2.75**
Yoghurt with eggplant (100 W)	0.1%	4.33	32	23.30	2.4
	0.3%	4.35	31.6	23.79	2.5
	0.5%	4.32	33.6	23.7	2.4
Yoghurt with eggplant (80°C)	0.1%	4.34	33.8	23.31	2.5
	0.3%	4.35	33.2	23.49	2.45
	0.5 %	4.30	40	25.44	2.4
Norms		**4.4 - 5.7**		**23.9 -25.15**	**2.75 – 3.15**

Table XVII: Physico-chemical properties of yoghurt with broad bean pod at day**1**

	Concentration	pH	Viscosity (g)	Total dry extract (%)	Fat content (%)
Standard Yoghurt		4.45	23.5	23.6	2.35
Yoghurt with Broad bean pod) (100 W)	0.1%	4.50	23.5	19.90	2.35
	0.3%	4.50	25.9	23.48	2.2
	0.5%	4.51	24	21.58	2.3
Yoghurt with broad bean pod (60°C)	0.1%	4.43	28.57	21.80	2.4
	0.3%	4.46	26.3	17.44	2.4
	0.5 %	4.43	28.6	23.33	2.3
Norms		**4.4 - 5.7**		**23.9 -25.15**	**2.75 – 3.15**

Table XVIII: Physico-chemical properties of yoghurt with broad bean pod at day **14**

	Concentration	pH	Viscosity (g)	Total dry extract (%)	Fat content (%)
Standard Yoghurt		**4.45**	**24.6**	**23.6**	**2.75**
Yoghurt with broad bean pod (100 W)	0.1%	4.44	26.5	22.20	2.2
	0.3%	4.41	26.1	24	2.3
	0.3%	4.43	25.4	23.69	2.4
	0.3%	4.41	27.6	23.50	2.3
	0.3%	4.43	25.4	22.06	2.5
	0.3%	4.41	27.6	22.13	2.4
	0.5%	4.39	22.8	23.60	2.5
Yoghurt with broad bean pod (60°C)	0.1%	4.35	22.9	22.21	24
	0.3%	4.36	37.9	22.69	2.5
	0.3%	4.37	30.6	22.50	2.4
	0.3%	4.35	30.4	22.32	2.3
	0.3%	4.36	29.5	22.52	2.4
	0.3%	4.39	29.5	22.40	2.4
	0.5 %	4.32	26.3	22.39	2.5
Norms		**4.4 - 5.7**		**23.9 -25.15**	**2.75 – 3.15**

Table XIX: Physico-chemical properties of yoghurt with broad bean pod at day **28**

	Concentration	pH	Viscosity (g)	Total dry extract(%)	Fat content (%)
Standard Yoghurt		**4.45**	**24.6**	**23.6**	**2.75**
Yoghurt with broad bean pod (100 W)	0.1%	4.36	27.9	26.83	2.5
	0.3%	4.36	30.1	23.94	2.4
	0.5%	4.34	27.4	24.34	2.55
Yoghurt with broad bean pod (60°C)	0.1%	4.30	33	23.80	2.5
	0.3%	4.32	39.5	26.86	2.55
	0.5 %	4.29	30.6	26.65	2.6
Norms		**4.4 - 5.7**		**23.9 -25.15**	**2.75 – 3.15**

Results of all these physico-chemical analysis revealed that pH, fat content, acidity and dryextract were conform to norms. However a decrease in pH of the yoghurt enriched with eggplant peels and with broad bend pod was observed at day 14, probably due to the production of lactic acid by the lactic ferments.

Furtherthemore, an increase in viscosity was recorded after the addition of eggplant peel to standard yoghurt, on the other hand its impact on the aggregation of the casein network in yoghurts via electrostatic interaction and on the flow resistance of the yoghurt matrix in yoghurts via electrostatic interaction and on the resistance of the yoghurt matrix to flow. Indeed, the addition of plant extracts generally decreases the consistency of the products dueto the reduction of the water binding capacity of the proteins.

III-3 Optimization of enrichment conditions

The experimental designs are very used in industrial studies in research and development; they allow a good understanding of the phenomena involved in the design of a new product and to apprehend a variable response quickly **(Wang and al.,2009).**

III-3-1 Modeling and model fitting using RSM

The experimental design and subsequent responses related to pH, viscosity, solids and grease are summarized in **table XX**. Regression coefficients for intercept, linear, quadratic and interaction terms were calculated as represented in **table XXI.**

a -Yogurt enriched with oven-dried eggplant peels

Table XX: The results of the experimental design

/	Configuration	Storage time	Powder concentration	pH	Viscosity
1	00	14.5	0.3	4.37	32.4
2	-+	1	0.5	4.46	23.1
3	00	14.5	0.3	4.38	29.9
4	A0	1	0.3	4.41	27.8
5	0a	14.5	0.1	4.36	34.2
6	+-	28	0.1	4.34	33.8
7	00	14.5	0.3	4.36	28.6
8	00	14.5	0.3	4.39	27.6
9	A0	28	0.3	4.35	33.2
10	++	28	0.5	4.30	40
11	--	1	0.1	4.43	28.3
12	00	14.5	0.3	4.35	30.2
13	0A	14.5	0.5	4.36	32.4

Table XXI: The analyse of variance (ANOVA) for the experimental results of pH

Source	DF	Summe of squares	Mean squares	P-value
Model	5	0,01798327	0,003597	0.0044
Error	7	0,00252443	0,000361	
C.total	12	0,02050769		
Lack of fit	3	-0,051667	0,000508	**0.2519**
Pure error	4	-0,001667	0,000250	
Total error	7	0,0160345		
X1 : Storage time	1	-0 ,051667	-0 ,051667	**0,0003**
X2 : Powder conentration	1	-0,001667	-0,001667	0,8359
$X1^2$	1	0,0160345	0,0160345	0,2033
X1×X2	1	-0,0175	-0,0175	0,1079
$X2^2$	1	-0,003966	-0,003966	0,7388

R^2 = **88%**, R^2 Adj = **78 %**, CV: Coefficient of variation RMSE /MEAN OF REPONSE .100
CV= **0,04 %**

❖ pH

The pH is an important factor used to verify the quality of yogurt. The pH of the yoghurt enriched with eggplants peels samples after 1, 14 and 28 days of storage in the refrigerator are presented in the table (**tab XX**). By increasing the storage time, the pH decreased, which is quite normal because of the production of lactic acid during the storage time (**Mousavi and al.,2019).**

As shown in the table above, one factor, storage time, present a p-value less than **0.05**, which means that it is significantly different from zero at the **88%** confidence level. This is in perfect harmony with the results of the Pareto chart, which indicates that the storage time significantly influences the pH of the yogurt enriched with eggplant peels.The $\mathbf{R^2}$, being an indicator value of the degree of explanation of the influence of the factors on the response, **88%**, thust the model could be well applied to predict the influence of the storage time on the pH of the yogurt enriched with plant powders. In addition, the value of the Lack of-fit was designed to determine if the chosen model is valid to describe the observed data **(Achat and al.,2012)**, thus this value is greater than **0.05**, so the validity of this design is confirmed.

Table XXII: Analyse of variance (ANOVA) for the experimental results

Source	DF	Summe of Squares	Mean squares	P-value
Model	5	175,35474	0,003597	0,0088
Error	7	31,42218	0,000361	
C.total	12	206,77692		
Lack of fit	3	18,230184	0,000508	**0,2798**
Pure error	4	13,192000	0,000250	
Total error	7	31,422184	31,422184	
X1	1	4,6333333	4,6333333	**0,0011**
X2	1	-0,133333	-0,133333	0,8818
$X1^2$	1	-0,572414	-0,572414	0,6670
X1 ×X2	1	2,85	2,85	**0,0311**
$X2^2$	1	2,2275862	2,2275862	0,1241

R^2= **85%**, CV = **0,59 %**

❖ Viscosity

Viscosity is an important factor in the quality and acceptability of yogurt. viscosity indicates the firmness and consistency of yogurt and its high amount is an indicator of yogurt quality **(Hasani and al. ,2016)**. The findings reported by **(Noh and al.,2013)** were similar to our results.

They found that the apparent viscosity values of all samples increased significantly with the addition of corn fructose extract during a 15-day storage period **(Noh and al.,2013)**. The increase in viscosity in samples containing plant powder may be related to the amount of fiber in this product, which resulted in improved viscosity and shrinkage.

Product that resulted in improvements and rearrangements of the casein gel network and inhibited the shrinkage and expulsion of whey. In addition, the viscosity of yogurt is related to acid production.Indeed, when acidity increases, the proteins present in the milk form a firmer gel, resulting in a yogurt with high viscosity **(Hernández and al.,2007).**

As shown in the table above, one factor (storage time) and the interaction between the two factors: storage time * powder concentration have their p-values less than **0.05**, which means that they are significantly different from zero at the **85%** confidence level. This is confirmed in the results of the Pareto chart, which indicates that the storage time significantly influences the viscosity of yogurt.The predicted models can be de- scribed by the following second-order polynomial equations:

$$\mathbf{Y_1 = 4,36 - 0,05\,X_1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(1)}$$

$$\mathbf{Y_2 = 30,12 + 4,63\,X_1 + 2,85\,X_1\,X_2} \quad \ldots\ldots\ldots\ldots \mathbf{(2)}$$

Where $\mathbf{Y_1}$ is pH and $\mathbf{Y_2}$ is viscosity.

The equation **(1)** indicated that the factor X_1(storage time) acts negatively on the pH of the yogurt enriched with eggplant peel.
As stated by the equation (**2**) the factor X_1 and the interaction between the two factors $X_1 * X_2$ act positively on the viscosity of yogurt enriched with eggplant peel.

