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VALORIZATION OF FIGS (*Ficus carica* L.) FOR AN EXTENDED SHELF LIFE

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Masters in Food Technology

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Declaration of Authorship of work

I declare to be the author of this work, which is original and unpublished. Consulted authors and papers are properly cited in the text and are included in the included reference list.

(JANET OMOLAYO AMANZE)

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ABSTRACT

Fig fruit (*Ficus carica L.*) is an important food product of the Middle East, Mediterranean region and well appreciated by most elderly groups in Portugal, as the symbol of longevity.
This study aims to develop two ways of adding value to highly perishable figs with no commercial acceptability, by accelerating fig drying with the use of a solar oven and producing a fig gum jelly which can be made available all year round with longer shelf life.
A higher drying rate was observed with the blanched product in the solar oven dryer than in the direct solar drying.

The optimization of the gum composition was carried out by using Response Surface Methodology (RSM) along with a mixture design, while the independent variables are: % *fig paste*, x_1; *% k-Carrageenan*, x_2 and % *honey*, x_3. The sensory panel composed of 10 elements of both sexes evaluated nine (9) responses Y_1 - Brilliance, Y_2 - Transparency, Y_3 - Aroma, Y_4 - Texture A, Y_5 -Texture C, Y_6 - Sweetness A, Y_7 - Sweetness B, Y_8 - Mouthfeel and Y_9 - Overall Opinion, originating nine polynomial models. Numerical optimization achieved the best fig gum jelly composition with: 55 % fig paste, 15 % k-carrageenan and 30 % honey.

The validation of optimum product was achieved by the same panel and the panelists preference of the optimum formulation for all responses with 0.3 desirability was stunning.

The shelf life of twenty-one days was achieved for unrefrigerated products while the refrigerated ones twenty-five days through microbiological analysis.
The physicochemical analysis showed that the fig gum jelly contained a minimum amount of protein and minerals with low ash content. Also, the moisture and water activity were found to be lower in the fig gum jelly than in the fresh fig.

Keywords: Fig, Fig gum jelly, K-carrageenan, shelf life, quality

Resumo

O Figo (*Ficus carica L.*), é um importante produto alimentar do Médio Oriente, região mediterrânica e bem apreciado pela maioria dos idosos em Portugal, como símbolo da longevidade.

Este estudo visa desenvolver duas formas de acrescentar valor a figos que são muito perecíveis sem aceitabilidade comercial, acelerando a secagem dos mesmos através com a ajuda de um forno solar e produzindo uma goma gelificada de figo que pode ser disponibilizada durante todo o ano com prazo de validade mais longo.

Observou-se uma maior velocidade de secagem para o produto branqueado quando utilizado o forno solar em relação á secagem solar direta.

A otimização da composição das gomas gelificadas foi efetuada utilizando a Metodologia de Superfície de Resposta (RSM) e um design de mistura, tendo como variáveis independentes: % *pasta de figo*, x_1; *% k-carragenato*, x_2 e % *mel*, x_3. O painel sensorial, composto por 10 elementos de ambos os sexos, avaliou nove respostas Y_1 - Brilho, Y_2 - Transparência, Y_3 - Aroma, Y_4 - Textura A, Y_5 -Textura C, Y_6 - Doçura A, Y_7 - Doçura B, Y_8 – Sensação na Boca e Y_9 - Opinião Geral, originando nove modelos polinomiais. A otimização numérica alcançou a melhor composição de goma gelificada de figo com: 55 % pasta de figo, 15 % k-carragenato e 30 % de mel.

A validação do produto ótimo foi conseguida pelo mesmo painel e a preferência dos provadores pela formulação ótima para todas as respostas com 0,3 de desejabilidade, foi impressionante.

O prazo de validade de 21 dias foi alcançado para produtos não refrigerados, enquanto que para os refrigerados se obteve 25 dias através de análise microbiológica.

A análise físico-química mostrou que a goma gelificada de figo continha um baixo teor em proteínas, minerais e cinzas. Além disso, verificou-se que a humidade e a atividade da água são mais baixas na goma gelificada de figo do que no figo fresco.

Keywords: Figo, goma gelificada de figo, k-carragenato, vida de prateleira, qualidade

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Chapter 1- State of the art

Fig (*Ficus carica L.*) is one amongst the primary plants that was cultivated by humans. Almost all the parts of fig plant are used as food and for medicinal purposes. Although the precise origin of figs (*Ficus carica L.*) may not be known precisely, but quite 2000 years ago, the Greeks considered the fig to be "more precious than gold". It is a conventional fruit in western Asia and eastern part of the Mediterranean area including Israel, Turkey up to India (Bouzo *et al*., 2012). In the Middle East and the Mediterranean region, the fig is part of their diet since the ancient years and it is considered because of the sign longevity (Arvaniti *et al*., 2019). *Ficus carica* is a gymnosperm in the mulberry family. It is known as the common fig, a fruit grown commercially not only in its traditional lands but cultivated throughout the world. *Ficus carica* has the highest commercial importance from all the species of figs (Borola *et al*., 2014). It is one of the largest genera of Angiosperms and an evergreen tree of mulberry family moraceae with more than 800 species of epiphytes, trees and shrubs in tropical and subtropical regions all over the world (Mitrofanova *et al*., 2016).

Fruits of fig can be eaten raw, dried, canned, or in other preserved forms like in sweets and jam which can be eaten fresh or used in preparation of delicacies and cakes. As per USDA data, dried fig has the highest nutrient score as it is an important source of vitamins and minerals among dried fruits (Nikhat *et al*., 2020). Fig is rich in iron, protein, calories, and highest fiber content. It has the highest source of calcium higher than milk. Fig has nutritive index of 11, as against 6, 8, and 9 for date palm and apple (Gani *et al*., 2018).

The fig is considered as a climacteric fruit with a moderate ethylene production and respiration rate and its commercial quality depends, mainly, on the maturity stage at which the fruit is harvested (Villalobos *et al*., 2016).

Figs are highly perishable, and post-harvest handling and storage difficult, because the thin fruit skin can easily get ruptured, resulting to rapid loss of nutritional contents and increased permeability for microbial invasion (Irfan *et al*., 2013) allowing just an occasional low percentage of figs to be sold as fresh fruits keeping all their sensory and nutritional properties. To extend the shelf life, traditionally, figs are dried and consumed this way or in cookies or snack bars (Reyes- Avalos *et al*., 2016). *Ficus carica Linn* (moraceae) contains one of the most important genera of angiosperms with many species of trees, shrubs, hemi-epiphytes, and creepers within the tropics and subtropics worldwide (Shukranul *et al*.,2013)

Ficus carica L. is a vital member of the genus *Ficus*. It is ordinarily deciduous and commonly cited as fig and is native to South west Asia and the countries of Eastern Mediterranean. The fig is an important harvest in most places for its dry and fresh consumption. Its common edible part is the fruit, which is fleshy with hollow receptacle (Duenas *et al*.,2008).

After harvesting, a late crop is left on the trees because is not any longer of business interest to farmers even to be dried in the sun due to its small size and because the rain season is starting in mid-September. This crop could be valued by using a solar drying oven or if converted in a fig product with a taste, color and nutritional properties close to the fresh fruit but with a longer shelf life such as gums which was the basis of this master's thesis.

The objectives of this thesis is to develop a product that will be available for easy consumption from fig, optimize formulation of the product, validation of optimized product, produce fig jellies coated with chocolate and carob and study the shelf life and physicochemical characteristics of the fig jellies.

1.1 Fig Botanical Description

Ficus carica is usually 15-30 feet high, large deciduous tree or a large shrub with several branches from a trunk. The fig tree bark is grey, smooth, or dull white or hairy. The leave type is broad ovate or nearly orbicular that is rough above and pubescent below. It has unisexual flowers that are minute, closely crowded on the inner surface of large, hollow, externally pear-shaped receptacle. The male flowers are few, found on the lower part of the receptacle. The female flower is found on the upper part of the receptacle. The fig "fruit" is a composite formed of a hollow shell of receptacle tissue enclosing hundreds of individual pedicellate drupelets that develop from the individual female flowers lining the. receptacle wall, with a small scale-lined opening (called the ostiole or eye) at the distal end (Fig. 1.1).

Figure 1 1- Pictorial representation of internal and external features of figs

There are about many varieties of figs. So much named fruit producing cultivars have been described. In fact, cultivated forms of figs are numberless (Stover *et al*., 2007).

Figs are easy to grow in warm climates but produce their best fruit in Mediterranean climates with hot, dry summers and cool, wet winters.

Figure 1 2 - Fig plant

Fig. 1.2 is a seasonal fruit that can be harvested twice a year, either during spring and summer season or in the beginning and late of summer, depending on the cultivar (Ouchemoukh *et al*., 2012; Vallejo *et al.*, 2012).

As one of earliest cultivated fruit trees within the world, over 600 fig (*Ficus carica L*.) cultivars are described (Flaishman *et al*., 2008). When the fruit matures its colors are diverse, counting on the cultivars, the peel colour may be green, yellow–green, yellow, red, purple, or violet–black. Fig peel colour is primarily due to the build-up of anthocyanins, with anthocyanin type and content differing among the various cultivars (Dueñas *et al*., 2008). Arvaniti *et al (*2019) found that phenolic acids and flavonoids are the key varieties of phytochemical compounds that have been found in fresh and dried figs. Various biological activities, like antibacterial, antiviral, phytochemical and antioxidant properties of fig fruit are problems with interest to researchers.

1.2 Phytochemistry of Figs

Reports shows that the dried fruits of *F. carica* is an important source of vitamins, minerals, carbohydrates, sugars, organic acids and phenolic compounds (Slatnar *et al*., 2011). The fresh and dried figs were found to contain high amounts of fibre and polyphenols. Figs was said to be excellent source of phenolic compounds, like proanthocyanidins (Vinson *et al.*, 2005).

Phytochemical studies on *F. carica* revealed the presence of diverse bioactive compounds like phenolic compounds, phytosterols, organic acids, anthocyanin compounds, triterpenoids, coumarins and volatile compounds like hydrocarbons, aliphatic alcohols, and a few other classes of secondary metabolites from different parts of *F. carica* (Shukranal *et al*.,2013).

Fifteen anthocyanin pigments were isolated from the fig fruit and bark of *F.carica*. most of them contain cyaniding as aglycone and a few pelargonidin derivatives (Slatnar *et al*.,2011). Aside from phenolics, and anthocyanins; fructose, glucose and sucrose were identified from the fig of *F. carica* (Caliskan and Aytekin, 2011).

Various volatile constituents of five (5) Portuguese kinds of *F.carica* fruits (pulps and peels) were isolated which has aldehydes, alcohols, ketones, esters, monoterpenes, sesquiterpenes, norisoprenoid and augenol (Oliveira *et al*.,2010).

Figs are used as an exquisite source of minerals, vitamins, carbohydrates, and dietary fibre because it`s fat and cholesterol free and contain high number of amino acids (Veberic *et al*., 2008).

Phytochemical studies on the leaves and fruits of the plant have shown that they are rich in flavonoids, vitamin C, alkaloids, saponins, tannins, organic acids and volatile compounds giving it great antioxidant property. Most interesting healing effects include hypoglycemic, hepatoprotective, anticancer, antimicrobial and hypolipidemic activities.

Ficus carica has been conventionally used for its medicinal benefits. The fruits juice mixed with honey is employed for cure or prevention of of haemorrhage. The fruit paste is applied to swellings, tumours and inflammations for relieving pain. It is profit-oriented within the market as sweet because of its high level of sugars (Veberic *et* *al*.,2008).

1.3 Pharmacological Properties

The pharmacological properties of Figs are well documented. It has anti-inflammatory, antioxidant, anti-bacterial, anti-acne, anti-pyretic, anti-hyperlipidemic, anti-cancerous, hepatoprotective, hypoglycaemic and nephroprotective activities [Kore *et al*., (2011); Ali *et al*., (2012); Camero *et al*., (2014); Soni *et al*., (2014); Joerin *et al*., (2014); Mahmoudi *et al*., (2016); Sivakrishnan and Kavitha (2019); Fazil and Akram (2019)].

1.4 Nutritional Properties of Figs

The fig is a nutritious fruit containing considerable amounts of vitamins, amino acids, antioxidants and dietary fibre (Martinez-Garcia *et al*., 2013). In addition, figs contain higher levels of potassium, calcium and iron than those usually found in other common fruits such as grapes, bananas, oranges, apples and strawberries. Also, figs are free of sodium, fats and cholesterol (Reyes-Avalos *et al*., 2016). Fig varieties with dark skin have been found to contain higher levels of polyphenols, anthocyanins, and flavonoids, together with higher antioxidant activity compared to fig varieties of lighter skin (Solomon *et a*l., 2006).

Table 1 1 - Nutritional content of fresh and dried figs

Dietary component	Value/100g fresh	Value/100g dried
Water (g)	79.11	30.05
Total Calories (Kcal)	74	249
Protein (g)	0.75	3.3
Total fat (g)	0.3	0.93
Saturated fat (g)	0.06	0.93
Fiber (g)	2.9	9.8
Sugars (g)	16.26	47.92
Cholesterol (mg)	0	0
Calcium (mg)	35	162
Iron (mg)	0.37	2.03
Magnesium (mg)	17	68
Phosphorus (mg)	14	67
Potasium (mg)	232	680
Sodium (mg)	1	10
Zinc (mg)	0.15	0.55
Vitamin A (IU)	142	10
Vitamin C (mg)	2	1.2
Thiamin (mg)	0.06	0.085
Riboflavin (mg)	0.05	0.082

Source: Data from the USDA National Nutrient Database for Standard References (2019).

Table 1 2 - Macronutrients (g/100 g fw) and energy value (kcal/100 g fw) of the *Ficus* (Palmeira et al 2019)

Parameters	Peel	Pulp	t-Student test p-value
Moisture	67 ± 3	73 ± 1	0.132
Ash	1.01 ± 0.05	0’79 ± 0.01	< 0.001
Protein	2.2 ± 0.1	1.99 ± 0.03	0.021
Fat	1.64 ± 0.03	1.24 ± 0.03	< 0.001
Carbohydrates	27.8 ± 0.1	23.74 ± 0.01	< 0.001
Energy	134.7 ± 0.2	114.4 ± 0.1	< 0.001

A student`s t-test was used to determine the significant difference between two different samples, with $\alpha = 0.05$: $p < 0.001$ means a significant difference between the samples.

Figs are often recommended to nourish and tone the intestines and act as a natural laxative because of their high fibre content. A diet rich in fruit and vegetables – including fresh figs, naturally increases potassium and is therefore encouraged to help lower blood pressure. Naturally high in dietary fibre, figs can be a useful food to include in the diet for those watching their weight. High fibre foods provide feelings of fullness and can reduce hunger and cravings. Figs also contain prebiotics, which help support the pre-existing good bacteria in the gut, improving digestive wellness. Figs are a good fruit source of calcium, a mineral that is involved in bone density. Their high potassium content may counteract the urinary excretion of calcium caused by high salt diets. This in turn helps to keep calcium in bones and lessens the risk of osteoporosis (Lewin, 2018).

This research is born out of the new trend in food industries which are as follow:

- Plant-Based Foods.
- A Return to Fruits and Veggies.
- Emphasis on Texture.
- On-the-Go Healthy Snacks.
- Gluten-Free Desserts.
- Sustainable Practices.
- Taste is On-Trend.