The total dry extract (Y_3) and the fat content (Y_4) they are invalid by the parameters **(Appendix 2 and 3).**

b- Yogurt enriched with eggplant peels dried by microwave

Table XXIII: The experimental design

/	Configuration	Storage Time	Powder concentration	pH	Fat Content
1	00	14.5	0.3	4.36	2.4
2	-+	1	0.5	4.42	2
3	00	14.5	0.3	4.33	2.4
4	A0	1	0.3	4.50	2
5	0a	14.5	0.1	4.36	2.3
6	+-	28	0.1	4.33	2.4
7	00	14.5	0.3	4.35	2.4
8	00	14.5	0.3	4.33	2.5
9	A0	28	0.3	4.35	2.5
10	++	28	0.5	4.32	2.4
11	--	1	0.1	4.43	2.3
12	00	14.5	0.3	4.36	2.3
13	0A	14.5	0.5	4.34	2.5

Table XXIV: Analyse of variance (ANOVA) for the experimental results of fat contents

Source	**DF**	**Summe of squares**	**Mean squares**	**P-value**
Model	5	0,02843307	0,005687	0,0038
Error	7	0,00379770	0,000543	
C.total	12	0,03223077		
Lack of fit	3	0,00287770	0,000959	**0,1007**
Pure error	4	0,00092000	0,000230	
Total error	7	0,00379770		
X1	1	-0,058333	-0,058333	**0,0005**
X2	1	-0,006667	-0,006667	0,5059
$X1^2$	1	2,193e-16	2,193e-16	1,0000
X1 ×X2	1	0,052931	0,052931	0,0069
$X2^2$	1	-0,022069	-0,022069	0,1593

R^2 =**88%**, R^2Adj =**80%**, CV = **0,53 %**

❖ pH

As shown in the table above, one factor (Storage time) has its p-value less than **0.05**, which means that it is significantly different from zero at the **88%** confidence level.

Table XXV: Analyzes of variance (ANOVA) for the experimental results

Source	DF	Summe of squares	Mean squares	P-value
Model	5	0,24867153	0,049734	0,0429
Error	7	0,08209770	0,011728	
C.total	12	0,33076923		
Lack of fit	3	0,06209770	0,020699	**0,1018**
Pure error	4	0,02000000	0,005000	
Total error	7	0,08209770		
X1	1	0,1666667	0,1666667	**0,0070**
X2	1	-0,016667	-0,016667	0,7174
$X1^2$	1	0,075	0,075	0,2086
X1 ×X2	1	-0,137931	-0,137931	0,0721
$X2^2$	1	0,012069	0,012069	0,8583

R^2 = **75%**, R^2Adj = **57%**, CV=**4, 63%**

- ## Fat content

The difference between R^2 and R^2 adjusted is 18% , only one factor (Storage time) has its p-value less than **0.05**, which means that it is significantly different from zero at the **75%** confidence level.The predicted models is described by the following second-order polynomial equations:

$$\mathbf{Y_1 = 4.35 – 0,058\ X_1 + 0,052\ X1^2} \quad \text{.................................... (3)}$$

$$\mathbf{Y_4 = 2,\ 39+ 0,\ 16\ X_1} \quad \text{.................................... (4)}$$

Where $\mathbf{Y_1}$ is pH and $\mathbf{Y_4}$ is fat content.

The 3rd and the 4th equations revealed that the factor X_1 and the interaction between the two factors (X_1^2) act positively on the pH of the yogurt enriched with eggplant peels.

The factors of the viscosity (Y_2) and the total dry extract (Y_3) are invalid by the parameters **(Appendix 4 and 5).**

c -Yogurt enriched with bean pods dried by microwave

Table XXVI: The experimental design

/	Configuration	Storage time	Powder concentration	pH	Viscosity
1	00	14.5	0.3	4.41	26.1
2	-+	1	0.5	4.51	24
3	00	14.5	0.3	4.43	25.4
4	A0	1	0.3	4.50	25.9
5	0a	14.5	0.1	4.39	22.8
6	+-	28	0.1	4.36	27.9
7	00	14.5	0.3	4.41	27.6
8	00	14.5	0.3	4.43	25.4
9	A0	28	0.3	4.36	30.1
10	++	28	0.5	4.34	27.4
11	--	1	0.1	4.50	23.5
12	00	14.5	0.3	4.41	27.6
13	0A	14.5	0.5	4.39	22.8

Table XXVII: Analyze of variance (ANOVA) for the experimental pH results

Source	**DF**	**Summe of squares**	**Mean squares**	**P-value**
Model	5	0,03575745	0,007151	<0,001
Error	7	0,00101178	0,000145	
C.total	12	0,03676923		
Lack of fit	3	0,00053178	0,000177	**0,3478**
Pure error	4	0,00048000	0,000120	
Total error	7	0,00101178		
X1	1	-0,008591	-0,008591	**0,0004**
X2	1	0,2672893	0,2672893	0,0544
$X1^2$	1	0,0001334	0,0001334	**0,0121**
X1 ×X2	1	-0,002778	-0,002778	0,2523
$X2^2$	1	-0,392241	-0,392241	0,0667

R^2 **= 97%,** R^2Adj **=95 %,** CV = **0,27 %**

❖ pH

The storage time as well as the powder concentration significantly influence the pH of yogurt (R^2 = 97%, P-value < 0, 05)

Table XXVIII: Analyse of variance (ANOVA) for the experimental viscosity results

Source	DF	Summe of squares	Mean squares	P-value
Model	5			0,0026
Error	7			
C.total	12			
Lack of fit	3	1,2316552	0,41055	**0,8050**
Pure error	4	4,9680000	1,24200	
Total error	7	6,1996552		
X1	1	-0,176886	-0,176886	0,1454
X2	1	46,083972	46,083972	**0,0014**
$X1^2$	1	0,0121659	0,0121659	0,0058
X1 ×X2	1	-0,092593	-0,092593	0,6116
$X2^2$	1	-74,56897	-74,56897	**0,0012**

R^2 **=89% ,**R^2Adj **= 81%,** CV **= 3,63 %**

❖ Viscosity

The storage time as well as the powder concentration significantly influence the viscosity of yogurt.Indeede as shown in the table above, two factors (X_1 : powder concentration and the interaction between X_1*X_1) give a p-value less than of **0.05**. The predicted models are expressed by second-order polynomial equations 5 and 6:

$$Y_1 = 4,47 - 0,0085 X_1 + 0,00013 X_1^2 \quad \text{......................} (5)$$

$$Y_2 = 19,53 + 46,08 X_2 - 74,56 X_2^2 \quad \text{.............................} (6)$$

Where $\mathbf{Y_1}$ is pH and $\mathbf{Y_2}$ is viscosity.

The equation 5 and 6 demonstrate, respectively, that the factor X_1 and the interaction between the two factors X_1^2 act positively on the pH of the yogurt enriched with bean pod and the factor X_2 acts positively on the viscosity of the yogurt, unlike to the interaction of the latter X_2^2 which acts negatively on the viscosity enriched with bean pod.

The total dry extract (Y_3) and the fat content (Y_4), their models were not valid.

d- Yogurt enriched with bean pods by oven 60 ° C

Study not validated for parameters for the 4 answers, namely: the pH, viscosity, total dryextract and fat content **(appendix 7, 8, 9 and 10).**

III-3-2 Response surface plans

In order to better understand the interaction between the factors, the 3D response surface plot response surface was constructed using the equations.The graphs were generated by plotting the response z-axis as a function of two independent variables, while holding the other independent variable at a fixed level **(Bouaoudia and al.,2019).**

The figure 11 show the interactions between powder concentration and storage time and the responses of pH, viscosity on yogurt enrichment.

a -Yogurt enriched with oven-dried eggplant peels

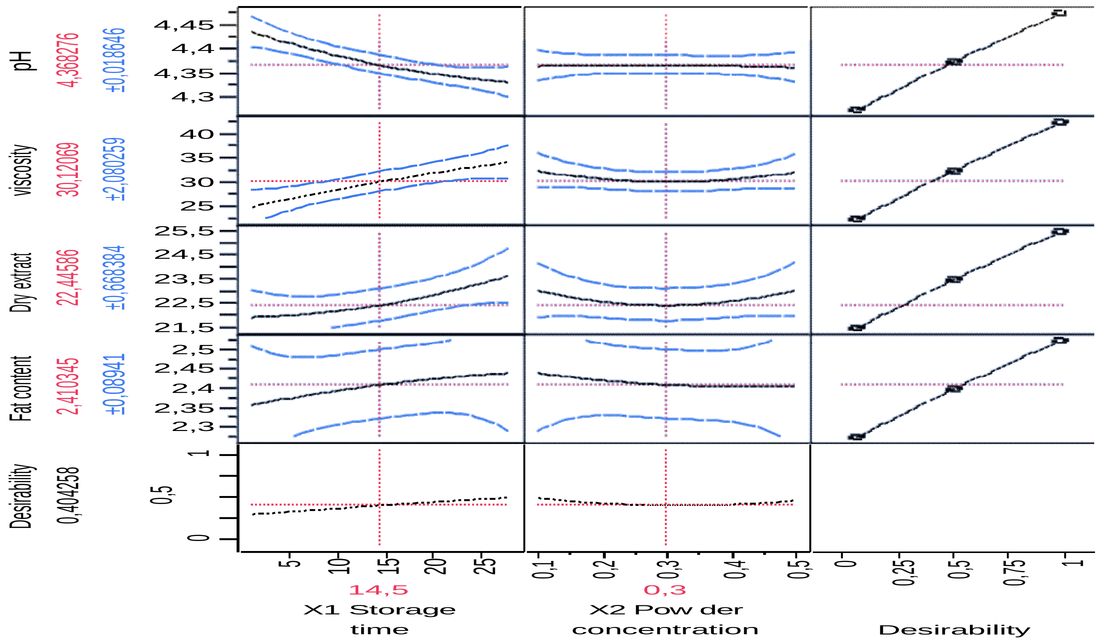


Figure 11: Graphical interpretation of results by JMP: General Effect of Factors

According to the observations made during the study of response surfaces **(Fig. 12)** on the enrichment of yoghurt in powder of eggplant peels dried in the oven and microwave as well as in powder of bean pods dried in the oven and microwave.Thus, the optimum of the concentration of powder and storage time is at the maximum of these two criteria, or 0.3 for the concentration of powder and 14 days and a half of storage. Under these conditions, the experimental value of pH is 4.36 ± 0,018646 , that of viscosity is 30, 12 ± 2,080252 .

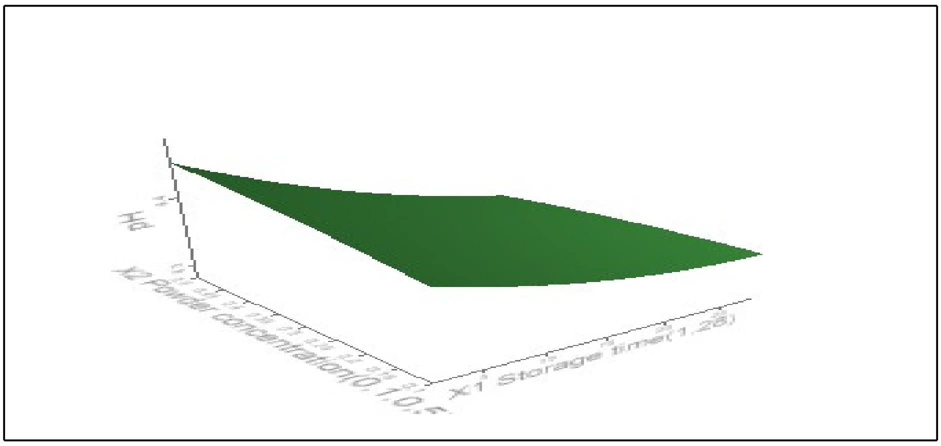


Figure 12: Response surface curves of the effects of storage time (X_1) and dried eggplant powder concentration at 80˚C (X_2) on pH .

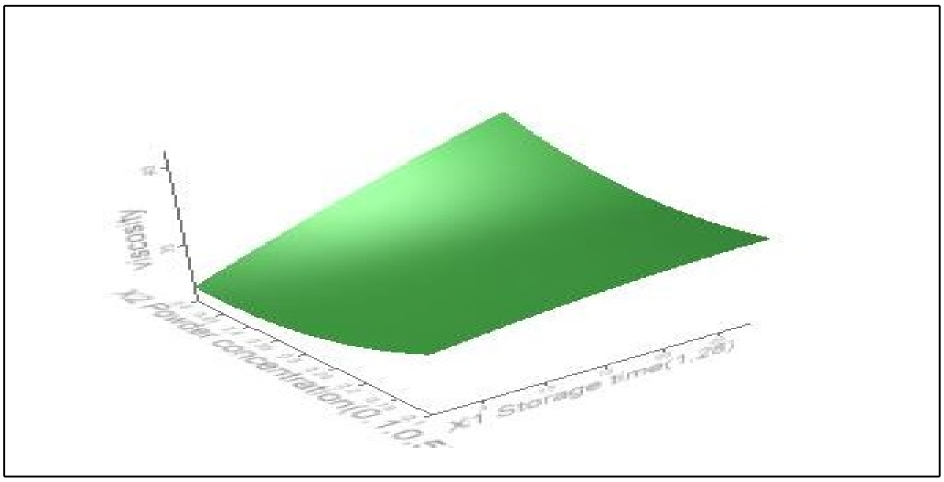


Figure 13: Response surface curves of the effects of storage time (X_1) and dried eggplant powder concentration at 80˚C (X_2) on viscosity.

- The duration of storage being a negative parameter as already found in the equation of the model, so really the concentration of eggplants dried by microwave does not influence positively, on the pH of yogurt.

$$\mathbf{Y_1 = 4{,}36 - 0{,}05\ X_1}$$

- Concerning the viscosity there is a very great capacity of conservation of yoghurt enriched by eggplants dried by oven, the viscosity has a positive influence on the duration of storage the higher the viscosity, the longer the storage time.If the concentration is very high, or even stable, the storage capacity is not better.

$$\mathbf{Y_2 = 30\ ,12 + 4{,}63\ X_1 + 2{,}85\ X_1\ X_2}$$

b -Yogurt enriched with eggplant peels dried by microwave at 100 W

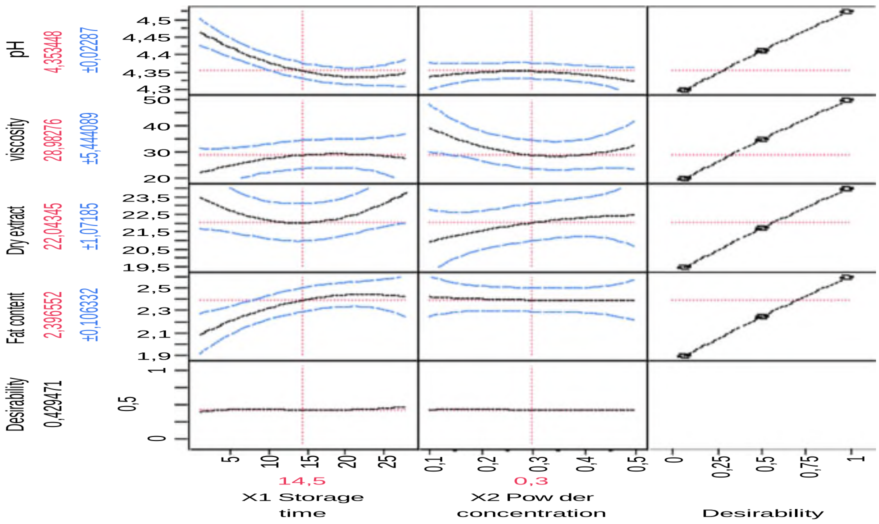


Figure 14: Graphical interpretation of results by JMP: General Effect of Factors

The optimum of the concentration of powder and storage time is at the maximum of these two criteria, or 0.3 for the concentration of powder and 14 days and a half of storage. Under these conditions, the experimental value of pH is 4.35 ± 0, 02287.

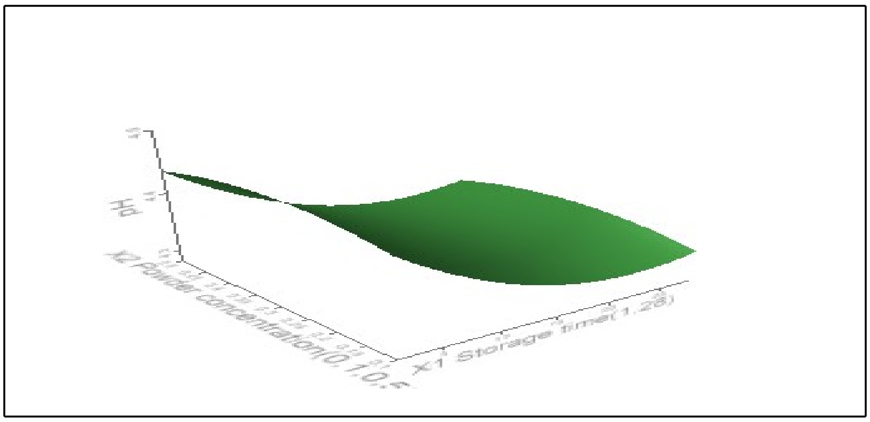


Figure 15: Response surface curves of the effects of storage time (X_1) and dried eggplant powder concentration at 100 W (X_2) on pH.

- In the case of eggplants dried by microwave, only the pH which is a parameter which influences the conservation and the concentration of the eggplant powder.

- The concentration of powder is very high and almost stable throughout the process, it has no influence, but between the pH and the storage time there is a negative effect.

There is a quadratic linear effect as already mentioned in the equation of the model which is a negative effect, so there is a negative influence on the ph of the yogurt.

$$Y_1 = 4.35 - 0{,}058\ X1 + 0{,}052\ X1^2$$

c/Yogurt enriched with bean pods dried by microwave at 100 W

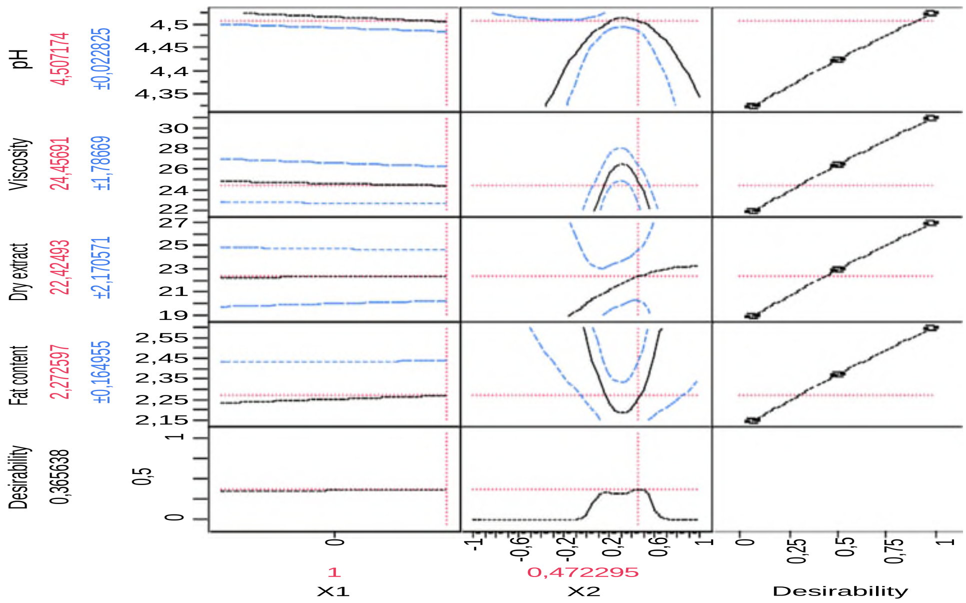


Figure 16: Graphical interpretation of results by JMP: General Effect of Factors

The optimum of the concentration of powder and storage time is at the maximum of these two criteria, or 0.3 for the concentration of powder and 14 days and a half of storage. Under these conditions, the experimental value of pH is 4.50 ± 0,022825, that of viscosity is 25, 45 ± 1,78669.

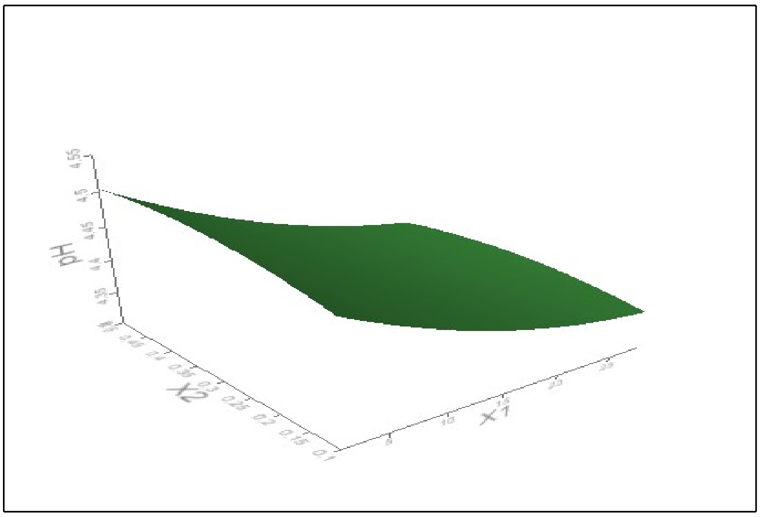


Figure 17: Response surface curves of the effects of storage time (X_1) and dried bean pods concentration at 100 W (X_2) on pH.