1.5 Valorisation of figs

Food waste is currently generated in significant quantities worldwide. One third (1/3) of food for human consumption is lost globally (as waste processing or loss in the chain). These losses are much higher in the industrialized countries than developing countries: per capital in Europe and North America is 95-115 kg / year while per capital in sub-Saharan Africa and South / Southeast Asia 6-11 kg / year (FAO., 2011).

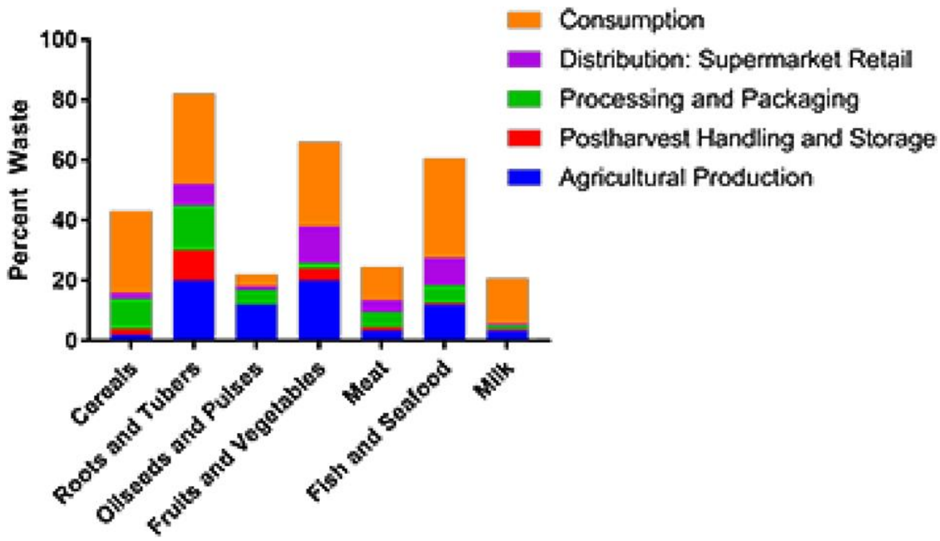


Figure 1 3 - Volumes of waste (Andler and Goddard, 2018)

While most of these have uses in landfilling or composting, advanced valorisation alternatives can be developed to maximize the value derived from such an important waste source. For instance, when figs which are highly perishable are harvested, late crops are left on the trees because they are no longer of commercial interest to farmers even to be dried in the sun due to its small size and because of the onset of the rainy season. These figs can be valorised for a sustainable future.

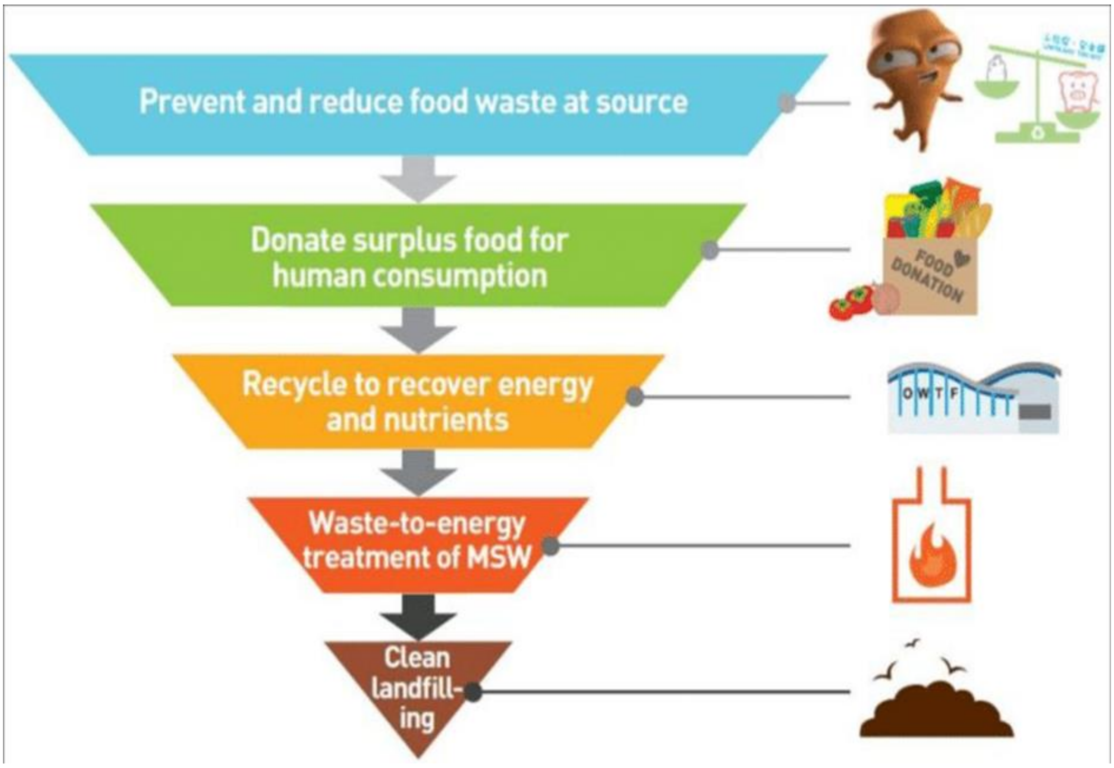


Figure 1 4 - Food Waste Management Hierarchy (Parameshwari, 2017)

1.6 Shelf life of figs

Figs, like other fruits and vegetables are highly perishable. Researchers have developed a lot of packing techniques that could extend the shelf life of figs by up to 21 days after harvesting. As stated earlier, micro-organisms such as moulds and yeasts are the main causative agents to this microbial invasion, leading to the loss of nutritional contents and inadvertently causes short shell life. Normally, figs experience a loss of quality in about a week after harvesting due to the fruits ripening, which results in certain changes that lead to a loss in sensory quality and a less appealing appearance.

Precisely because of the facts stated above, much of the figs harvested are traditionally processed into dried figs. This practice currently is changing due to increased market demand. A recent work by Vilalobos *et al.*, (2016) had shown that the shelf life of fig varieties can be prolonged through certain packaging formats that can triple the shelf life of fresh figs. One of their most interesting contributions is the reduction in drying time through the application of ultrasonic pre-treatments and improvements in the fruits handling. The fruits can be dried between one to three days as against traditional sun drying techniques that need an average of about fifteen days.

There is a current study to evaluate the physicochemical, microbiological and sensory quality of figs canned in syrup. Two treatments were applied to standard sucrose syrup and sweetness blends (such as sodium cyclamate, sodium saccharin, sucralose etc). These were stored at room temperature for 180 days and evaluated once a month.

The pH, soluble solids, titratable acidity, texture and sensory evaluation of canned figs in syrup showed no significant difference, therefore, they were considered commercially sterile and kept their sensory characteristics throughout storage (Caetano *et al*., 2017).

Canned fruits in low-sucrose or no sucrose seem to be rising in food markets. Fruits in syrup have become an important alternative in fruit production and consumption by providing flavour, colour and good texture, avoiding waste and fulfilling a current niche in the market (Caetano *et al*., 2015).

However, processing standard and diet canned fruits carry some challenges, such as preserving its original integrity, promoting longer shelf life and making them more attractive to palates. Moreover, some positive and negative changes can occur during the process such as destruction of the inhibitors and desirable complexes formation between food components and metal ions. Also, nutrient losses, changes in sensory properties such as colour, flavour, aroma and texture (Barbosa *et al*., 2016).

The works of Caetano *et al.,* (2017) showed that canned figs in sucrose syrup or sweeteners showed no microbial growth, ensuring its commercial sterility. Both canned figs kept their sensory characteristics during the study period. In both treatments, canned figs were stable over six months of storage, as shown by their physicochemical, microbiological, and sensory results.

Khapre (2015) and co-workers developed a process technology to prepare figs fruit powder and subsequently utilized it to add value to an Indian cookie (Burfi). In contrast to fig pulp and dried figs, the fig powder was found to be superior in terms of yield and ease of processing technology. The products, that is figs powder and fig cookie, were chemically and sensorially assessed and found to be nutritionally rich in terms of fibre (3.70 %), potassium (0.46 %) and protein (13.12 %).

Organoleptic assessment of figs was carried out recently. Comparative studies were carried out to establish the nutritional profiles of fresh and dried fig fruit. The proximate profiles of carbohydrate, minerals, proteins and dietary fibre were analyzed. Further, to project the organoleptic appeal of the fig under study, invasive and non-invasive sensory evaluation was carried out by a semi-trained panelist. This was executed with a recipe. The statistical data proved that the fig recipe was accepted. (Vora *et al*., 2017).

1.7 Packaging/ Storage methods of figs

There is an increasing market demand for dehydrated fruits and vegetable world-wide (Abul-Fadi *et al*., 2015). Dry fruits have substantial quantities of essential nutrients in a rational proportion and have a considerably more energy than fresh fruits because the nutrients are concentrated in solid when the water is removed (Khan *et al*., 2011). Fully ripened fresh figs have a shelf life of 2-3 days if refrigerated. They take 4-5 days to dry in the sun and 10-12 hours in a dehydrator. But dry figs can be stored for six to eight months and are considered a rich source of nutrients especially essential minerals and energy (CRFG, 2010). Fig fruits is one among such nutritious dry fruits, which in available throughout the year.

Abul-Fadi and co-researchers (2015) investigated the effect of microwave-air drying and microwave vacuum on the physical, chemical and sensory properties of dried figs and the cost of operation. They also studied the chemical composition, physicochemical attributes and sensory evaluation of fig fruits compared to conventional air drying (AD) and vacuum drying (VD) methods. The results obtained from the study showed that, the drying rate of tested samples by using microwave air convection drying method (MWAD) was faster than those for dried with air convection drying method at the corresponding drying condition (60^{o}C and 1.5 m/s air velocity), and that the microwave vacuum drying system (MWVD) could produce final dried product throughout short time not exceeding 120 minutes, whereas this requires 36 hours by using vacuum drying system.

It is worthy of note that dehydration removes most of the water from fruits and this highly improves the shelf life of the final dried products resulting from reduced water activity.

In another study, researchers collected fig fruits at two maturity stages. The fruits were coated with an alginate-chitosan bilayer edible (A-Ch BE) film. The main physiological and quality attributes were evaluated during storage at low temperature (6^{o}C) for 15 days (Reyes-Avalos *et al*., 2016). Ethylene and CO_2 production were considered as physiological parameters, while firmness, colour changes, weight loss and visual infection were the quality attributes evaluated.

The results showed that the application film reduces CO_2 production and increased ethylene emission, regardless of the maturity stage of the figs. Firmness for uncoated figs underwent a significant decrease during storage exhibiting values lower than 1.0 N.

On the contrary for coated figs, firmness was not only maintained but also even increased up to 3.0 N. Furthermore, coated figs exhibited better external colour retention, lower weight loss and lower visual fungal contamination than uncoated fruits during the 15 days of storage at 6 ^oC, regardless of the maturity stage. Therefore, the results indicate that application of an A-Ch BE film not only can improve the overall quality of figs stored at 6 ^oC but is also able to extend shelf life.

In a related study, Irfan *et.al*., (2013) evaluated the use of 4 % calcium chloride and measured the impact of the salt solution in terms of retention of fruit colour, texture and increased accumulation of ascorbic acid, compared to untreated control figs. Pre-treatment with calcium chloride (4 %) was found to be effective in checking the growth of both mesophilic aerobic bacteria, yeast and moulds at low temperature.

The effect of different packaging materials on post-harvest quality of fresh fig fruits was investigated (Bouzo *et al*., 2012). The fruits were stored at 2 ^oC. While some were wrapped with a 20um polyethylene film in plastic trays, others were unwrapped. The wrapped were subjected to the following treatments: (1) Without CO_2 and O_2 permeability (CC); (2) with modified atmospheric packaging (MAP); (3) with additive potassium permanent ethylene absorbent (AB) and (4) the unwrapped serve as control (T). Quality attributes such as: weight loss (% PF), firmness (kg), total soluble solids, TSS (Brix), juice acidity (pH), CO_2 and C_2H_4 concentration and other volatile compounds were measured.

Although very limited research has been done to identify the optimum environmental conditions for extending postharvest life of fresh figs. However, low temperatures from 0 to 2 ^oC and a high relative humidity (90 to 95 % RH) are recommended.

In the research conducted by Bouzo *et al*., (2012), the MAP treatment resulted in better internal appearance and the fruit of the control (T) had a significant loss of quality.

1.8 Food product development

The importance of introducing new products in the market for continuing business success cannot be overemphasized. To achieve improved new product, the process of gathering information and evaluation can lead to decisions on the part of firms by limiting the level of risk and minimizing the resources committed to products that eventually fail. The process of NPD consists of several key stages, including identifying customer requirements, developing a product concept, generating a detailed design, testing, and product commercialization. At each of these stages, several functional areas are involved. The key stages of the new industrial product development are concept, design and production.

1.81 Design of Experiments

Experimental design is a systematic approach to apply statistical methods to experimental processes to improve input-output factors and process parameters. That is, experimental design is usually used as a methodology for selecting the levels of independent factors which provides the least variation on the required quality.

1.82 Response surface methodology (RSM)

The response surface methodology (RSM) is a mathematical and statistical method that is commonly used for modelling and analysing a process where the response of interest is affected by various variables (Braimah *et al*., 2016) and the objective of this method is meant to optimize the effect on the response (Montgomery, 2005). The parameters that affect the process are called independent variables, while the responses are called dependent variables (Salkind, 2010). This has great applications in the design, development, and formulation of new products and for improvement of existing product designs.

1.83 Mixture design

Mixture design is defined as a special type of response surface methodology (RSM) in which the factors are the components of a mixture and the response on the proportions vary, i.e., the response is affected by the variation of the proportions (Khuri and Cornell 1996; Cornell, 2002).

1.9 Sensory Analyses

Sensory evaluation is a discipline that applies the principles of experimental designs, statistical analysis and the use of human senses (sight, smell, taste, touch and hearing) for the purpose of evaluating consumer products (Vora *et al.*, 2017). This is especially relevant as the human system's sensory output has 4 important characteristics:

1. Each sense is governed by specific biochemical activities and is capable of individual action.
2. The response to the stimulus by sense is mediated through nervous transmission and is based on previous neural input i.e., memory.

3. There is a synergistic effect of one or more senses in which case the biochemical effect is more sophisticated.
4. Sensory evaluation has many evaluations where the input governs both positive and negative responses.

Quality is the main criteria for the desirability of any food product to the consumer. Sensory quality is ensured by the techniques of sensory evaluation. This is a parameter of great importance to both the processor and the consumer. To the processor, the attraction of consumers is the main goal and for the consumers, the satisfaction, health-wise and the sense of taste.

Sensory quality is a combination of different sensors of perception coming onto play in choosing and rating a food, which are as follows:

1. Appearance- which can be judged by the eye; for example, parameters like colour, size, shape, uniformity and absence of defects are of first importance in food selection.
2. Important attribute concerns texture and consistency
3. Flavour, which embraces the sense of taste, smell and feelings. Odour check is done by sniffing food before putting it in the mouth.