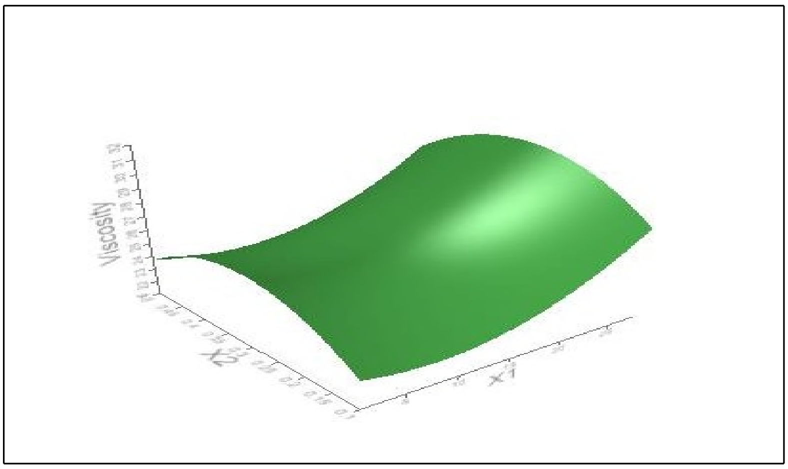


Figure 18: Response surface curves of the effects of storage time (X_1) and powder concentration of dried bean pods at 100 W (X_2) on viscosity.

- The more the concentration of the beans dried by microwave is not very high, the more I don't have to store the yogurt for a long time it is enough to have a storage condition of about 10 days or even 5 days to have the best storage conditions for the yogurt conservation a small concentration of beans dried in the microwave is enough to have a good ph at the same time a small storage time of the yogurt.

$$\mathbf{Y_1 = 4,47 - 0,0085\, X_1 + 0,00013\, X_1^2}$$

- The smaller the viscosity, the higher the X_1 (storage time) and the more the X_2 (powder concentration) must be intermediate, so it is enough to have an average concentration of beans dried by microwave to have a good capacity to store the yogurt.

$$Y_2 = 19,53 + 46,08 X_2 - 74,56 X_2^2$$

III-4 Sensory evaluation

12 samples of yoghurt A(A_1 ,A_2 ,A_3),B(B_1 ,B_2, B_3),C(C_1 ,C_2 ,C_3),D(D_1 ,D_2 ,D_3) at 80 °C, 60 °C and 100 W respectively, were sensorially evaluated and the scores were recorded below.

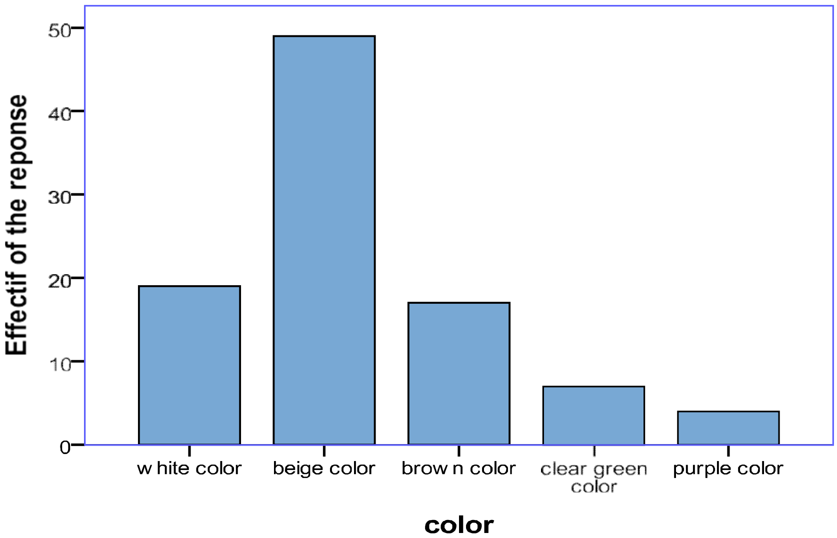


Figure 19: The color variation represented by a diagram

This diagram informs us about the redundancy of the answers to the propositions given to the 08 experts, thus concerning the variable color and on the various samples, we note that the proposition 2 the **beige color**, is the one which dominates the most, hence the rate of 51%, against the proposition 5 **(green color)** which is the least present with a rate of 4.2%.

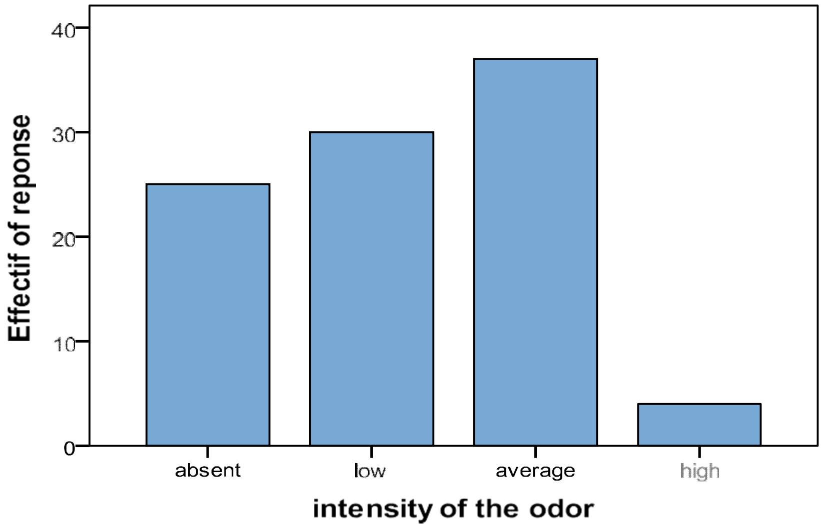


Figure 20: Diagram representing the odor intensity variable

This diagram informs us on the redundancy of the answers to the propositions given to the 08 experts, thus concerning the variable intensity of the odor on the various samples, we note that the proposition 3, namely the **average intensity**, is the one which dominates the most, hence the rate of 38.5% against the proposition 4 **(strong intensity)** which is the least present with a rate of 4.2%.

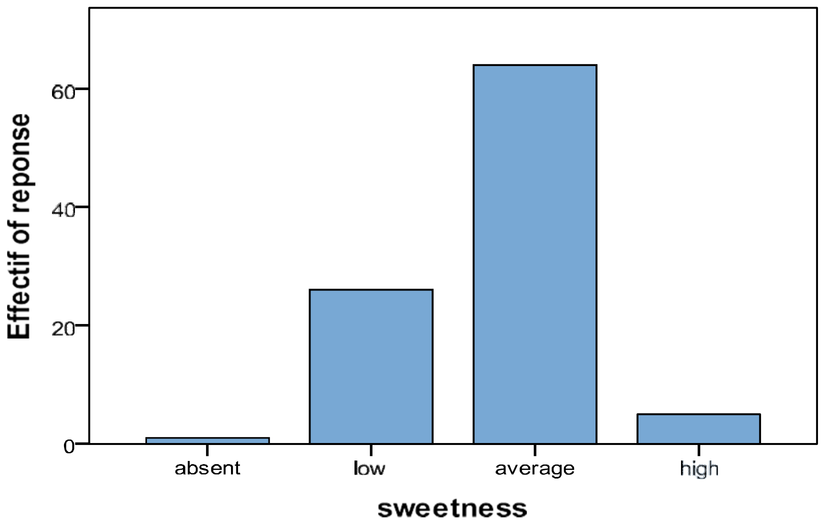


Figure 21: The sweetness variable represented by a diagram

The data of this diagram informs us about the redundancy of the answers to the propositions given to the 08 experts, thus concerning the variable sweetness on the various samples, we note that the proposition 3, **the low quantity**, is the one which dominates the most. We can see that proposition 3, **the low quantit**y, is the most dominant, with a rate of 66.7%, compared to proposition 1 (**absence of sweetness)** which is the least present with a rate of 1%.

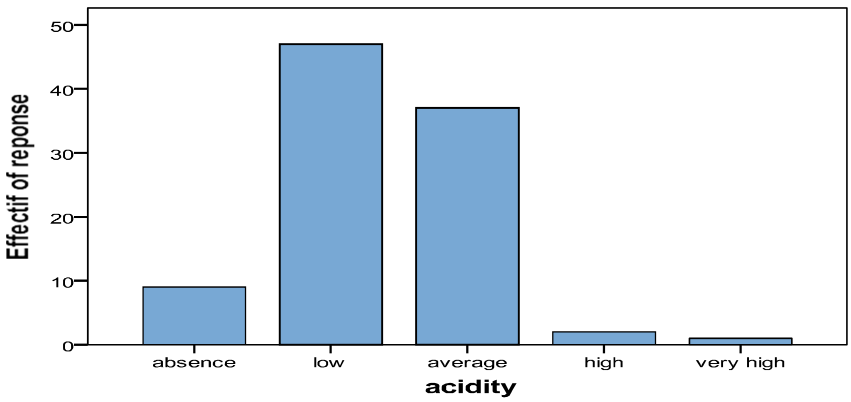


Figure 22: Diagram representing the acidity variable

The data of this diagram give us information on the redundancy of the answers to the propositions given to the 08 experts, Thus, concerning the variable acidity on the various samples, we note that proposal 2, **low acidity**, is the most dominant, hence the rate of 49.0%, in second place with 38.5% comes proposal 3, which is **an average acidity**, against proposal 5 **(very high acidity)** which is the least present with a rate of 1%.

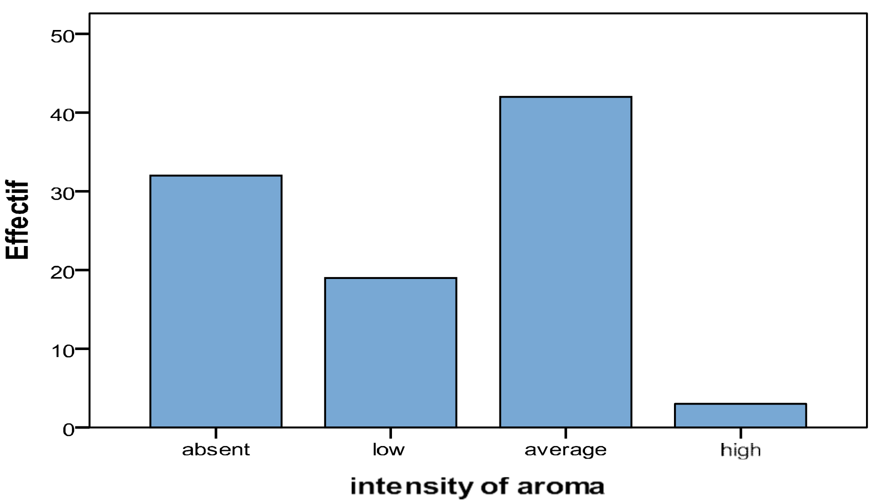


Figure 23: The aroma intensity variable represented by a diagram

This diagram informs us about the redundancy of the answers to the propositions given to the 08 experts, thus concerning the variable intensity of the aroma on the various samples, we notice that the proposition 3, namely the average intensity, is the one which dominates the most, hence the rate of 43.8%, against the proposition 4 **(strong intensity)** which is the least present with a rate of 3.1%.

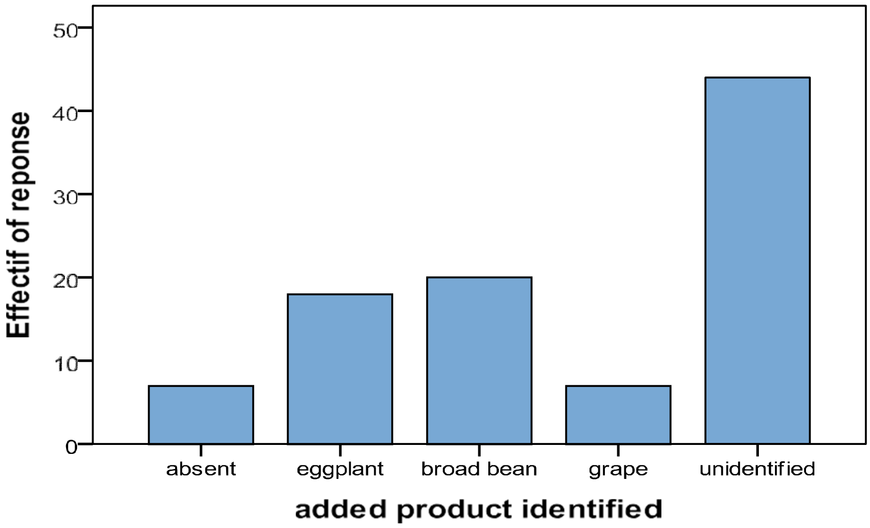


Figure 24: Diagram representing the product added indentified variable

The data of this diagram informs us about the redundancy of the answers to the propositions given to the 08 experts, thus concerning the variable added identified product on the various samples, we notice that the proposition 5 to know **not identified** is the one which dominates the most where the rate of 40.6%, in second position 27.1 to judge that the samples were rather pleasant, against the proposition 4 (**rather unpleasant**) which is less present with a rate of 3.1%. Rate of 45.8%, in second position 20.8% have distinguished the product added to know **the beans.**18.8 % have, as for them identified **the eggplant** as well as added product.

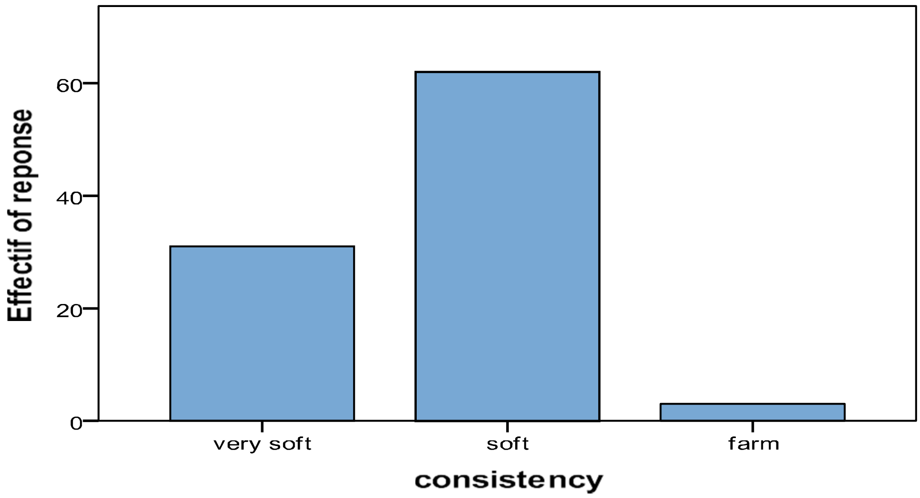


Figure 25: The consistensy variable represented by a diagram

This diagram informs us about the redundancy of the answers to the propositions given to the 08 experts, thus concerning the variable consistency of the products on the various samples, we note that the proposition 3, namely the **soft consistency**, is the one which dominates the most, hence the rate of 64.6%, against the proposition 4 **(firm consistency**) which is the least present with a rate of 3.1%.

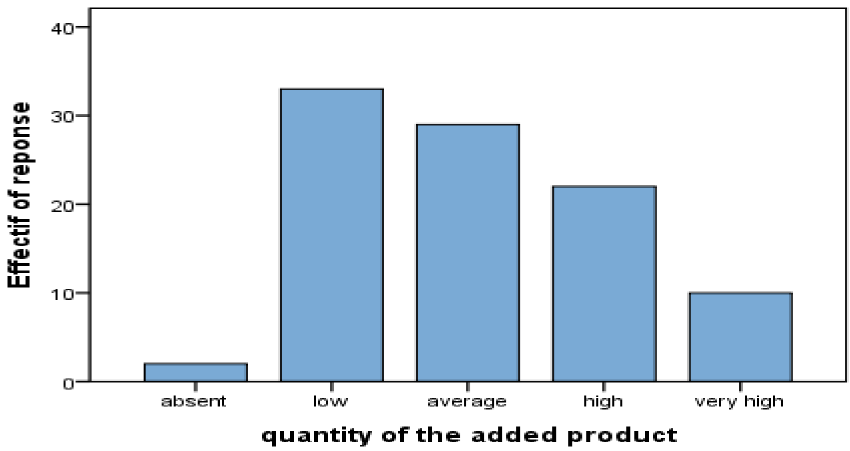


Figure 26: Diagram representing the quantity of added product variable

This diagram informs us about the redundancy of the answers to the propositions given to the 08 experts, thus concerning the variable quantity of the added product on the various samples, we note that proposition 2, namely the low quantity, is the one that dominates the most, hence the rate of 34.4%, against proposition 1 (absence of added product) which is the least present with a rate of 2.1%.

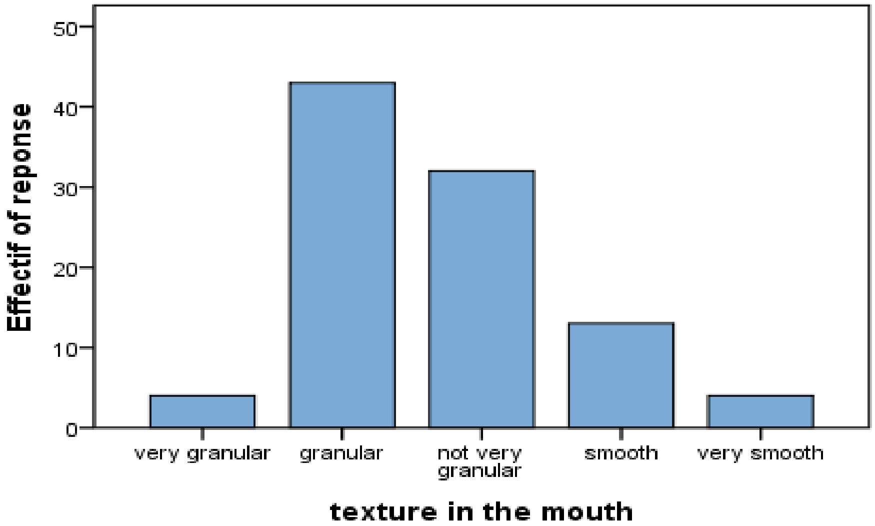


Figure 27: The mouth texture variable represented by a diagram

The diagram data informs us on the redundancy of the answers to the propositions given to the 08 experts, thus concerning the variable texture in mouth on the various samples, we notice that the proposition 2 to Thus, concerning the variable texture in the mouth on the different samples, we can see that the proposal 2, **namely the granular texture** is the one that dominates the most, hence the rate of 44.8%, against the proposals 1 and 5 **(very granular and very smooth)** which are the least present with a rate of 4.2%.

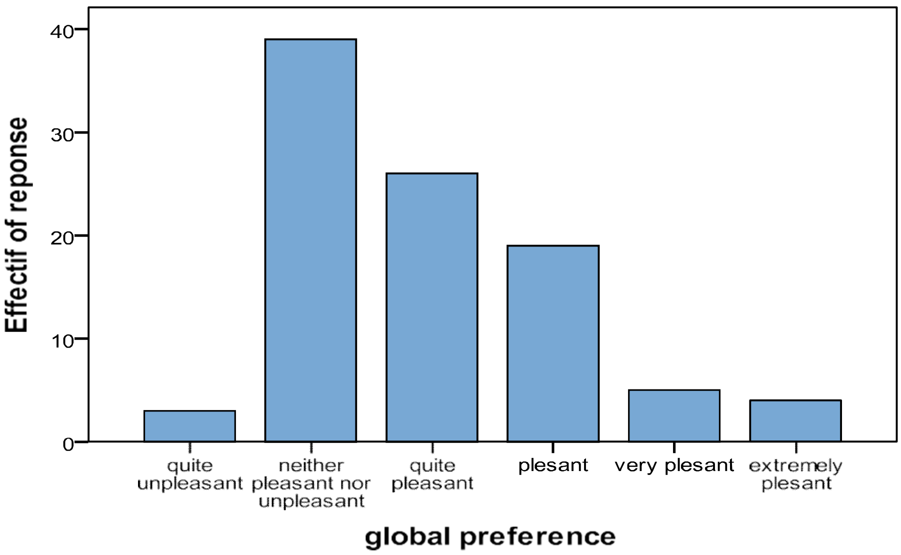


Figure 28: Diagram representing the global preference variable

The data of this diagram informs us on the redundancy of the answers to the propositions given to the 08 experts, thus concerning the global variable preference of the product on the various samples, we notice that the proposition 5 to **know neither pleasant nor unpleasant** is the one which dominates the most where the rate is 40.6%.

In second position, 27.1% judged that the samples were **quite pleasant**, against proposal 4 **(quite unpleasant)** which is the least present with a rate of 3.1%.

Conclusion

Conclusion:

In view of the nutritional value and the valorization of eggplant peels, bean and pea pods, the present study is focused on the enrichment of the stirred yoghurt by the addition of powders of these agricultural wastes, for their high content of bioactive substances and fibre.

The present study focused on the elaboration of yoghurts based on by-products, namely eggplant's peel, bean pods and pea pods, by two methods; microwave and conventional oven drying.