   In the mouth, assessment of flavour is done by putting food into the mouth and assessing the differences in sensation
4. After tastes measurements is done with sensations perceived after food is swallowed in the mouth. Trained panellists are used to detect and describe the organoleptic characteristics of food products. Sensory evaluation is basically used for:

- Ingredients processing or packaging evaluation.
- Shelf life testing
- Competitive comparisms
- Research applications.

A quality test panellist must meet certain requirements before he participates in a sensory evaluation exercise:

1. Good health.
2. No consumption of tobacco or food that will influence the taste 2-3 hours before sensory evaluation is carried out.

3. Absence of taste blindness.
4. Average sensitivity.
5. High degree of personal integrity.
6. Intellectual curiosity and interest in sensory evaluation process.

1.10 Validation of the optimum formulation

Optimization according to Britannica is the collection of mathematical principles and methods used for solving quantitative problems in many disciplines, in this case food processing. This was performed using a multiple response method called desirability. This optimization method incorporated desires and priorities for each of the variables developed, a procedure for specifying the relationship between predicted responses on a dependent variable and the desirability of the responses.

1.11 Gums

Gums also known as hydrocolloids represent a unique category of food additive. This was used in the production of the fig gum jelly. They are carbohydrates of relatively high molecular weight, when compared to ingredients such as sucrose or the various forms of corn syrup. Hydrocolloids are used in technical and regulated applications to thicken and to stabilize formulations. In processed foods, they are ubiquitous – no other group of ingredients contributes more to viscosity, texture, and body like hydrocolloids do (Wiley-VCH and Co., 2015).

1.12 Physicochemical parameters

1.12.1 Colour

The colour of a food is determined by pigments, chemical compounds, which could absorb light in the visible range of the electromagnetic spectrum (380-750 nm). Fruits and vegetables have several natural pigments such as anthocyanins, carotenoids, betanin and chlorophylls, which determine the sensory and nutritional characteristics of foods. However, different factors and treatments like blanching could influence the colour of the fruit. Chlorophyll degradation in plant tissues occur during natural leaf senescence and fruit ripening, and as a response due to varied biotic and abiotic effect, which may include temperature, humidity and light (Hörtensteiner, 2013).

1.12.2 Texture evaluation

The importance of texture in the overall acceptability of foods cannot be overemphasised. The sensation of food texture plays a vital role in influencing consumers' liking and preference of a food product which widely depends upon the type of food. The application of food processing generally leads to changes in the texture of the food product (Chen and Opara, 2013).

1.12.3 pH

This is the expression of free water concentration in a food. pH is a measure of acidity and alkalinity of food. Therefore, measurement of pH will help to determine the shelf stability, excellence and safety of the food. It also influences safety and quality, which are two major attributes of food. This is according to Vijayakumar and Adedeji (2017).

1.12.4 Total acidity

Titratable acidity provides a simple estimate of acid in food. Acidity is an important topic within the food industry because it affects the flavour of food and influences the growth ability of microorganisms, such as bacteria and fungi. The acidity content of food can affect the taste and the shelf life of food.

1.12.5 Moisture Content

The moisture condition of a product can be measured as the equilibrium relative humidity (ERH) expressed in percentage or as the water activity expressed as a decimal. Moisture content is the total amount of water present in any food commodity, or it is defined as the amount of water lost per gram of food product at 100 degrees Celsius. Moisture content normally is expressed as a percentage by weight according to the following equation. (Srivastava, 2018)

Moisture Content = (wet weight-dry weight)/wet weight x 100).

1.12.6 Water Activity(a_w)

Water activity runs from zero to one and zero means reduced probability of spoilage and while higher water activity means high risk of spoilage (Sandulachi, 2016). Water Activity (a_w) is an indication of the amount of Free Water in a food.

1.12.7 Dietary fibre

Dietary fibre is a group of carbohydrates that cannot be digested by the enzymes in the body (Dhingra *et al*., 2012; Otles and Ozgoz, 2014). It can be found in edible plant foods like fruits, vegetables, peas, cereals, nuts, lentils and grains. Fibre is grouped to their physical properties such as soluble, insoluble or resistant starch. The dietary fibre is very important for bulk generation in the digestive system with lots of health benefits.

1.12.8 Ash

Ash

Ash is the inorganic material, such as minerals that are found after the incineration of organic food material. The ash analysis has been mainly used to determine the adulteration of certain foods according to Park (1996). This is determined after ashing the food component at a temperature higher than 500 °C. Calculation of ash based on wet or dry basis is as follows:

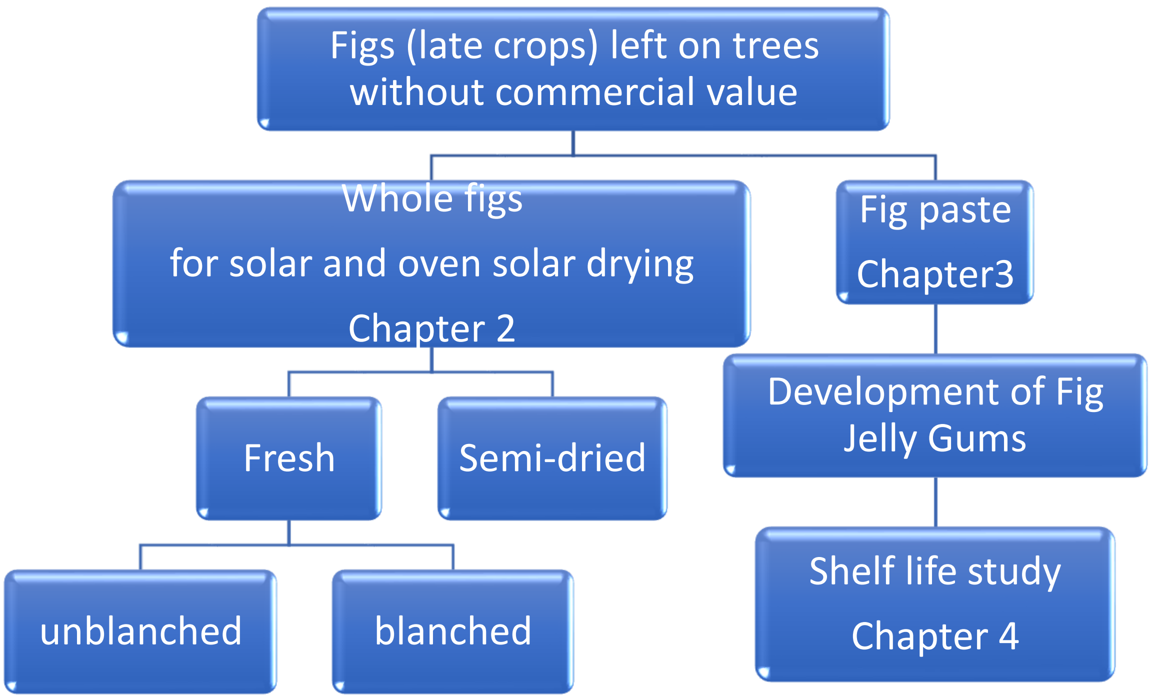
% ash (wet basis) = $\frac{wt\ after\ ashing - tare\ wt\ of\ crucible}{original\ sample\ weight}\ x\ 100$

% ash (dry basis) = $\frac{\%\ ash\ wet}{100 - \%\ moisture}\ x\ 100$

The main objectives of this thesis are:

- ✓ Solar dry figs and study the drying rates
- ✓ develop a product that will be available for easy consumption from fig
- ✓ Evaluate the shelf life of the fig products

Schematic diagram of thesis Organization is shown below:



Chapter 2 - Solar Oven Drying of Figs

2. 1 Introduction

Drying is an old and ancient practice to remove water from foods and other materials. The drying of the figs during this work in the sun for the purpose of removing water from the fruit and inhibit the growth of microorganisms was not as efficient as when solar dryer was used for same purpose and it helps to improve the shelf life of the product.

A solar oven drying experiment was carried out with the whole figs previously harvested with a solar dryer.

2.2 Materials and Methods

2.21 Collection of Fruits

The figs (*Ficus carica*) for this work were harvested in September from a local fruit orchard in Quelfes, Algarve. The fig fruits, free of physical damage and without microbial contamination, were used for the study. The fruits were divided into three groups: I -figs to be oven-solar dried as presented, II-figs to be blanched before oven-solar drier and III- figs to be solar dried.

2.22 Solar Oven Drying Study

A solar oven drier gently borrowed from Prof. Celestino Ruivo who built it in the Department of Mechanical Engineering of ISE/ UAlg was used throughout this study.

Figure 2 1 - A solar oven dryer

The heating in the oven is produced through radiation from the sun in absence of baffles or fans, under unsteady-state conditions. The oven was heated to the possible maximum temperature which was dependent for each experiment on the weather conditions. Two hundred grams of figs were placed on a metallic tray with the dimension and inside the solar dryer, keeping the door slightly opened (a small gap was left to allow the humidity to escape from the oven chamber).

Radiation and temperature were measured before the study start with a thermometer (HANNA HI935005N, Portugal) and a radiometer (OHM, Italy). Sunny days in October were chosen and the temperature, radiation and samples weight were taken from 9am to 4pm every half hour, (weighed with a scale ADAM, UK), until weight was stable and the dried products in Figure 2 2 was achieved and packaged in air tight glass wares.

Figure 2 2 – Oven dried figs

2.23 Moisture evaluation

Moisture was monitored throughout the drying experiment by checking the weight every hour with the weighing balance to build the drying curve.

2.24 A_w measurement

Before and after drying the samples, measurements of aw with the equipment Hygrolab C1 – Switzerland and moisture (%) with Mettler LP16 USA, took place to test the results of the drying process.

2.25 Colour evaluation

The colour was determined with a PCE instrument, Spectrophotometer model number: PCE-CSM 10 using the Hunter Lab system, in which the coordinates of L, a and b were determined. The colorimeter was subsequently calibrated with a black (X = 4.12, Y = 4.38, Z = 4.71) and a white (X = 84.60, Y = 89.46, Z = 93.85) plate, with the D65 illuminant and 10 ° observer. This analysis was performed in triplicate for each fresh and processed sample, with 5 measurements being made for each sample.

2.26 Texture evaluation

In performing the penetration test, a texture meter was used (Brookfield, LFRA 1500, U.S.A.) to evaluate the resistance to puncture force, according to Chen and Opara (2013) with some modifications. The samples were measured at six different locations using a 60mm width (TA7*) knife edge probe with a clear perspex of 3 mm penetration and a test speed of 0.6 mm/s, together with texture prolite v1.1 *software.*

For the presentation of the results in graph forms two variables where calculated, the free moisture content (*X=g* H_2O*/g dry solid*) and drying rate (*R=g* H_2O*/h.m2*).

For the *X* variable the following equation was used:

$$Xt = (W-Ws)/Ws \qquad eq\ (1)$$

where *W* is the total weight of the wet solid (dry solid plus moisture) at different times *t* in the drying period and *Ws* is the weight of the dry solid.

The rate, which was calculated for each point, except for the constant period's points that weren't calculated separately (from 0min to 150min), was found from the following equation:

$$R = -(Ls/A)\ x\ (dX/dt) \qquad eq\ (2)$$

Where *Ls* is grams of dry solid that have been used and *A* (779.1cm2 or 0.07791 m2) is the exposed surface for drying. To obtain the rate-of-drying curve from the plots, the slopes of the tangents drawn to the curve can be measured, which give values of *dX/dt* at given values of t. To calculate the *dX/dt* values the time and the *X* of the periods where used. For the constant period one *dX/dt* value was calculated.

2.3 Results and Discussion

The result shows that the blanched oven solar dried figs dried faster with higher drying rate than the untreated oven solar dried and direct solar drying which corresponds to the one reported by Ramos *et al.*, (2014) although the blanching was in the 0.1 % sunflower oil emulsion. Also, the rate of drying in fresh figs was faster than that in ripened figs. The dried fruits have a longer shelf life than the fresh figs.

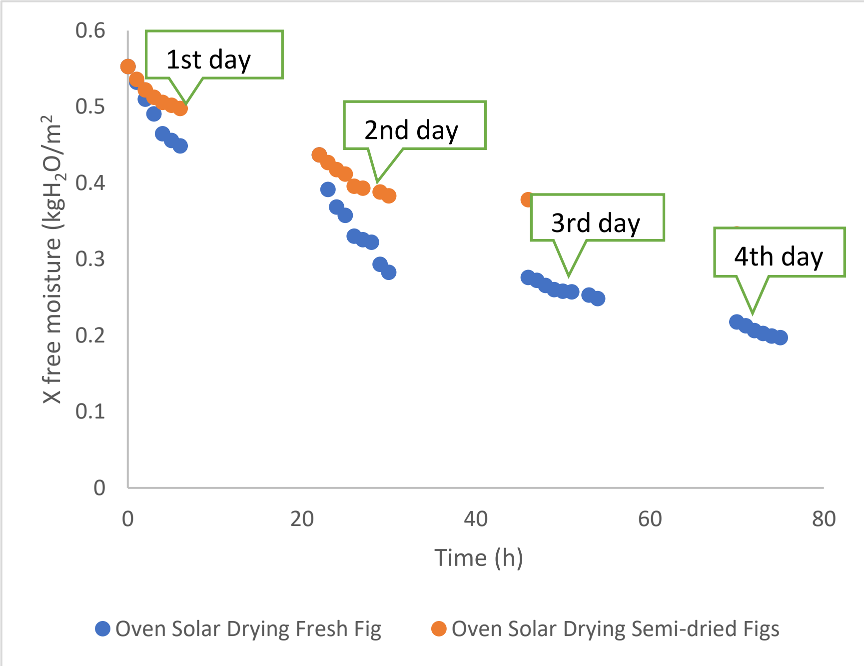


Figure 2 3 - moisture loss with time for unblanched oven solar dried figs for fresh and semi-dried figs

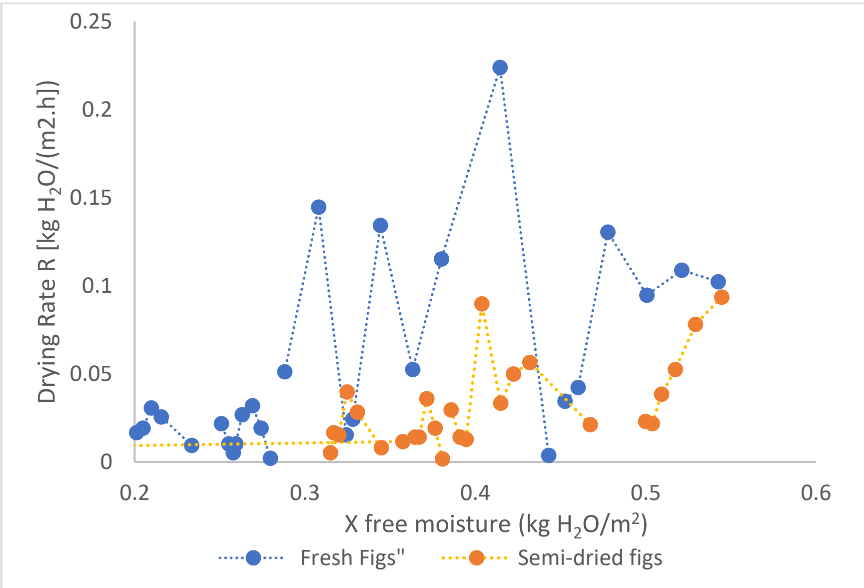


Figure 2 4 - drying rate for unblanched oven solar dried figs for fresh and semi-dried figs

Figure 2 3 shows a fast decline in the water content of fig for fresh figs than the ripened figs with oven solar drying which is also indicated in the drying rate in Figure 2.4. The drying using an oven solar drying can reduce the water content of fig at a higher drying rate than using the direct solar drying, this could be due to the concentration of solar energy and the reflection of light from the solar oven glass thereby concentrating the solar energy on the figs, for easy evaporation of the water on the surface of the material. Also, the drying rate was faster for fresh figs than for semi-dried figs.