We have previously decontaminated the powders in order to eliminate any pathogenic element or element that could alter the quality of our product, by pasteurizing them in a water bath at a temperature of 95°C for 5 minutes, which was the best time/temperature combination to obtain a hygienic quality of the yogurt.

We then proceeded to the enrichment of the stirred yoghurt in bioactive substances and fibers, following an experimental plan established by the JMP software, and finally the physico-chemical analysis of the latter.

According to the results obtained following the different manipulations proposed by the software, yogurt with the best physicochemical and sensory properties was obtained by adding 0.3% of vegetable's powders and storage time of 14 days and a half in the refrigerated storage. The optimal composition of the yogurt formulation was obtained based on each desired response.

Regarding the sensory analysis, the results are quite satisfactory because the yoghurts were appreciated by the tasting panel, they had a preference for the yoghurt enriched with dried eggplant (0.3% and 0.5%), as well as the yoghurt enriched with dried beans (0.3%and 0.5%)

The results of the physico-chemical (pH, viscosity, fat content and total dry extract) and microbiological analyses carried out on the stirred yoghurt in the **'Danone Djurdjura laboratories'** are perfectly in conformity with the established standards.

.

In perspective, it seems very interesting for the yoghurt industries to use vegetable peels as a natural food ingredient, to improve the quality of yoghurts, we encourage that there would be other deeper researches, which will accentuate the present work and complete it. We therefore propose:

- Evaluation of the antioxidant activity during the storage period ;
- Dosing of total polyphenols and fiber;
- The study of other parameters using the experimental design software, such as: syneresis, lactic flora and antioxidant activity ;
- To carry out an economic study on the short production run at the industrial level .

Due to the abundance of phenolic compounds in the vegetables wastes used, and their low cost, the dosage of total polyphenols would have in dicated the antioxidant activity of the enriched yoghurt, and would have allowed us to really see the health contribution of the latter .

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-A-

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Appendix

Appendix 01: Questionnaire of Sensory Analysis of stirred yogurt

Age : **Date :** **h : ......**

Sexe : Féminin ☐ **masculin** ☐

Dans le cadre d'une analyse sensorielle d'un yaourt brassé, 12 Échantillons codés A (A_1, A_2 ,A_3) ,B (B_1 ,B_2,B_3) , C(C_1 ,C_2 ,C_3) et D (D_1, D_2 ,D_3) vous sont présentés. Il vous est demandé d'évaluer différentes caractéristiques et attribuer une appréciation selon des 0 codes donnés de 1 à 5 :

1. **La Couleur**

1. Blanc
2. Beige
3. marron
4. Vert clair
5. Violet

Echantillon A		Echantillon B		Echantillon C		Echantillon D	
A_1		B_1		C_1		D_1	
A_2		B_2		C_2		D_2	
A3		B_3		C_3		D_3	

2. **Intensité de l'odeur (sans gouter)**

1-Absente
2-Faible
3-Moyenne
4-Forte
5-Très forte

Echantillon A		Echantillon B		Echantillon C		Echantillon D	
A_1		B_1		C_1		D_1	
A_2		B_2		C_2		D_2	
A3		B_3		C_3		D_3	

3. **Sucrosité**

1-Absente
2-Faible
3-Moyenne
4-Forte
5-Très forte

Echantillon A		Echantillon B		Echantillon C		Echantillon D	
A_1		B_1		C_1		D_1	
A_2		B_2		C_2		D_2	
A3		B_3		C_3		D_3	

4. Acidité

1-Absente
2-Faible
3-Moyenne
4-Forte
5-Très forte

Echantillon A		**Echantillon B**		**Echantillon C**		**Echantillon D**	
A_1		**B_1**		**C_1**		**D_1**	
A_2		**B_2**		**C_2**		**D_2**	
A3		**B_3**		**C_3**		**D_3**	

5. Intensité de l'Arome (après avoir gouté le yaourt)

1-Absent
2-Faible
3-Moyenne
4-Forte
5-Très forte

Echantillon A		**Echantillon B**		**Echantillon C**		**Echantillon D**	
A_1		**B_1**		**C_1**		**D_1**	
A_2		**B_2**		**C_2**		**D_2**	
A3		**B_3**		**C_3**		**D_3**	

6. Produit ajouté identifié:

1. Absent
2. aubergine
3. fève
4. raisins
5. Non identifié

Echantillon A		**Echantillon B**		**Echantillon C**		**Echantillon D**	
A_1		**B_1**		**C_1**		**D_1**	
A_2		**B_2**		**C_2**		**D_2**	
A3		**B_3**		**C_3**		**D_3**	

7. Consistance

1-liquide
2-très molle
3-molle

4-ferme
5-très ferme

Echantillon A		**Echantillon B**		**Echantillon C**		**Echantillon D**	
A_1		**B_1**		**C_1**		**D_1**	
A_2		**B_2**		**C_2**		**D_2**	
A3		**B_3**		**C_3**		**D_3**	

8. Quantité du produit ajouté :

1-Absent
2-Faible

3-Moyenne
4-Forte
5-Très forte

Echantillon A		**Echantillon B**		**Echantillon C**		**Echantillon D**	
A_1		**B_1**		**C_1**		**D_1**	
A_2		**B_2**		**C_2**		**D_2**	
A3		**B_3**		**C_3**		**D_3**	

9. Texture en bouche

1. Très granuleuse
2. Granuleuse
3. Peu granuleuse
4. Lisse
5. Très lisse

Echantillon A		Echantillon B		Echantillon C		Echantillon D	
A_1		**B_1**		**C_1**		**D_1**	
A_2		**B_2**		**C_2**		**D_2**	
A3		**B_3**		**C_3**		**D_3**	

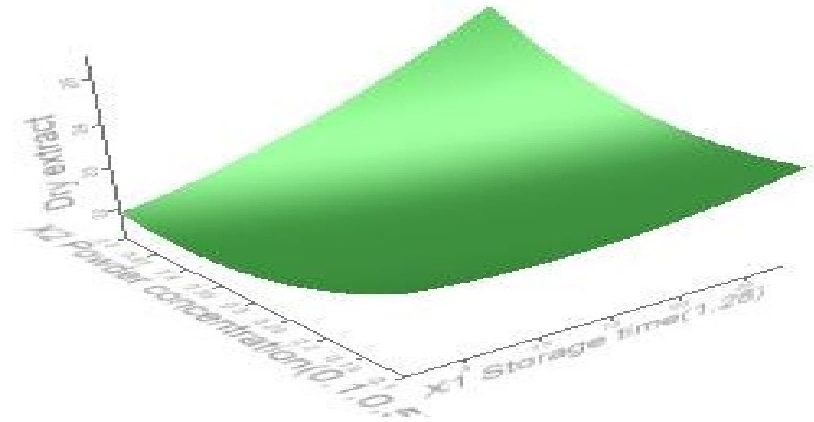
10. **Préférence globale :** Attribuer une note de 1 à 9 pour chaque échantillon selon votre préférence sachant que 1 correspond au moins préféré et le 9 au plus préféré comme présenté dans l'échelle ci-dessous.

1-Extrêmement désagréable
2-Très désagréable
3- désagréable
4-Assez désagréable
5-Ni agréable ni désagréable
6-Assez agréable
7- Agréable
8-Très agréable
9- Extrêmement agréable

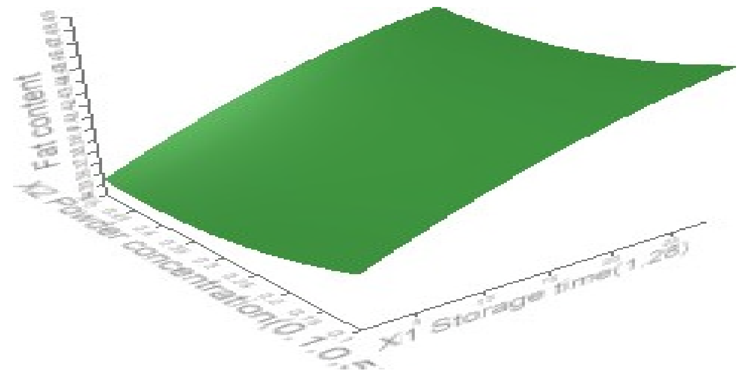
Echantillon A		Echantillon B		Echantillon C		Echantillon D	
A_1		**B_1**		**C_1**		**D_1**	
A_2		**B_2**		**C_2**		**D_2**	
A3		**B_3**		**C_3**		**D_3**	

Merci pour votre participation

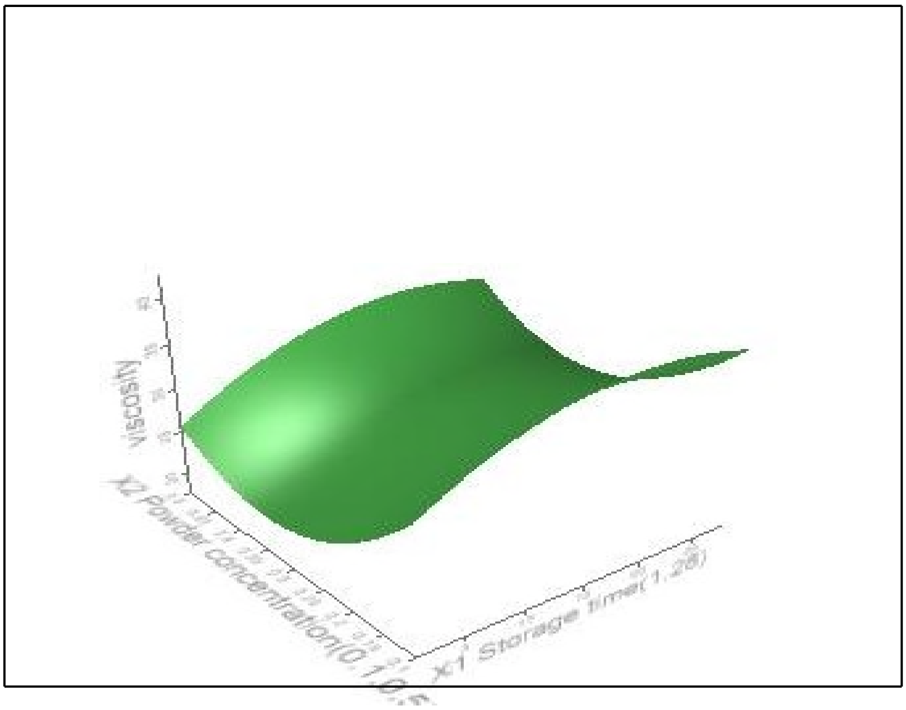
Appendix 02: Response surface curves of the effects of storage time (X_1) and powder concentration of dried eggplant peel at 80˚C (X_2) on dry extract .