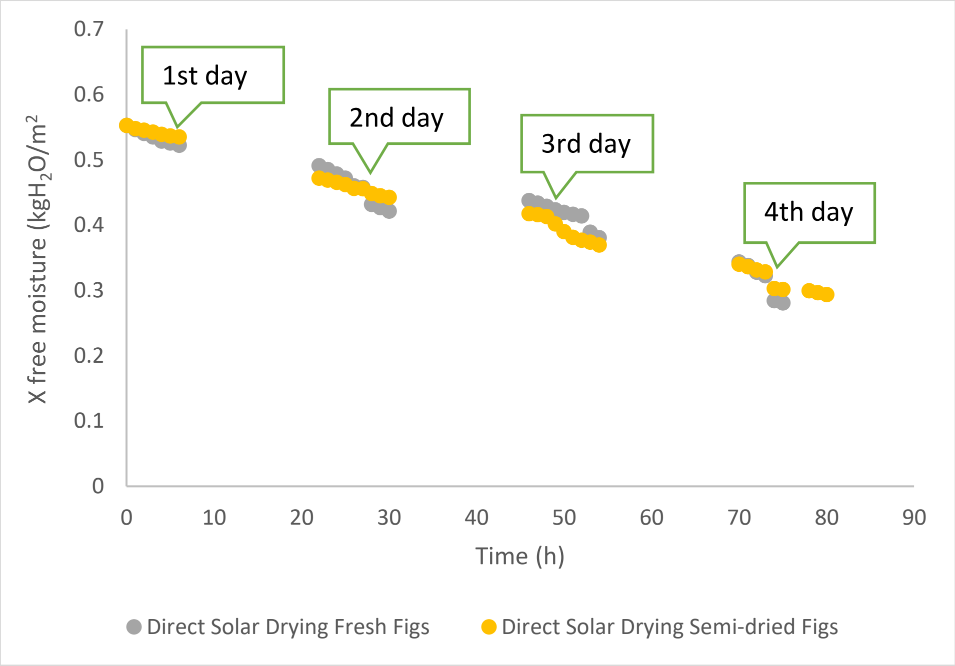


Figure 2 5 - moisture loss with time for unblanched direct solar drying figs for fresh and semi-dried figs

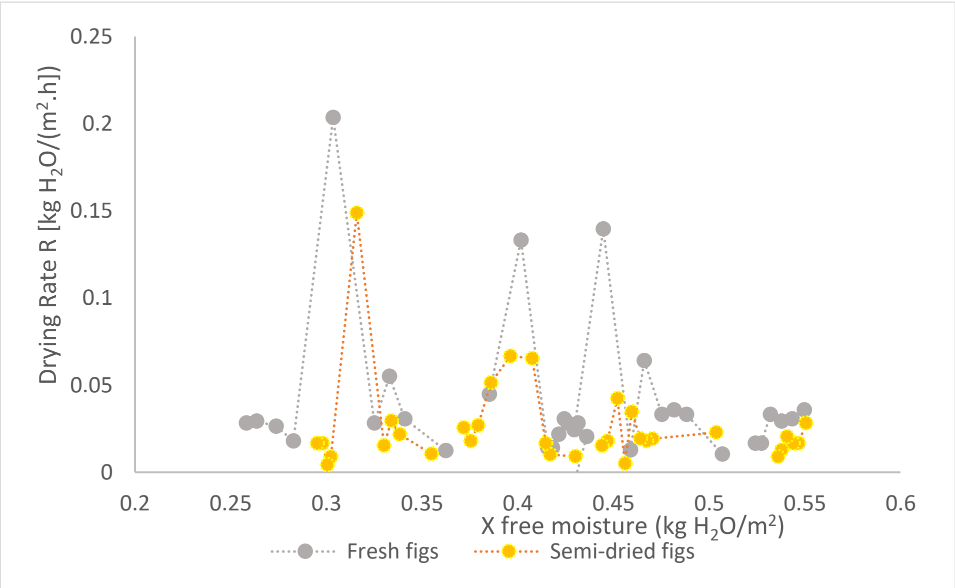


Figure 2 6. - drying rate for unblanched direct solar drying for fresh and semi-dried figs

Figure 2 5 shows a slow decline in the water content for direct solar drying of fresh and ripened unblanched fig with time though it is lower in semi-dried figs. This drying shows a very slow rate of drying as shown in figure 2 6 which led to spoilage of most of the figs.

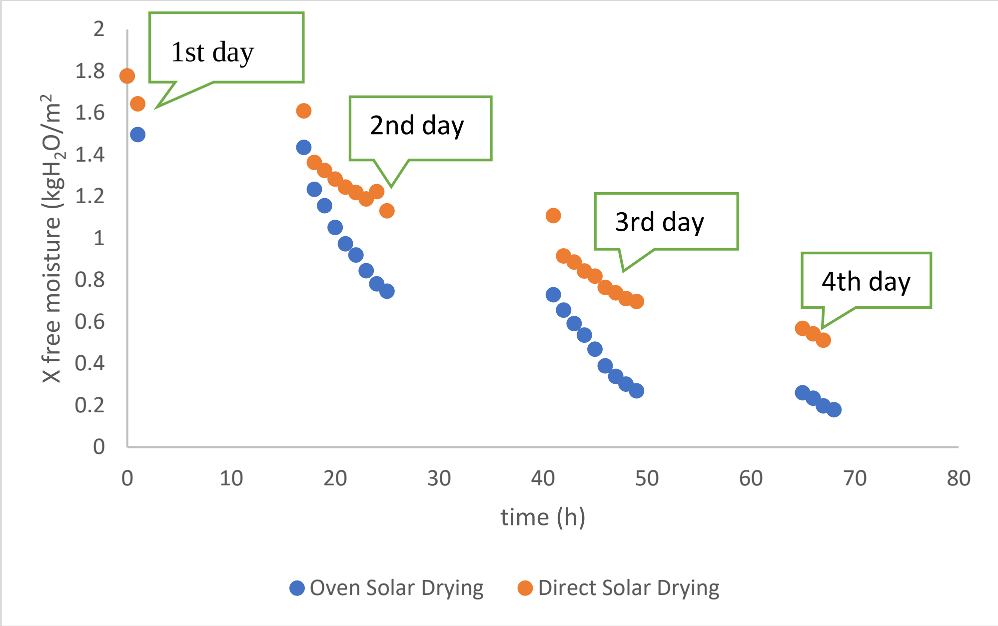


Figure 2 7. - moisture loss with time for blanched oven solar and direct solar dried figs.

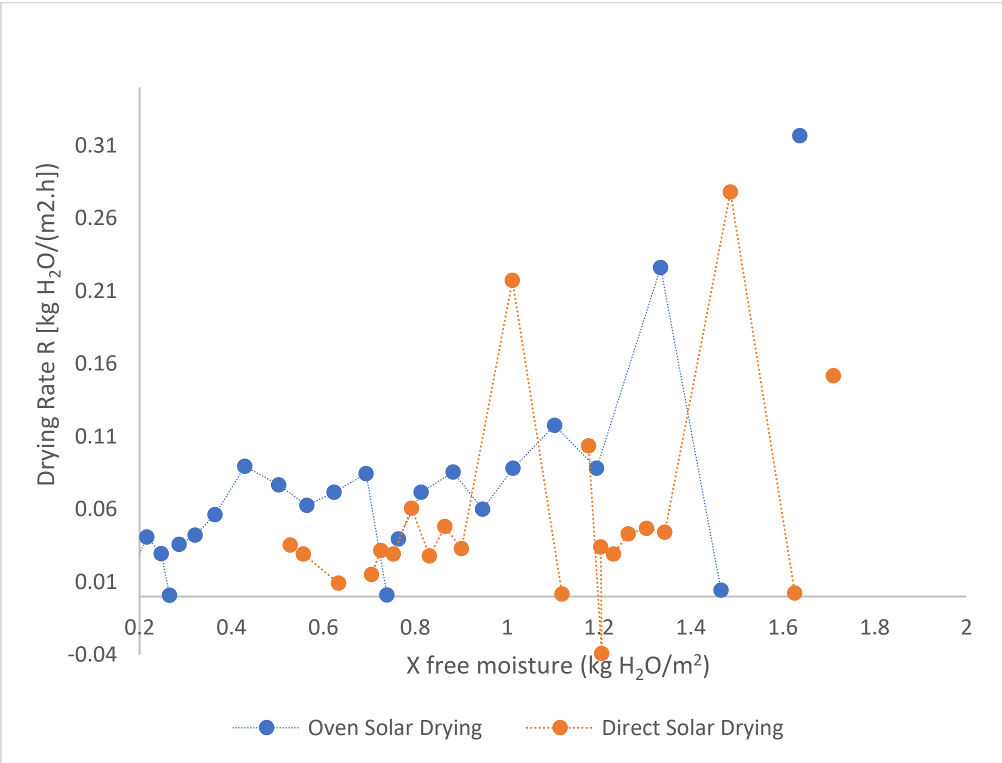


Figure 2 8 - Drying rates for oven solar and direct solar drying for blanched figs

Figure 2 7 shows a decline in the water content of fig for both oven solar drying and direct solar drying with time. The drying with the oven solar dryer was able to reduce the water content of fig faster than the direct solar, this could be due to the concentration of solar energy due to reflection of light from the solar oven reflector thereby concentrating the solar energy on the figs, for easy evaporation of the water on the surface of the material. Also, Figure 2 8 shows that the drying rate was faster for oven solar drying than for direct drying.

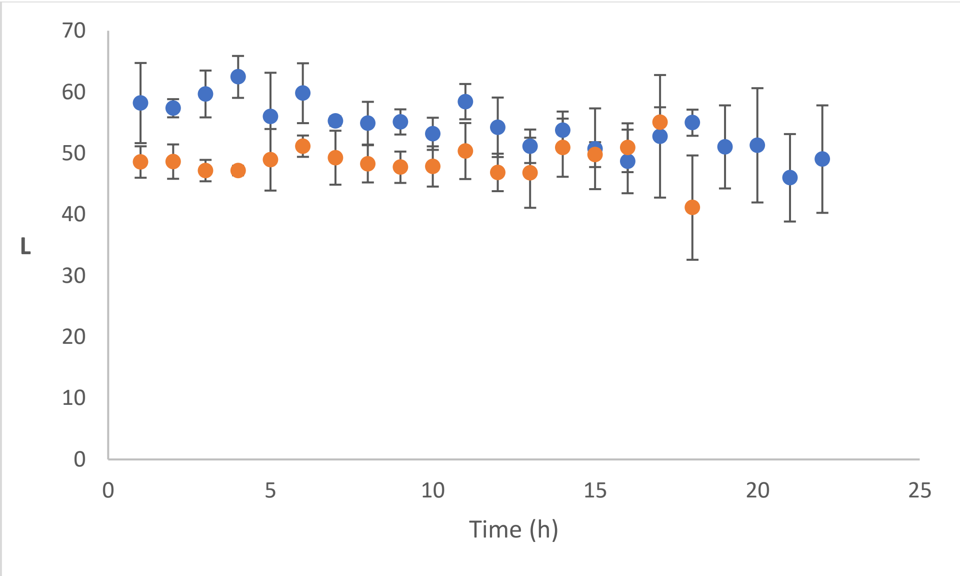


Figure 2 9 - L* colour parameter evolution for blanched ● and non-blanched ●

The change of parameter L values during drying process for blanched and non-blanched figs are illustrated in Figure 2 9 With increasing time, the figs became darker which is in accordance to what was reported by a decrease in L value. Although the fresh fig was darker at the beginning but towards the drying process their colour was very close in the level of darkness the degradation in L value might be influenced by an increase in time and the effect of increased temperature from solar energy. Indeed, the literatures showed that time affect the change of colour during the heat treatment of the agricultural products. Most of the previous works demonstrated that the changes in L value as affected by heat treatment but the effect of drying principle are not available

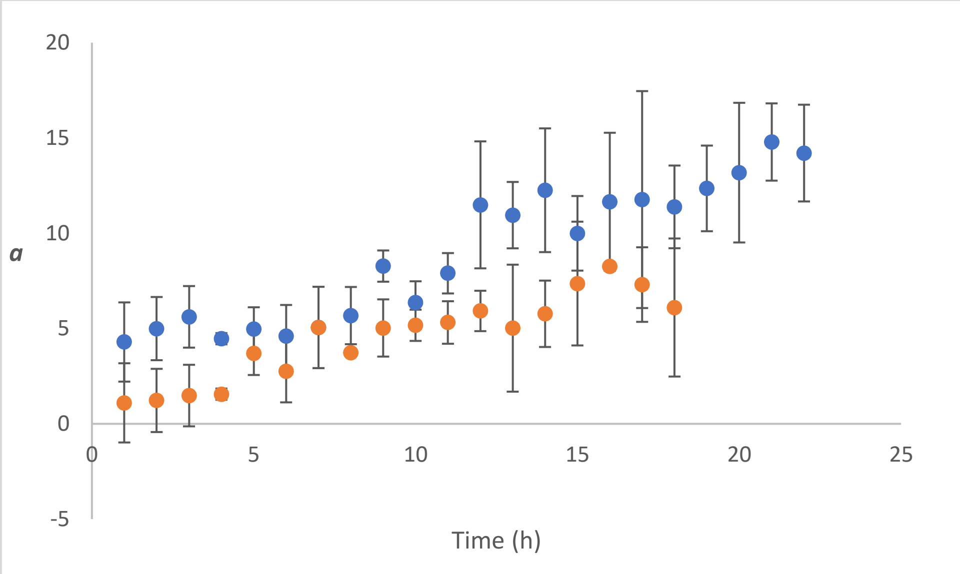


Figure 2 10 - a* colour parameter evolution for blanched ● and unblanched ●

Fig 2 10 shows an increase in the a* values during the drying process of the blanched and unblanched figs. At the end of drying, the colour changed from green towards brown. The degradation of Hunter "a" value of fig increased with drying time. The increase in the positive values of "a" parameter implied that the dried figs were browner than the fresh figs. Many studies of the colour changes during heat treatment of fruit demonstrated similar result but effect of drying principle on relative Hunter parameters have not been described in the literature.

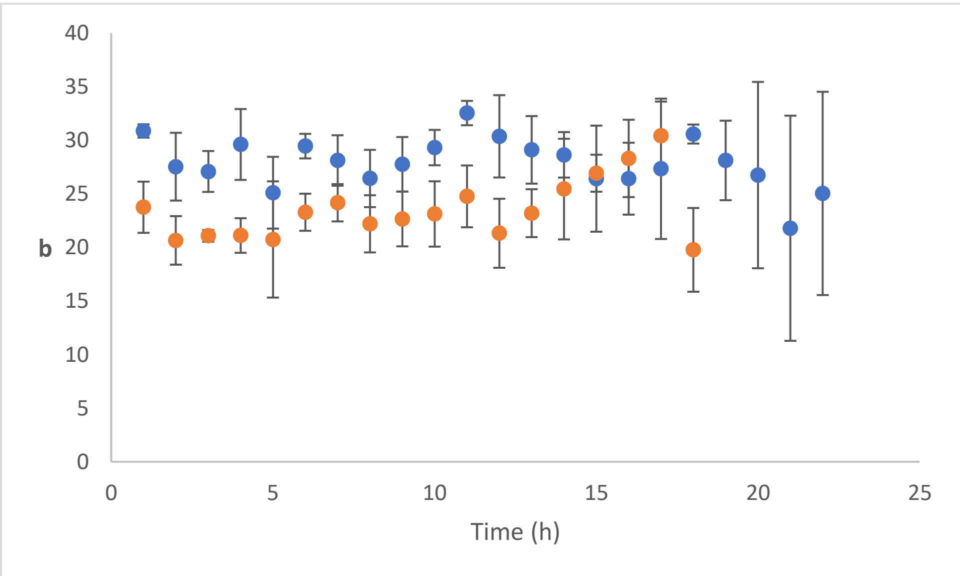


Figure 2 11 - b* colour parameter evolution for blanched ● and unblanched ●

In this study, the b value was used as an indicator to describe the pigment destruction in the fig. Figure 2 11 shows plots between relative Hunter parameter b and processing time for blanched and unblanched figs during drying. The relative visual yellow colour parameter (b values) decreased during drying.

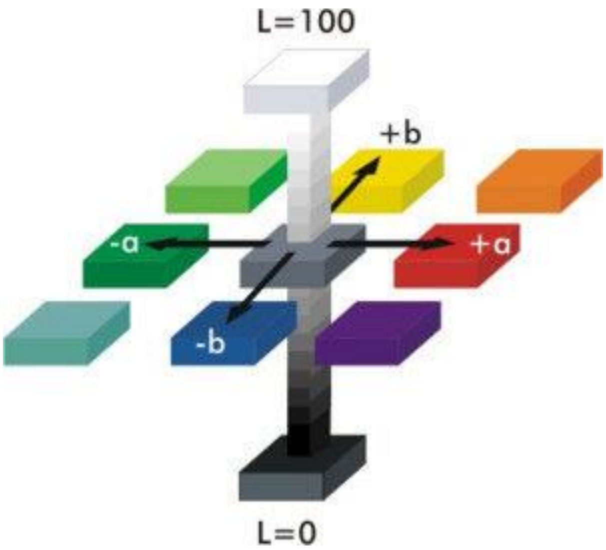


Figure 2 12 - Hunter Lab colour space (Andrade et al., 2015)

Note: (L* a* b* are colour parameters: Lightness/darkness, green/red, blue/yellow)

This shows that the blanched figs showed a lighter colour than the unblanched at the beginning but turned out to be almost same with unblanched with darker colour after drying. The unblanched showed to be more greenish than the blanched, this could be because of heat on the enzymatic action of the fruit thereby affecting the chlorophyll content of the fig during drying. According to Solomon *et al*., 2006; Lansky and Paavilainen, 2011 and Harzallah *et al*., 2016, figs colours differ from yellow to green and purple to black and it is obtained during ripening stage.

2.4 Conclusions

Oven solar dried figs gave a better result with a better shelf life than conventional direct solar dried figs. Natural changes occur in fruits and vegetables as they grow and develop, just like senescence and ripening, influence the chlorophyll content of fresh green produce, so also blanching affects the colour of food to an extent. This shows that blanching treatment can inhibit various undesirable enzymatic reactions which may be required to improve the final quality of the processed product as reported by Nilnakara *et al*., (2009); Yoshida *et al*., (2014) and Orikasa *et al*., (2018).

Chapter 3 - Development of a fig gum

The importance of introducing new products in the market for continuing business success cannot be overemphasized. To achieve improved new product, the process of gathering information and evaluation can lead to decisions on the part of firms by limiting the level of risk and minimizing the resources committed to products that eventually fail. The process of New Product Development (NPD) consists of several key stages, including identifying customer requirements, developing a product concept, generating a detailed design, testing, and product commercialization. At each of these stages, several functional areas are involved. The key stages of the new industrial product development are concept, design and production.

Jelly gums are very much appreciated by children but very often its composition is based in sugar, thickeners, mostly complex carbohydrates, colourants, and fruit aroma. The inclusion of a fruit will add a nutritional value to this product. In this chapter the development of a fig gum jelly is described.

Figure 3 1 - Fig gum jelly product

3.1 Materials and Methods

3.11 Selection of thickeners to use in the development of the fig gum.

Three thickeners were first tried, K-carrageenan, gellan and alginate. Different percentages were formulated with water to form a paste that was heated at about 82-85 °C to form the gum that was mixed with the fruit to formulate the product.

Preliminary Tests

Fig was combined with various natural food materials at various percentages to formulate fig gums before arriving at a design which was formulated for optimum design. The firmness of the product was analysed to get the best texture for the product. This is shown in the figures 3.2 and 3.3.

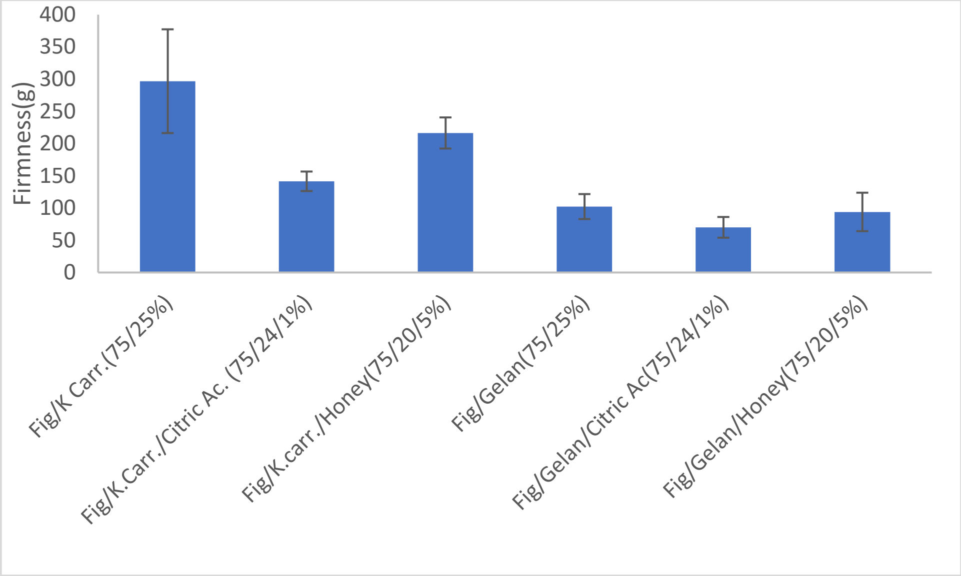


Figure 3 2 - Textural analysis of fig gum using flat end probe.

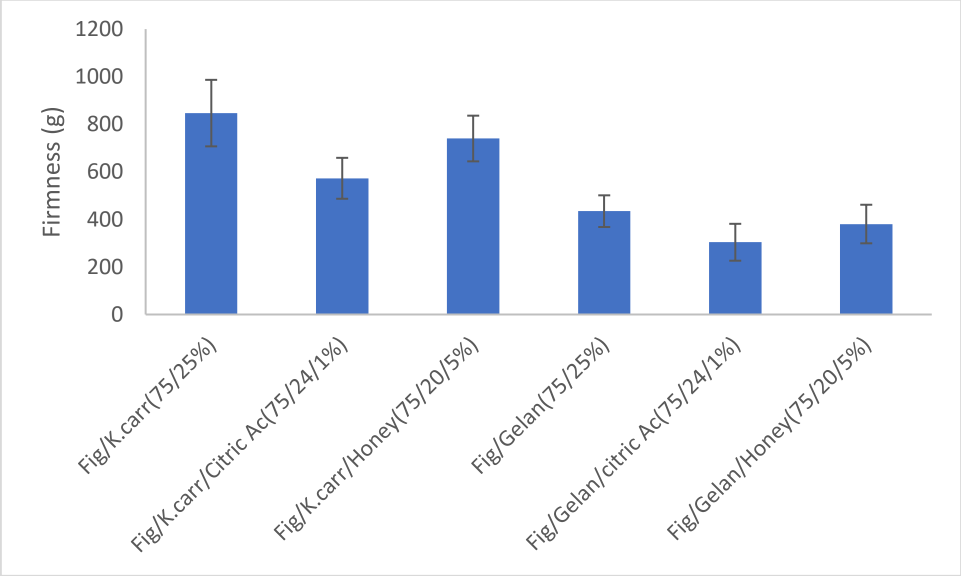


Figure 3 3 - Textural analysis of fig gum using knife edge probe.

The best result was achieved with K- carrageenan. Therefore, the solution of 7.5 g of Kappa carrageenan gum in water (Table 3 1) was used throughout the study to develop the fig gum jelly.

Table 3 1 - Constitution of Kappa carrageenan solution

Water(mL)	Gum(g)	Gum(%)
92.5	7.5	7.5

3.12 Mixture Design

For the development of the fig jelly-gums four components were used: Fig paste, k-carrageenan, honey and water. Water was always present in a fixed proportion (92.5 %) in the K carrageenan. Minimum and maximum levels of each component were established, as described in table 3 2.

Table 3 2 - Minimum and maximum limits for x_1; x_2 and x_3 to establish the mixture design

	Mínimum (%)	Máximum (%)
x_1 *Fig paste*	55	75
x_2 k-carrageenan	15	35
x_3 *Honey*	10	30

According to Anderson and Whitcomb (1999), to select the ideal number of experiences, a general procedure is followed:

1. The order of the polynomial was chosen to obtain a prediction model for the answer studied. In this case, we opted for the quadratic polynomial model of Scheffée:

$$Y_i = \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_{12} x_1 x_2 + \beta_{23} x_2 x_3 + \beta_{13} x_1 x_3 \qquad \text{eq. (3)}$$

Where Y_i is the value of the dependent variable of parameter *I and* x_1, x_2 and x3 *represent* the three components of the film; β_1, β_2 and β_3 represent the linear regression coefficients; β_{12}, β_{23} and β_{13} are the quadratic regression coefficients (Myers and Montgomery, 1995). It started by choosing the minimum and maximum values of each component according to table 3.2.

2. Then, the *software generated* a design *with* several excess points, to fit chosen polynomial model.

3. After obtaining the design, an evaluation of the *design* was carried out, with the objective of minimizing the error of the standard deviation in the most central region, since this region was of the most interest, also to be able to balance the number of degrees of freedom between those destined to evaluate the pure error (*g.l.* 3; error inherent to the experimental procedure) and to evaluate the lack of adjustment of the model to the experimental *points (g.l.* 3; table 3.2, 3.3 and figure 3. 4).

The *design* was divided into three blocks, with the purpose of reducing/eliminating the error because the experiments were done in three (3) different days. To evaluate the pure error, the center and vertices were replicated. In total, a design was obtained with 18 experiences.

Table 3 3 - Mixture Design

			Component 1	Component 2	Component 3
Std	Run	Block	A: fig paste	B: carrageenan	C: honey
10	1	Block 1	65	25	10
6	2	Block 1	61.7	21.7	16.7
5	3	Block 1	58.3	18.3	23.3
2	4	Block 1	55	25	20
15	15	Block 1	58.3	18.3	23.3
7	5	Block 1	75	15	10
1	6	Block 2	65	15	20
4	7	Block 2	58.3	28.3	13.3
11	11	Block 2	61.7	21.7	16.7
14	14	Block 2	58.3	28.3	13.3
16	16	Block 2	75	15	10
8	9	Block 2	55	15	30
3	8	Block 3	68.3	18.3	13.3
9	10	Block 3	55	35	10
12	12	Block 3	61.7	21.7	16.7
13	13	Block 3	68.3	18.3	13.3
17	17	Block 3	55	15	30
18	18	Block 3	55	35	10

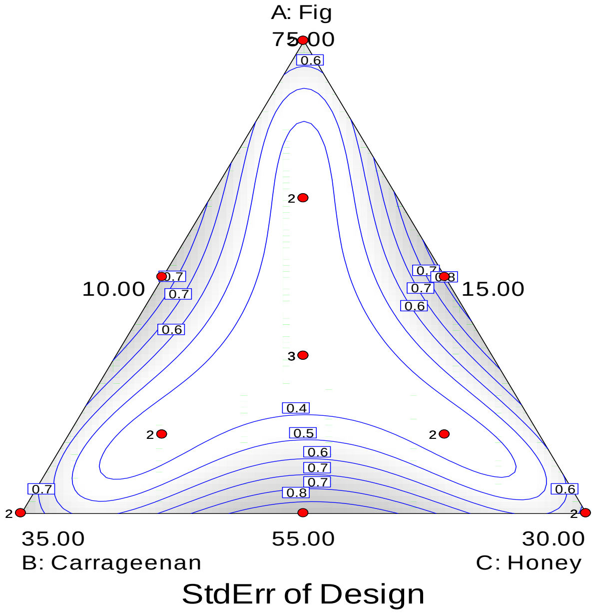


Figure 3 4 - Standard Error estimation within the design triangular area and experimental points distribution

3.2 Sensory Evaluation

This was carried out using six points hedonic scale. Hedonic scale is a term used in tasting panels, where the judges indicate the extent of their like or dislike for the food. Table 3.4 shows the six hedonic scale used for sensory analysis.

Table 3 4 - Hedonic scale for sensory analysis

	A	B	C
1	Dislike extremely	Unnoticeable	Extremely hard
2	Dislike moderately	Slightly noticeable	Moderately hard
3	Dislike slightly	Noticeable	Slightly hard
4	Like slightly	Slightly intense	Moderately soft
5	Like moderately	Intense	Extremely soft
6	Like extremely	Strongly Intense	Extremely soft

Note: B stands for Aroma and Mouthfeel while C is for Texture

3.3 Optimization of Fig jelly gum

Optimization of fig jelly gum was achieved through experimental design and sensory analysis to achieve the best formulation. Experimental design is a systematic approach to apply statistical methods to experimental processes to improve input-output factors and process parameters. That is, experimental design is usually used as a methodology for selecting the levels of independent factors which provides the least variation on the required quality. Experimental design is also a powerful tool for fitting experimental data to an empirical function to provide information about a system. A desirable range was obtained through transformation of the estimates after goals and constraints (minimum and maximum) were established for each response (Anderson and Whitcomb 1996).

3.4 Validation of the optimum formulation

Optimization was performed using a multiple response method called desirability. This optimization method incorporated desires and priorities for each of the variables developed, a procedure for specifying the relationship between predicted responses on a dependent variable and the desirability of the responses.

The optimum formulation was validated by same sensory panel using the optimum value and an option that was close to the optimum but deviated from the optimum. After the sensory evaluation, the mean and standard deviation was calculated, and the optimum value was sustained with higher value.