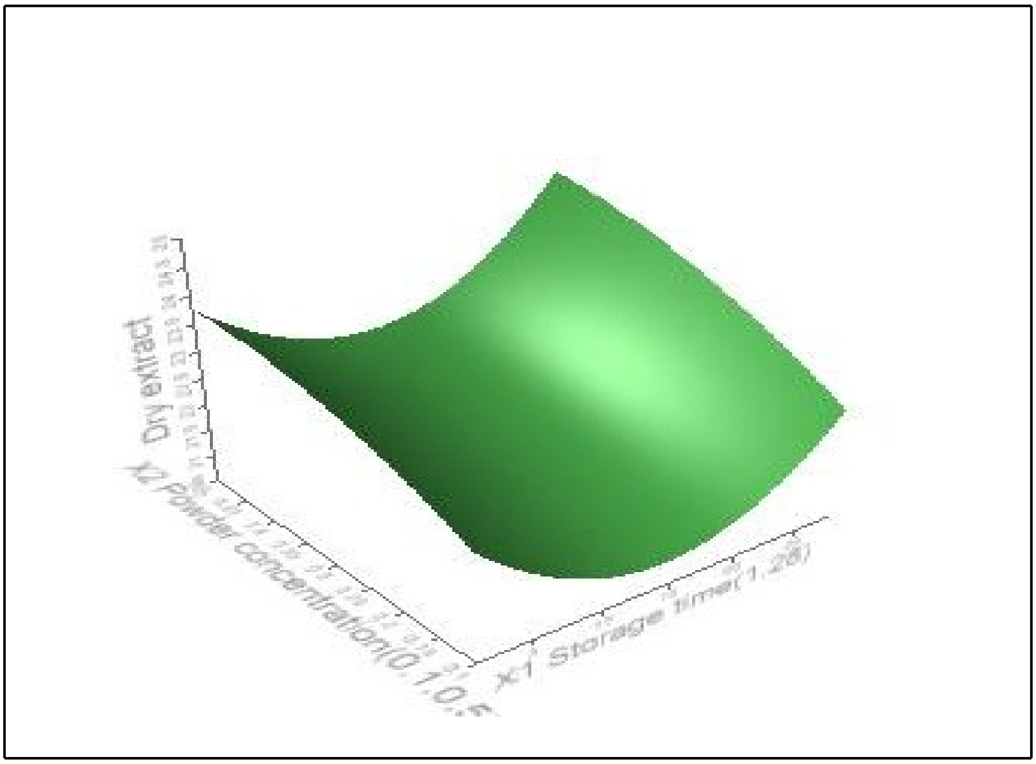
Appendix 03: Response surface curves of the effects of storage time (X_1) and powder concentration of dried eggplant peels at 80 ° C (X_2) on fat content.



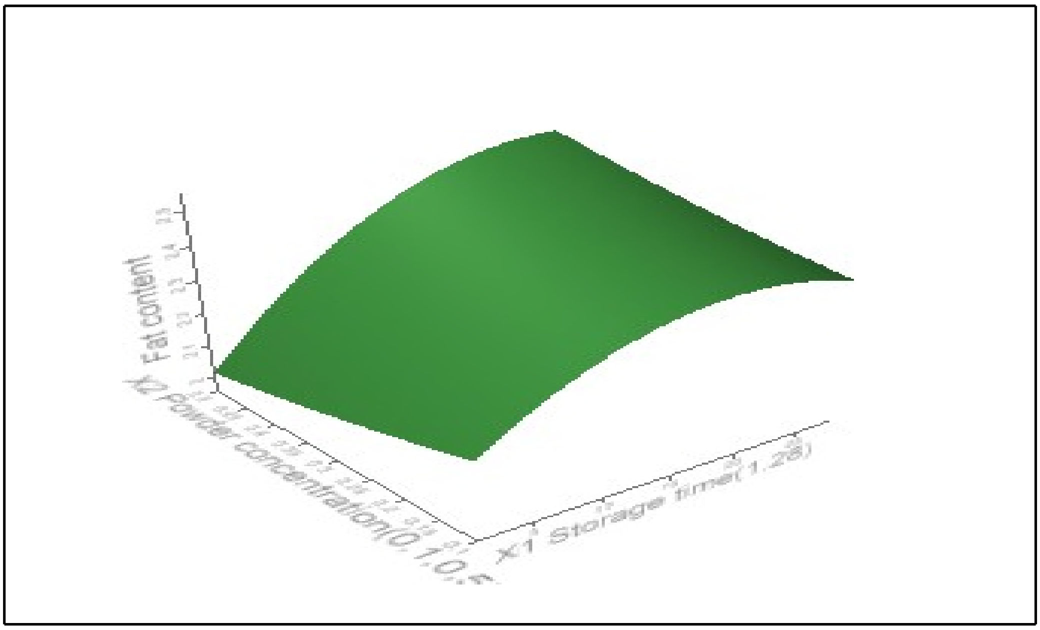
Appendix 04: Response surface curves of the effects of storage time (X_1) and powder concentration of dried eggplant peel at 100 W (X_2) on viscosity .



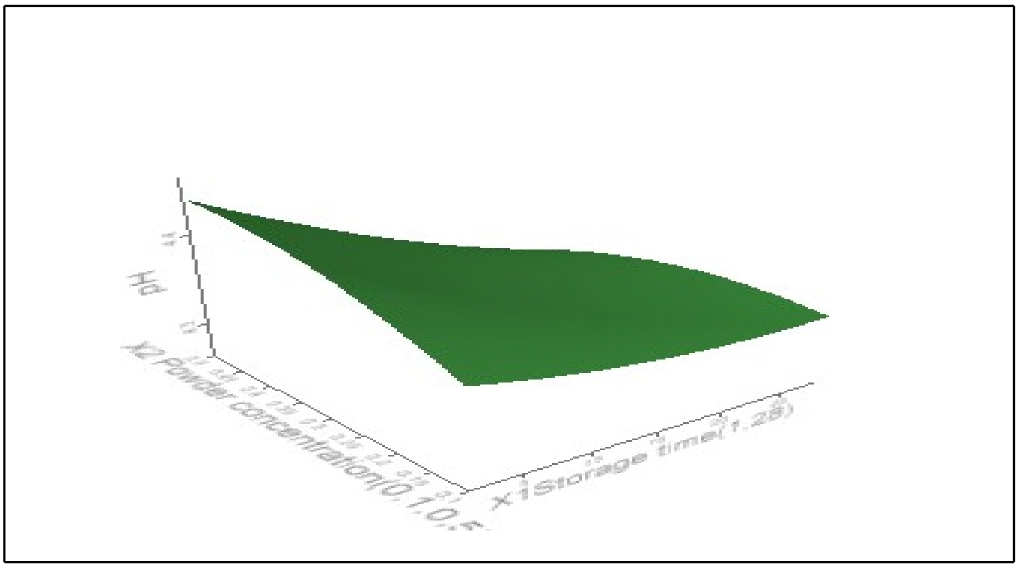
Appendix 05: Response surface curves of the effects of storage time (X_1) and powder concentration of dried eggplant peels at 100 W (X_2) on dry extract.



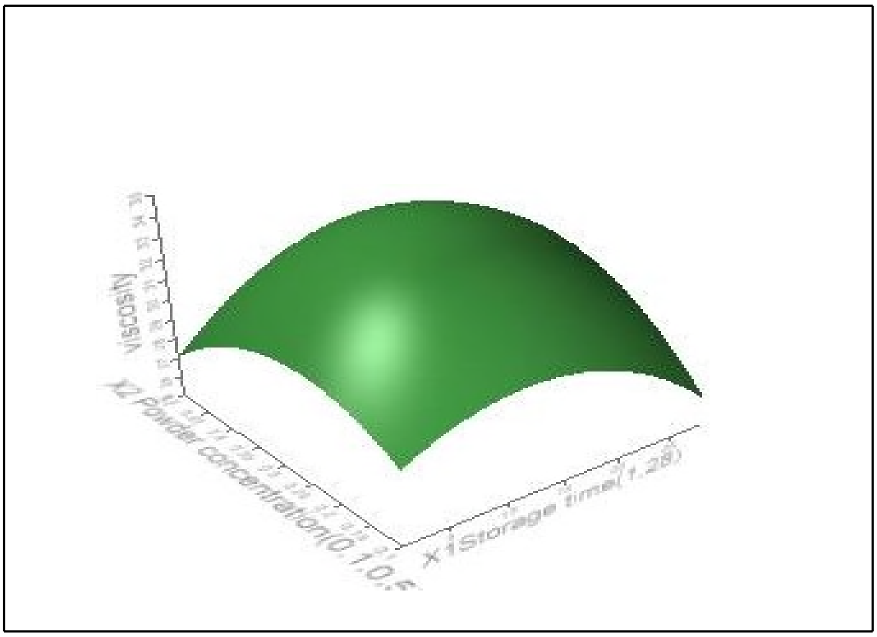
Appendix 06: Response surface curves of the effects of storage time (X_1) and powder concentration of dried eggplant peels at 100 W (X_2) on fat content



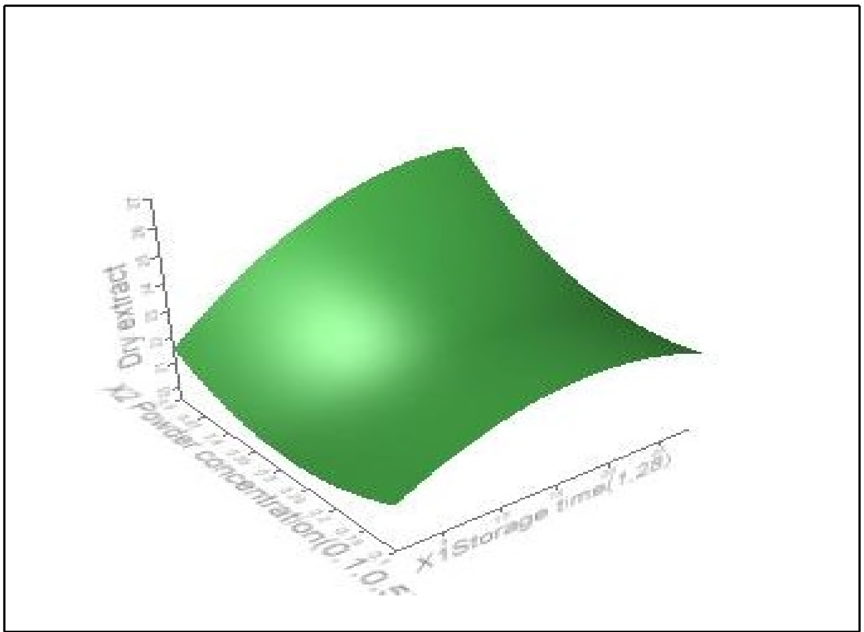
Appendix 07: Response surface curves of the effects of storage time (X_1) and powder concentration of dried bean pods at 60 °C (X_2) on pH.