3.5 Physicochemical characterization of the optimum formulation

The physicochemical characteristics are the physical and chemical characteristics. The optimum formulated jellies were characterised by determining its colour (L, a and b parameters using a colorimeter), Texture, pH, a_w, brix, total acidity, fibre and ash

3.51 Colour determination

The colour was determined with a PCE instrument as shown in Figure 3 5, Spectrophotometer model number: PCE-CSM 10 using the Hunter Lab system, in which the coordinates of L, a and b were determined. The colorimeter was subsequently calibrated with a black (X = 4.12, Y = 4.38, Z = 4.71) and a white (X = 84.60, Y = 89.46, Z = 93.85) plate, with the D65 illuminant and 10 ° observer. This analysis was performed in triplicate for each fresh and processed sample, with 5 measurements being made for each sample.

Figure 3 5 - Spectrophotometer

3.52 Texture Measurement

The texture of the fig jellies samples was determined using a LFRA Brookfield texture meter and with the Texture Pro Lite® software in which a penetration test was performed using a probe (TA7*) with 60 mm width. The conditions used in the test in relation to the test speed, trigger point and target value were, respectively, 0.6 mm / s, 5 g and 3 mm.

Texture analyser with a knife edge probe was driven into the food material, and the depth or force of penetration measured to be 3 mm in diameter into the fig jellies. Figure 3 6 (a) and (b) shows the Texture profile analysis (TPA) using a Texture analyser with knife edge blade, (a) shows the main part of a Texture analyser and (b) an example of a TPA curve showing the loading versus time to detect the texture of the fig gum jelly

(a) (b)

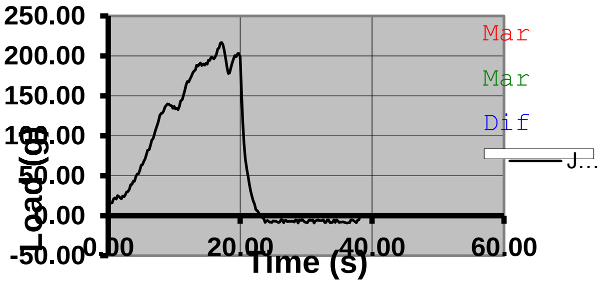


Figure 3 6 - Texture profile analysis (TPA) using a Texture analyser with knife edge blade. (a) Main part of a Texture analyser and (b)example of a TPA curve with typical parameters

3.53 pH measurement

This was determined by measuring with the pH meter as shown in Figure 3 7. The pH meter was calibrated, and the probe was inserted into different parts of fig gum jellies in triplicate with the readings taken. The result of the pH was determined by average of the readings and standard deviation

Figure 3 7 - pH meter

3.54 Total acidity determination

This was determined by dissolving 10g of fig gum jelly in 50 mL of water and heated for 30minutes.The solution was filtered and 25 mL of the filtrate was put in conical flask with 2-3 drops of phenolphthalein before titrating with 0.1 M NaOH solution. There was continuous drop by drop addition of the alkali and stirring of the content until the first definite change to pink colour was observed.

3.55 Moisture Content

Fig jellies of five (5) grams each, were put in pre weighed petri dishes that had been preheated in the oven for about an hour and cooled in the desiccator. These were put in an oven preheated to 105 °C to dry overnight. These were put in the desiccator and the weights of samples were measured using the same laboratory analytical balance and noted down to calculate the initial moisture content.

3.56 Water activity(a_w)

The measurement of a_w was performed using a Rotronic Hygrolab hygrometer as shown in Figure 3 8, which consists of a potentiometer, a sample sensor holder and a sensor. The required amount of sample was crushed and placed in a water activity sample vessel and brought to ambient temperature. The sample was then placed within the air-tight measuring cell of a calibrated water activity meter. Once the atmosphere within the cell was equilibrated, and the digital read-out was stabilised, the a_w value was then recorded within for 20 mins. The

a_w is a ratio, so does not have units. Values range from 0.0 for a completely anhydrous sample to 1.0 for pure, salt-free water.

Figure 3 8 - The hygrometer used for water activity

3.57 Brix

This is the percent by weight of Total sugar solids in a pure sucrose solution. A degree (1°) Brix is 1 gram of sucrose in 100 grams of solution and represents the strength of the solution as percentage by mass. This was determined using laboratory Refractometer to get the value. This was done in triplicate and the average value taken with the standard deviation.

3.58 Dietary fibre

This was achieved by using the AACC (1991) and AOAC (2007) method in which analysis was done on low or fat free sample.

Fig gum jelly sample of 1 g was weighed in duplicate, accurate to 0.1 mg, into 400 mL tall-form beakers. Then, 50 mL of phosphate buffer (pH 6.0) was added to each beaker and pH checked with pH meter and adjusted when pH was not equal 6.0±0.1. Addition of 50 µL heat-stable -amylase solution was done, and the beaker covered with aluminium foil and placed in boiling water bath. Beaker was incubated at 100 °C for 15 min. While shaking gently at 5 mins intervals. Total of 30 min in boiling water bath was sufficient

The solution was cooled to room temperature and then adjusted to pH 7.5±0.1 by adding 10 mL 0.275 N NaOH solution using pH meter. Then, 100 µL of protease solution was added and beaker covered with aluminium foil and incubated at 60 °C with continuous agitation for 30min. Then cooled with 10 mL 0.325 N HCl solution added to adjust pH to 4.5±0.2 using pH meter.

Then, 200 µL amyloglucosidase was added and covered with aluminium foil and incubated for 30 min at 60 °C with continuous agitation. Also, 280 mL 95 % EtOH pre-heated to 60 °C (volume measured before heating) was added and allowed to form precipitate at room temperature for 60 min. The crucibles containing Celite were weighed to nearest 0.1 mg, then the bed of Celite in crucible were wetted and distributed by using stream of 78 % EtOH from wash bottle before applying suction as shown in Figure 3 9 to draw Celite onto fritted glass as even mat. Maintained suction and quantitatively transferred precipitate from enzyme digest to crucible. Washing of residue successively with three 20 mL portions of 78 % EtOH, two 10 mL portions of 95 % EtOH, and two 10 mL portions of acetone was then carried out.

The crucibles containing residue were dried overnight in 70 °C vacuum oven or 105 °C air oven, cooled in desiccator and weigh to nearest 0.1 mg. The weight of residue was determined by subtracting crucible and Celite weights. The residue was analysed from one sample of set of duplicates for protein by AACC (1991) Method using N x 6.25 as conversion factor while the second residue sample of duplicate was incinerated for 5 h at 525 °C, cooled in desiccator and weighed\ to 0.1 mg. Crucible and Celite weights were subtracted to determine ash.

Figure 3 9 - Filtration process through suction during total fibre determination

3.59 Ash and Protein

Ashing was performed at 525 °C for 5 h, after which the dish was cooled in a desiccator and weighed. The difference in weight of crucible and final product after ashing was calculated and the mean of the duplicate results obtained with the standard deviation.

Protein was determined after drying, the samples were digested (including blanks) using non ash filter paper in the digestion tube and allowed to digest over a heating mantle, the clear product from the digester was added 50 mL distilled water and 50 mL of 40 % NaOH. In a conical flask was added boric acid and Tashiro indicator. The digested sample was distilled and collected into the conical flask containing the boric acid. Collected distillate was titrated with 0.1 M HCl until there was a colour change and the readings taken.

3.6 Results

3.61 Fig Gum Jelly Prediction Models

The results were analyzed through ANOVA as referred to in Table 3 5 which shows the values obtained in the work for each of the answers (Y_i) for the 21 formulations in which the independent variables x_1 (Fig Paste), x_2 (k-carrageenan) and x_3 (honey) were varied, according to table 3 2.

Table 3 5 - ANOVA for model adjustments for all the responses

Response	Model	Lack of fit	R^2	$R^2_{adjusted}$	$R^2_{predicted}$
Y_1 (Brilliance)	F= *12.34* Prob > F = 0.0015	F= *0.41* Prob > F =0.84	0.80	0.74	0.44
Y_2 (Transparency)	F= 5.10 Prob > F =0.02	F= 8.81 Prob > F =0.01	0.60	0.49	-0.12
Y_3 (Aroma)	F=10.7 Prob > F = 0.003	F=0.52 Prob > F =0.76	0.84	0.76	0.31
Y_4 (Texture A)	F= 17.91 Prob > F =0.0002	F= 1.26 Prob > F =0.44	0.75	0.71	0.50
Y_5 (Texture C)	F= 12.95 Prob > F =0.0008	F= 0.59 Prob > F =0.76	0.67	0.61	0.35
Y_6 (Sweetness A)	F= 22.03 Prob > F <0.0001	F= 0.75 Prob > F =0.67	0.77	0.74	0.57
Y_7 (Sweetness B)	F= 42.27 Prob > F <0.0001	F= 0.77 Prob >F =0.66	0.87	0.85	0.77
Y_8 (Mouthfeel)	F= 30.80 Prob > F <0001	F= 0.52 Prob > F =0.81	0.83	0.80	0.66
Y_9 (Overall Opinion)	F= 46.74 Prob > F <0.0001	F=0.12 Prob > F =0.99	0.88	0.86	0.77

The prediction models were obtained for:

In table 3 6 the prediction models were described for: Y_1 - Brilliance, Y_2 - Transparency, Y_3 - Aroma, Y_4 - Texture A, Y_5 -Texture C, Y_6 - Sweetness A, Y_7 - Sweetness B, Y_8 - Mouthfeel and Y_9 - Overall Opinion. The graphs for each response are shown in the contour plots in Figures 3 2 to 3 8, which shows the responses in the actual components.

Table 3 6 - Predicted models for the responses in actual components

Model	Reduced Quadratic	Reduced Quadratic	Reduced Quadratic	Linear	Linear	Linear	Linear	Linear	Linear
Coefi.	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Y_7	Y_8	Y_9
β1	0.066	0.045	0.067	0.038	0.044	0.043	0.038	0.04	0.04
β2	0.017	0.035	0.228	0.012	-2.278E-3	-0.013	-0.016	-6.31E-3	-0.01
β3	0.351	0.193	0.034	0.075	0.056	0.085	0.073	0.08	0.08
β12	------	-----	-3.896E-3	-----	----	----	----	----	----
β13	-5.772 E-3	-2.59E-3	------	-----	----	----	-----	----	----
β23	-------		-2.499E-3	-----	----	----	----	----	----

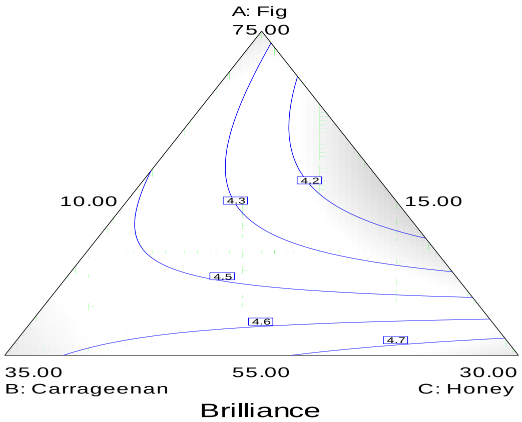


Figure 3 10 - Contour plot of the response Y_1 - Brilliance

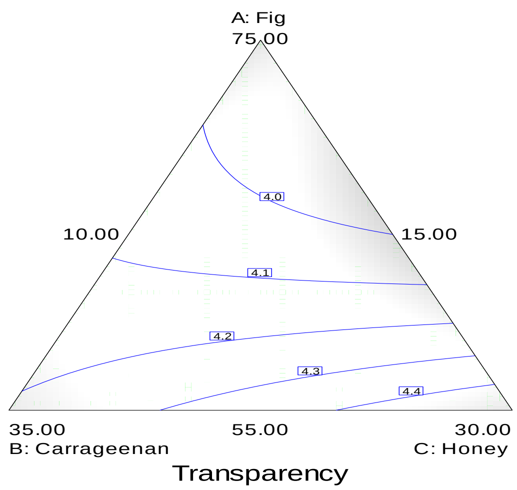


Figure 3 11 - Contour plot of response Y_2 - Transparency

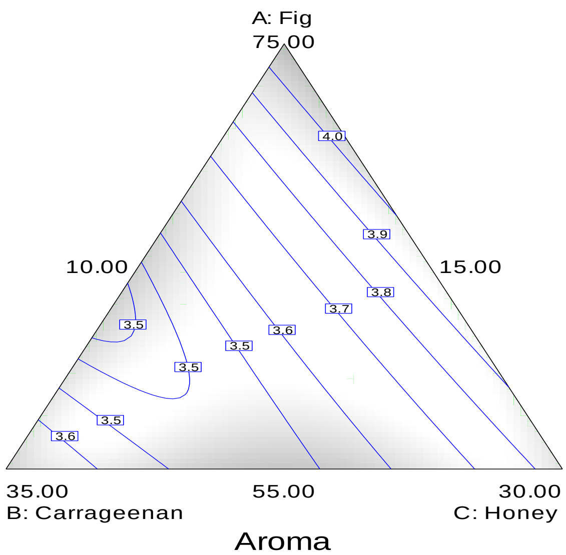


Figure 3 12 - Contour plot of response Y_3 - Aroma

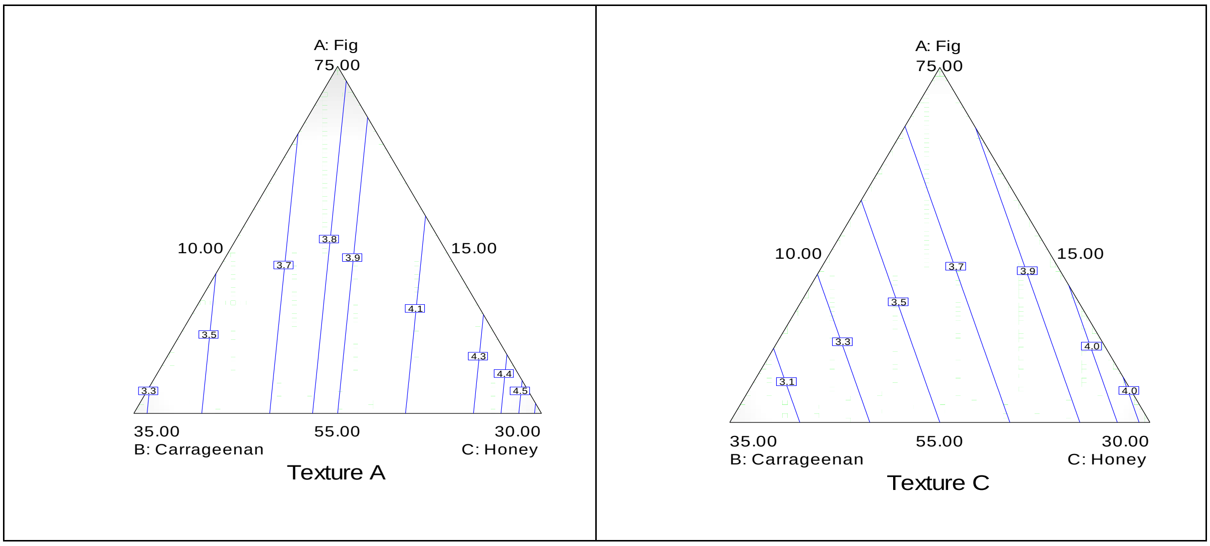


Figure 3 13 - Contour plots of response Y_4 - Texture A and Y_5 - Texture C

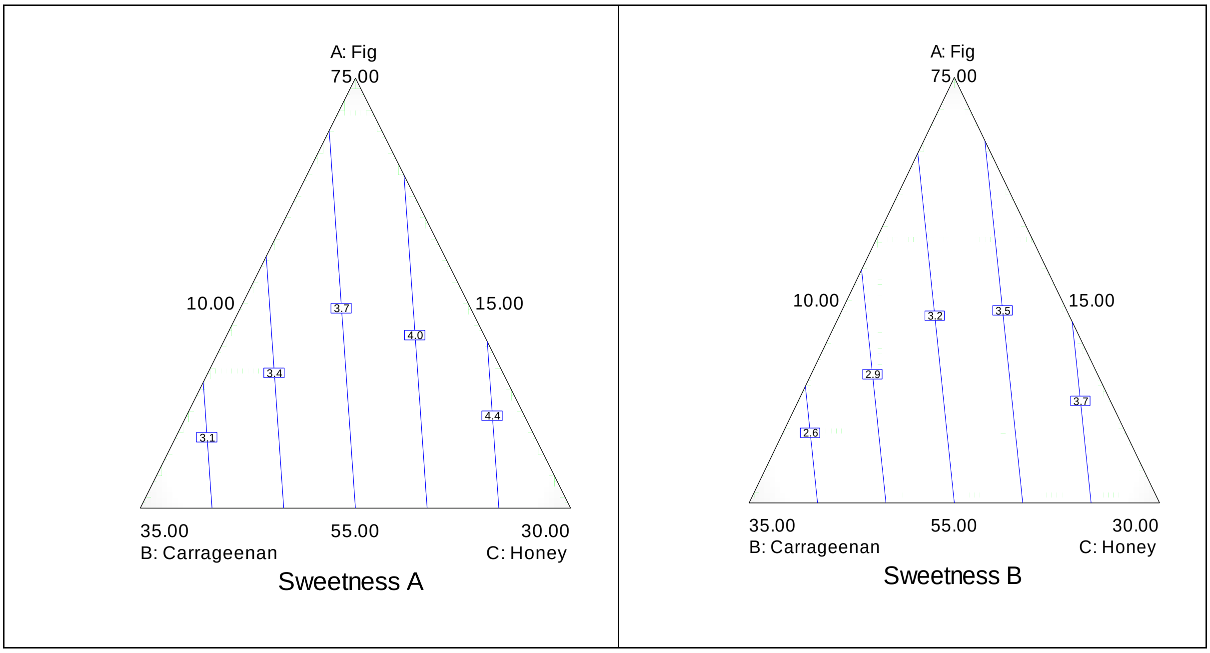


Figure 3 14 - Contour plot of response Y_6 - Sweetness A and Y_7 - sweetness B

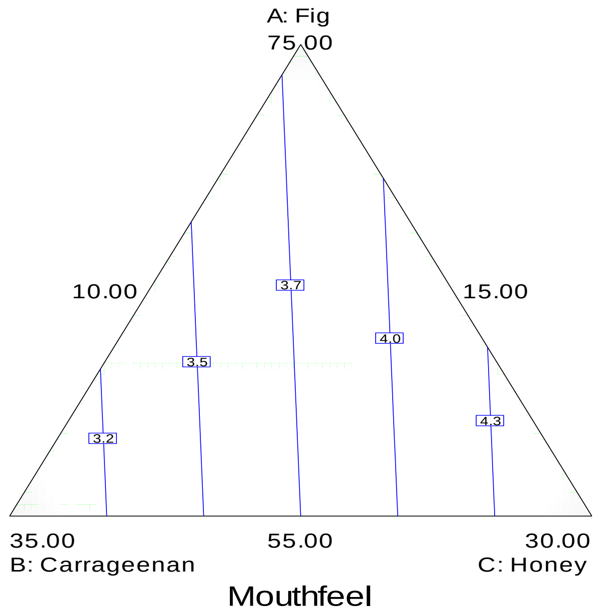


Figure 3 15 - Contour plot of response Y_8 Mouthfeel

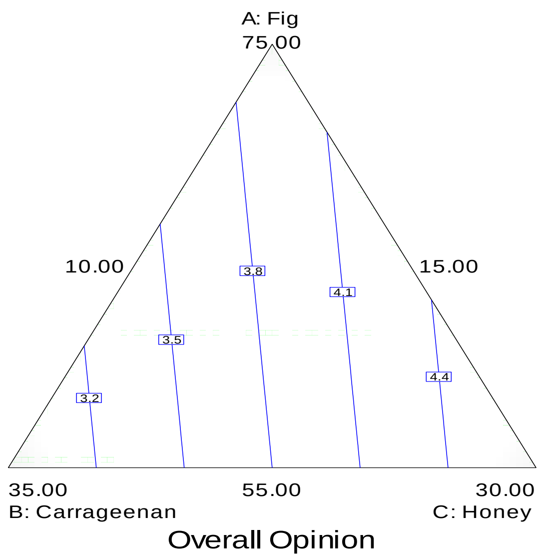


Figure 3 16 - Contour plot of response Y_9 Overall Opinion

3.62 Optimization

For optimization and validation, the parameters that had the most effect on the model were considered as restrictions. For each response, a restriction was imposed according to the requirements required for the film that was intended to develop. This restriction was in some cases a minimum value and in others a maximum value (Table 3.7). In the optimization of the best formulation, it was necessary to obtain a desirability value (di) (eq. 2) for each response, through the transformation of the Yi responses (Anderson and Whitcomb, 1996).

Table 3 7 - Optimization Criteria

Name	Goal	Lower limit	Upper limit	Lower weight	Upper weight	Importance
Fig	is in range	55	75	1	1	3
Carrageenan	is in range	15	35	1	1	3
Honey	is in range	10	30	1	1	3
Brilliance	maximize	4.5	6	1	1	3
Transparency	maximize	4	6	1	1	3
Aroma	is target = 3.5	3	4	1	1	3
Texture A	maximize	4	6	1	1	3
Texture C	is target = 3.5	2.5	4.5	1	1	3
Sweetness A	maximize	4	6	1	1	3
Sweetness B	is target = 3.5	2.5	4.5	1	1	3
Mouthfeel	is target = 3.5	2.5	4.5	1	1	3
Overall Opinion	maximize	4	6	1	1	3

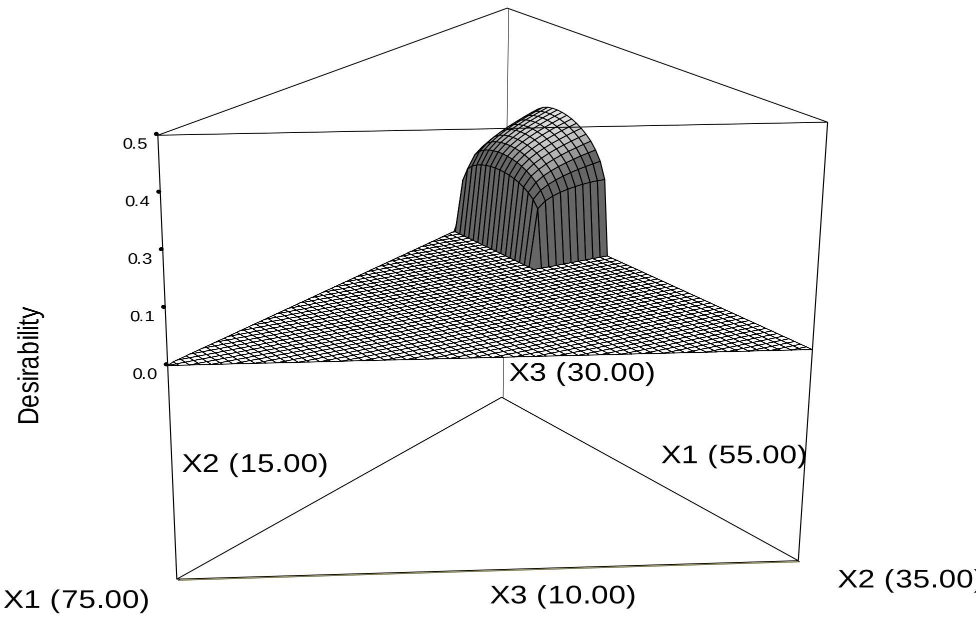


Figure 3 17 - Response Surface of the optimization result.

The percentage value for the optimized fig jelly product was found to be in percentage of 55, 15 and 30 respectively for fig, K. carrageenan and honey as shown in Table 3 8.

Table 3 8 - Percentage value of components of the optimized fig jellies

Components	fig	K.carrageenan	honey
%	55	15	30

Table 3 9 - Composition of the optimum film and corresponding values predicted for each response

Fig	55 %
Carrageenan	18.6 %
Honey	26.4 %
Y 1 Brilliance	4.8
Y2 Transparency	4.5
Y3 Aroma	3.6
Y4 Texture A	4.3
Y5 Texture C	3.8
Y6 Sweetness A	4.3
Y7 Sweetness B	3.7
Y8 Mouthfeel	4.3
Y9 Overall Opinion	4.4
Desirability	0.3

Table 3 10 - Sensory Analysis for Validation of the optimized product

Samples	Brilliance A	Transparency A	Aroma B	Texture A	Texture C	Sweetness A	Sweetness B	Mouthfeel	Overall Opinion
Optimized	5.17 ± 0.83	5 ± 1.28	4.08 ± 1.24	5.5 ± 0.52	4.75 ± 0.97	5.83 ± 0.39	4.08 ± 1.31	4.67 ± 1.15	4.75 ± 1.14
other	4.8 ±0.89	4.73 ± 0.79	3.93 ± 1.16	4.40 ± 0.78	3.73 ± 1.24	4.33 ± 0.65	4.00 ± 1.08	4.67 ± 0.89	4.27 ± 0.97

Table 3 11 is the statistical analysis of Variance (ANOVA) for the optimized and other product with their responses. This shows that the responses are significantly different from one another with $P < 0.05$ while the two samples are not significantly different from each other.

Table 3 11 Statistical analysis of variance (ANOVA) for responses and the of optimum versus other sample

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Responses	1.372272	1	1.372272	9.868222	0.013777	5.317655
Samples	2.762478	8	0.34531	2.483176	0.109923	3.438101
Error	1.112478	8	0.13906			
Total	5.247228	17				

Figure 3.18 and 3.19 show the graphical and radar representation of the sensory characteristics of the optimized and other sample which is very close to the optimized fig gum jelly, in terms of visual aspect (brilliance, trnsparency and overall opinion), aroma (aroma of fruit), texture (consistency, hardness), taste (sweetness, mouthfeel and overall opinion) and finally global appreciation. For all attributes a 6 point Hedonic scale was used ranging from 1 (Dislike extremely) to 6 (like extremely).

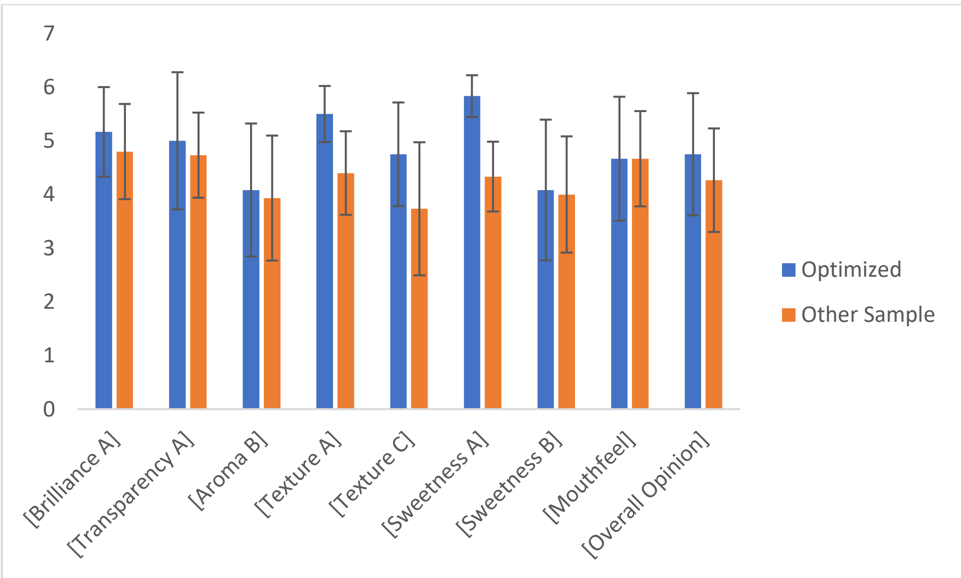


Figure 3 18 - Comparison of the optimized fig jelly against with another sample formulation randomly chosen

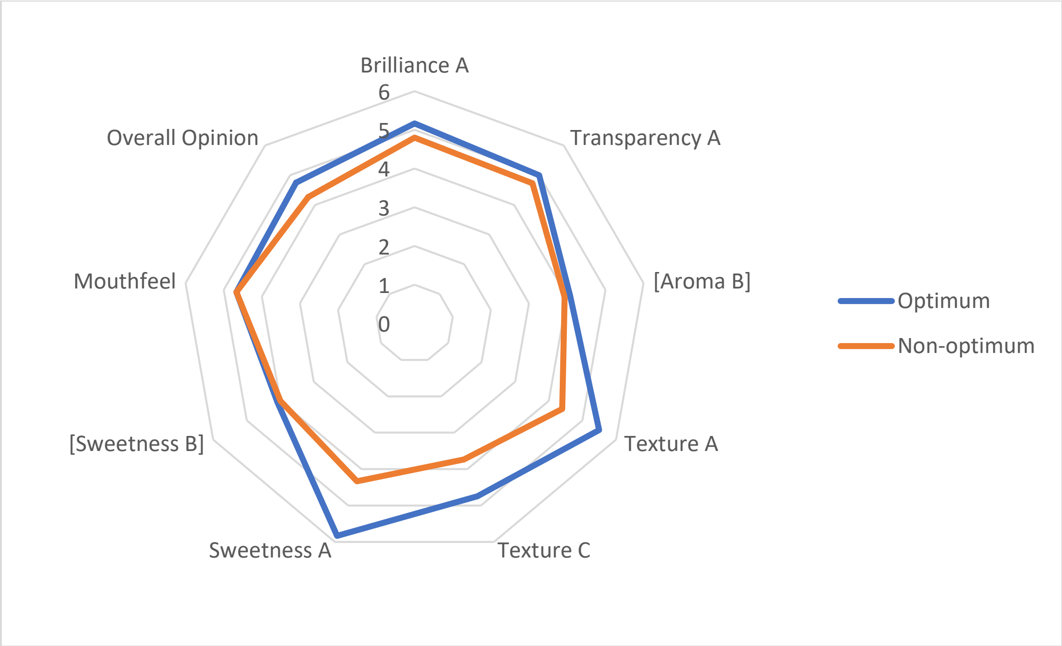


Figure 3 19 - Radar representation for optimum and non-optimum points

3.7 Statistical analysis

The experimental data were treated with the design-Expert 6.0 software. An analysis of variance (ANOVA) was performed by the design expert for model adjustment of responses. Design-Expert is a powerful program for design of experiments (DOE). It helps to screen for vital factors and detect ideal process settings to accomplish peak performance and to discover the optimal product formulations.