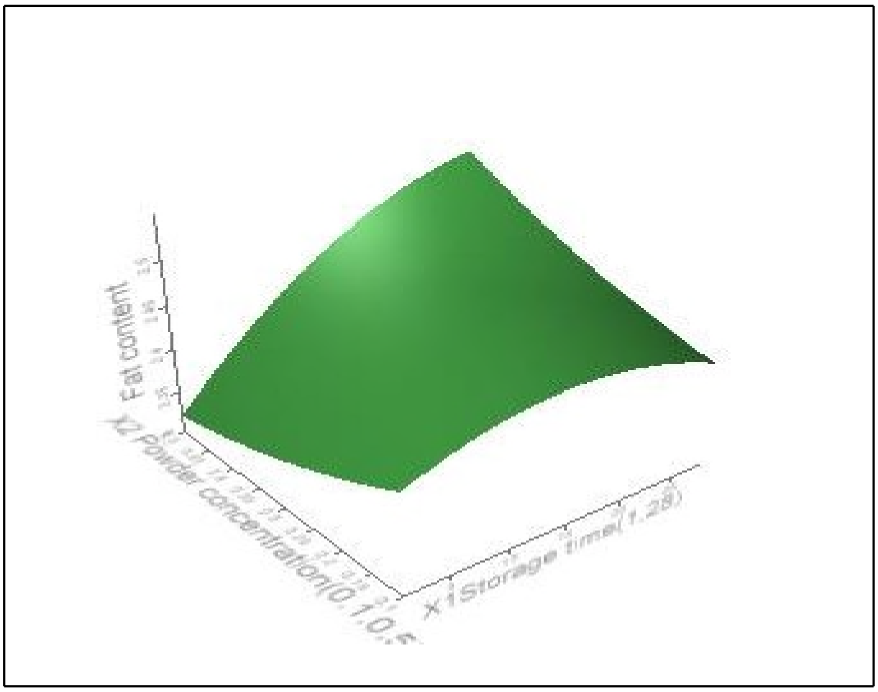
Appendix 08: Response surface curves of the effects of storage time (X_1) and powder concentration of dried bean pods at 60 °C (X_2) on viscosity.



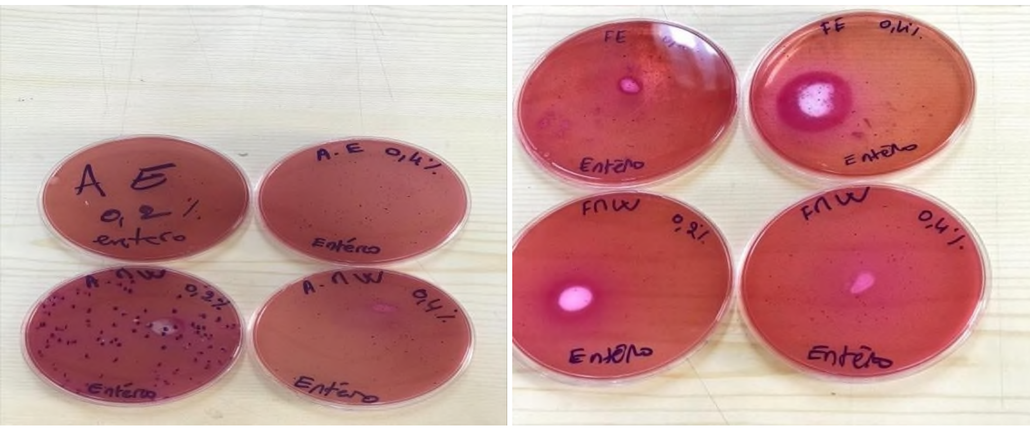
Appendix 09: Response surface curves of the effects of storage time (X_1) and powder concentration of dried bean pods at 60 °C (X_2) on dry extract.

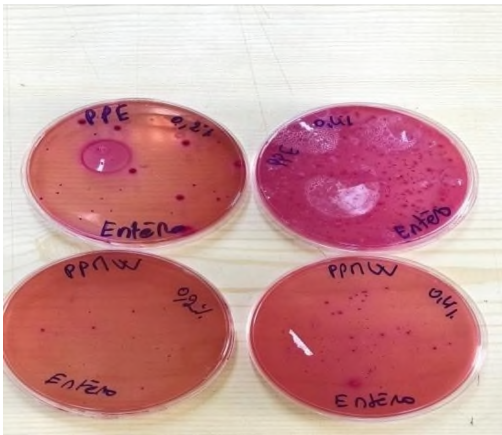


Appendix 10: Response surface curves of the effects of storage time (X_1) and powder concentration of dried bean pods at 60 °C (X_2) on fat content.



Appendix 11: prensence of enterobacteria in pea powders before any heat tretement





Appendix 12:¨Presence of yeast and mold in pean powder before any heat tretement

Appendix 13: presence of enterobacteria in pean powder dried at 40°C and 100 W

Appendix 14 : Color

	Workforce	Percentage	Validated percentage	Cumulative percentage
1	19	19,8	19,8	19,8
2	49	51,0	51,0	70,8
3	17	17,7	17,7	88,5
4	7	7,3	7,3	95,8
5	4	4,2	4,2	100,0
Total	96	100,0	100,0	

Appendix 15 : Odor intensity

	Workforce	Percentage	Validated percentage	Cumulative percentage
1	25	26,0	26,0	26,0
2	30	31,3	31,3	57,3
3	37	38,5	38,5	95,8
4	4	4,2	4,2	100,0
Total	96	100,0	100,0	

Appendix 16 : Sweetness

	Workforce	Percentage	Validated percentage	Cumulative percentage
1	1	1,0	1,0	1,0
2	26	27,1	27,1	28,1
3	64	66,7	66,7	94,8
4	5	5,2	5,2	100,0
Total	96	100,0	100,0	

Appendix 17 : Acidity

	Workforce	Percentage	Validated percentage	Cumulative percentage
1	9	9,4	9,4	9,4
2	47	49,0	49,0	58,3
3	37	38,5	38,5	96,9
4	2	2,1	2,1	99,0
5	1	1,0	1,0	100,0
Total	96	100,0	100,0	

Appendix 18: Aroma intensity

	Workforce	Percentage	Validated percentage	Cumulative percentage
1	32	33,3	33,3	33,3
2	19	19,8	19,8	53,1
3	42	43,8	43,8	96,9
4	3	3,1	3,1	100,0
Total	96	100,0	100,0	

Appendix 19: Product added identified

	Workforce	Percentage	Valitdated percentage	Cumulative percentage
1	7	7,3	7,3	7,3
2	18	18,8	18,8	26,0
3	20	20,8	20,8	46,9
4	7	7,3	7,3	54,2
5	44	45,8	45,8	100,0
Total	96	100,0	100,0	

Appendix 20 : Consistency

	Workforce	Percentage	Validated Percentage	Cumulative percentage
2	31	32,3	32,3	32,3
3	62	64,6	64,6	96,9
4	3	3,1	3,1	100,0
Total	96	100,0	100,0	

Appendix 21: Quantity of added product

	Workforce	Percentage	Validated percentage	Cumulative percentage
1	2	2,1	2,1	2,1
2	33	34,4	34,4	36,5
3	29	30,2	30,2	66,7
4	22	22,9	22,9	89,6
5	10	10,4	10,4	100,0
Total	96	100,0	100,0	

Appendix 22: Mouth texture

	Workforce	Percentage	Validated percentage	Cumulative percentage
1	4	4,2	4,2	4,2
2	43	44,8	44,8	49,0
3	32	33,3	33,3	82,3
4	13	13,5	13,5	95,8
5	4	4,2	4,2	100,0
Total	96	100,0	100,0	

Appendix 23 : Global preference

	Workforce	Percentage	Validated percentage	Cumulative percentage
4	3	3,1	3,1	3,1
5	39	40,6	40,6	43,8
6	26	27,1	27,1	70,8
7	19	19,8	19,8	90,6
8	5	5,2	5,2	95,8
9	4	4,2	4,2	100,0
Total	96	100,0	100,0	

Abstract:

The objective of this work is first of all to valorize the waste of some vegetables; eggplants, broad beans and peas.

And to use them after drying by two methods; in the oven and in the microwave then reduced in powder to enrich a natural stirred yoghurt in order to improve its nutritional and sensory value and to make a functional food by bringing bioactive substances.

The powders were pasteurized at 95°C for 5 minutes in a water bath to be decontaminated.

The experiments were performed using an experimental design with two independent variables: the concentration of the powder (0.1%, 0.3% and 0.5%) and storage time (1 - 28 days). The attributes of the yogurt, physicochemical, textural and sensory attributes were determined and optimized.

The results obtained after enrichment according to the experimental design indicate that the best percentage of vegetable powder is 0.3% with an optimal storage time of 14.5 days. The concentration of the powders and the storage time significantly affected the texture and sensory attributes of the yogurt.
Keywords: valorization, enrichment, drying, yoghurt; experimental design.

Résumé:

L'objectif de ce travail est tout d'abord de valoriser les déchets de certains légumes ; aubergines, fèves, petits pois.

Le séchage est réalisé par deux méthodes ; à l'étuve et au micro-onde puis réduits en poudre pour enrichir un yaourt nature brassé afin d'améliorer sa valeur nutritionnelle et sensorielle et d'en faire un aliment fonctionnel en apportant des substances bioactives.

Les poudres ont été pasteurisées à 95°C pendant 5 minutes au bain-marie pour être décontaminées.

Les expériences ont été réalisées en utilisant un plan d'expérience avec deux variables indépendantes : la concentration de la poudre (0,1%, 0,3% et 0,5%) et le temps de stockage (1 - 28 jours). Les attributs du yaourt, physicochimiques, texturaux et sensoriels ont été déterminés et optimisés.

Les résultats obtenus après enrichissement selon le plan expérimental indiquent que le meilleur pourcentage de poudre végétale est de 0,3% avec un temps de stockage optimal de 14,5 jours. La concentration des poudres et le temps de stockage ont affecté de manière significative la texture et les attributs sensoriels du yaourt.
Mots clés : valorisation, enrichissement, séchage, yaourt, plan d'expérience.