Chapter 4 - Shelf life study of Fig Gum

Shelf-life study is a very important subject that cannot be over-emphasized. It plays a very important role in the development of new products. It helps to know how long a particular food can be in its best nutritional quality condition at a given period, which helps in food labelling to show the expiry date, best before date and so on to give important information to manufacturers and consumers.

4.1 Design of the Shelf-life study

This shelf-life study was designed to make the products undergo microbiological analysis to achieve the best keeping quality of the product. This work was carried out aseptically to avoid the influence of external contamination by microorganism.

4.11 Packaging

The packaging of this product was a closed but unsealed polyethene film. A part of the optimum fig jelly was coated with chocolate and another part with carob before analysing the shelf life microbiologically. The shelf-life study of the three products was based on two storage conditions: 1.) refrigeration temperature and 2.) room temperature.

4.2 Microbiological Analysis of Optimum value for shelf-life study

4.21 Medium Preparation

Medium preparation was carried out according to ISO 4833(2013) and ISO 6887(2010)

4.21.1 Mould and yeast medium

For the growth of mould and yeast, The ISO Dichloran Rose Bengan chloramphenicol Agar (DRBCA) was used. This was prepared according to the manufacturer`s description by suspending 31.6 g of powder in 1 L of distilled water and heated to boiling until totally dissolved. This was then sterilized at 121 °C for 15 min.

4.21.2. Total count medium

Plate Count Agar (PCA) was formulated for total plate count according to the manufacturers prescription by dissolving 23.5 g of the powder in 1 L of distilled water and sterilized by autoclaving at 121 °C for 15mins.

4.21.3 Diluent

Diluent was prepared according to manufacturer`s direction in which one (1) tablet of the salt of Ringer`s solution was added to 500 mL of distilled water and shaken with stirrer until it was totally dissolved. This was then sterilized at 121 °C for 15min

4.22 Sterilization

The medium was autoclaved at about 15 lbs and 121 °C for 15 min. Then, the media were poured aseptically into sterilized Petri plates and set to cool.

4.23 Sample preparation

Aseptically, 10 g of each sample and 90 mL of sterile buffer peptone water were used in preparing the sample for analysis. This was taken to a mechanical stomach for digestion within one minute. This is the first dilution

4.24 Serial dilution

The serial dilution technique according to ISO 6887 was adopted. For the observation of mould and yeast, 1 mL of fig gum jelly sample to 9 mL ringer`s solution. It gave dilution of 1:10. Briefly,1 mL of suspension from 1:10 was transferred to second test tube which gave 1:100 dilutions. Similarly, 1:1,000, 1:10,000 and1:100,000 dilutions were made. Dilutions were transferred to the sterilized Petri plates containing media. Then these Petri plates were incubated at 30 °C or 25 °C for 3-5 days respectively for total plate count or mould and yeast count according to ISO 2008 for macroscopic identification Plating. Colonies obtained from plates were identified and counted with illuminated base with a dark background fitted with magnifier. The number of moulds per gram of sample was calculated from the number of colonies on plates.

4.25 Total plate count

Total Plate Count method was carried out based on the method of Keyser *et al.*, (2008). where 10 g of sample and 90 mL of sterile buffer peptone water were used in preparing a dilution. Then, a serial dilution was carried out and aseptically spread on Plate Count Agar (PCA). The prepared dishes were inverted and they were incubated at 30 °C for 48 hours.

4.26 Yeast and mould count

Then, a serial dilution was carried out and aseptically spread on Dichloran Rose Bengal Chloramphenicol Agar (DRBC). The agar plates were inverted and incubated at 25 °C for five days (ISO, 2013). After incubation plates, numbers of Petri plates were counted and multiplied by dilution factor to find out the number of spores per gram of a sample.

No: of spores/g = No of colonies × Dilution factor

4.3 Results of Microbial Analysis

The results for microbial analysis to determine the shelf life of the fig gum jelly are in Figures 4 1 and 4 2. These show the shelf life of the fig gum jelly having a moderate microbial load for unrefrigerated and refrigerated fig gum jelly products within 21 to 25 days, respectively.

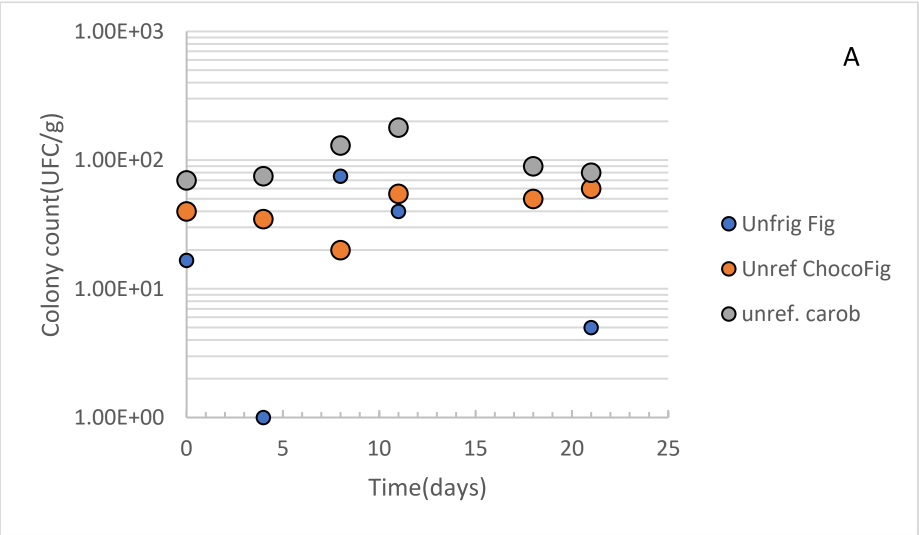


Figure 4 1- Microbial representation of colony counts for unrefrigerated samples per day.

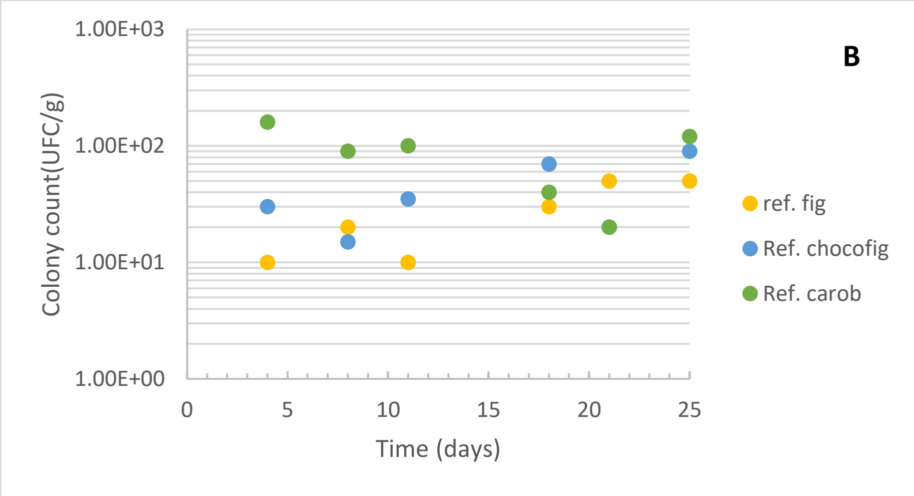


Figure 4 2 - Microbial representation of colony counts for refrigerated samples per day.

4.4 Results of Physicochemical Analysis

The results for physicochemical analysis can be observed in Tables 4 1 to 4 6. The colour analysis results determined that L*, a*, and b* parameters of fig jelly gum were affected by the formulation, the K- carrageenan dose, and the addition of sweetener (honey) and processing. The pH and the total acidity show that the product is mildly acidic which can help contribute to the quality stability and shelf life of the product this can be related to the findings of Velickova *et al.*, (2013) though their work was on strawberry. The ash content (Table 4.6) which can be used to know the level of adulteration and mineral content is very low which is a good indication of a good product. The moisture content shows a higher amount in the fresh fig than the fig gum jelly. This shows the impact of processing and food product ingredients to improve shelf life.

Table 4 1 – physicochemical analysis of fig products

Parameters for processed samples	fig Jelly gum	Carob figjelly
pH	4.58±0.01	4.84±0.13
Total acidity(g/100 mL)	2.37 ± 0.06	3.07 ± 0.06
a_w	0.87 ± 0.01	0.87± 0.001
Texture(N)	208.0 ± 28.56	
Brix(%)	49.00 ± 3.12	

The result for colour in the fig gum jelly is represented in Table 4.4 which shows L* [lightness, 0=black, 100=white], a* [greenness (−), redness (+)] and b* [blueness (−), yellowness (+)

Table 4 2 - Fig gum jelly Colour analysis

Colour	
L	39.8 ± 2.39
a	0.07 ± 0.01
b	8.14 ± 1.88
C	8.14 ± 1.88
H	89.54 ±0.11

The moisture contents of the fresh figs and the fig gum jelly products are represented in Table 4.3 below. This shows higher percentage of moisture content in the fresh fig compared to the fig jelly products.

Table 4 3 - Moisture content

Sample	Fresh Fig	Fig gum Jelly	Carob Fig	chocofig
% Moisture	76.17 ± 0.63	51.62 ± 0.31	39.45 ± 3.48	33.99 ± 1.63

Table 4 4 - Ash content of fig jelly

fig Jelly	Carob fig
0.03±0.02	0.05±0.04

The fig product has lower level of protein when compared with the protein content found in the peel and pulp of *Ficus* (2.2 ± 0.1 and 1.99 ± 0.03) respectively, as researched by Palmeira *et al*.,2019

Table 4 5 - Percentage protein of dry sample

	Protein (g)
Fig gum jelly	0.48 ± 0.04
Carobfig gum jelly	1.36 ± 0.04

The fig gum jelly product has a high fibre content as represented in Table 4 6. This is beneficial to health.

Table 4 6 - Percentage fibre of dry sample

% fibre in the dry sample (%)	
fig gum jelly	55.23
carobfig gum jelly	33.62

4.5 Treatment of results

In the treatment of the results, the values of the samples for each parameter were normalized by dividing the values of each sample by the average of the values of the fresh sample and processed sample. The standard deviation was statistically obtained to know the level of error.

4.6 Conclusion

The microbial and physicochemical analysis show that the fig gum jelly has the shelf life of about 21 days when unrefrigerated and about 25 days when refrigerated which is longer than that of fresh fig which is within a week according to research.

CHAPTER 5 - General Discussion and Conclusion

Figs are very important fruits with high nutritional values which should not be allowed to waste either in the farm or at the consumers table. Valorization of figs gives it a longer shelf life and producing a product like fig gum that can be a fun for both young and old for a healthy life. This study observed a faster drying rate with the solar oven dryer and the blanched product.
Fig gum jelly was formulated after researching on the best composition for a better sensory opinion for which Kappa carrageenan gave the best option the gums tested with fig paste and honey.

The optimization of the gum composition was carried out by using Response Surface Methodology (RSM) along with a mixture design, being the independent variables: % *fig paste*, x_1; *% k-Carrageenan*, x_2 and % *honey*, x_3. A sensory panel composed of 10 elements of both sexes evaluated six (6) responses: *brilliance* (Y_1), *transparency* (Y_2), *aroma* (Y_3); *texture* (Y_4); *sweetness* (Y_5) and *overall opinion* (Y_6) originating six polynomial models. Through numerical optimization, the best fig gum jelly composition was found to be one with: 55 % fig paste, 15 % k-carrageenan and 30 % honey with significant responses.

The optimum predicted responses matched the averaged values given by the panellists after validation.
Shelf life of the product was achieved through microbial and physicochemical analysis of the fig gum jellies**.**
A formulation of fig gum jelly that was acceptable by the panellists was obtained. The fig gum jelly could stay up to 25 days for refrigerated and 21 days for unrefrigerated product which is longer than the shelf life of the fresh fig that is within a week from research. Although, properly sealed plastic pouches could have been used to further increase the shelf life of the product, proper packaging material with a modified atmospheric condition could further increase the shelf life of the fig gum jelly in future research.

This study will be a contribution to product development in food industries which is sustainable to the economy and the environment. More study needs to be performed to increase the shelf life without reducing the nutritional quality of the product

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Appendix

Weghts during fig drying

R	Xaverage	SDD	X	dx/dt	R		CDF	X	dx/dt	R		CDD	x	dx/dt	R		TEMP°C		A Area cm2		
		675.8	0.553036				648.8	0.553036				704.8	0.553036				38.2		780		
0.102345	0.542669	668.5	0.53626	-0.01678	0.093558	0.544648	646	0.546334	-0.0067	0.035832	0.549685	702.6	0.548188	-0.00485	0.028216	0.550612	77				
0.108741	0.521286	662.4	0.522242	-0.01402	0.078179	0.529251	643.6	0.540589	-0.00574	0.030713	0.543461	701.3	0.545324	-0.00286	0.016673	0.546756					
0.094669	0.500681	658.3	0.51282	-0.00942	0.052546	0.517531	641.3	0.535083	-0.00551	0.029433	0.537836	700	0.542459	-0.00286	0.016673	0.543892	64.6				
0.13049	0.477873	655.3	0.505926	-0.00689	0.038448	0.509373	638.7	0.52886	-0.00622	0.033273	0.531972	698.4	0.538934	-0.00353	0.020521	0.540697	60.8				
0.042217	0.460378	653.6	0.502019	-0.00391	0.021787	0.503972	637.4	0.525748	-0.00311	0.016636	0.527304	697.4	0.53673	-0.0022	0.012826	0.537832	61.7				
0.034541	0.452602	651.8	0.497882	-0.00414	0.023069	0.499951	636.1	0.522636	-0.00311	0.016636	0.524192	696.7	0.535188	-0.00154	0.008978	0.535959	55.6		Ls		
																			g of dry solid	0.078	Ls/A
0.003678	0.443142	625.3	0.436984	-0.00381	0.021227	0.467433	623	0.491279	-0.00196	0.010478	0.506957	668.1	0.472167	-0.00394	0.022926	0.503677		SDF	385.82488	0.385	4.935897
0.223879	0.414502	620.9	0.426872	-0.01011	0.056391	0.431928	620.4	0.485055	-0.00622	0.033273	0.488167	666.6	0.468862	-0.00331	0.019238	0.470515		SDD	435.14762	0.435	5.576923
0.115138	0.38016	617	0.41791	-0.00896	0.049983	0.422391	617.6	0.478353	-0.0067	0.035832	0.481704	665.2	0.465777	-0.00308	0.017956	0.46732		CDF	417.76232	0.417	5.346154
0.052452	0.363183	614.4	0.411935	-0.00597	0.033322	0.414922	615	0.472129	-0.00622	0.033273	0.475241	663.7	0.462472	-0.00331	0.019238	0.464124		CDD	453.82072	0.454	5.820513
0.134328	0.344263	607.4	0.395848	-0.01609	0.089713	0.403891	610	0.46016	-0.01197	0.063986	0.466145	661	0.456522	-0.00595	0.034629	0.459497					
0.024307	0.328193	606.4	0.39355	-0.0023	0.012816	0.394699	609	0.457767	-0.00239	0.012797	0.458964	660.6	0.455641	-0.00088	0.00513	0.456082					
0.015352	0.324176						598.1	0.431675	-0.02609	0.139489	0.444721	657.3	0.448369	-0.00727	0.042324	0.452005					

0.144562	0.307977	604.2	0.388494	-0.00253	0.014098	0.391022	596.2	0.427127	-0.00455	0.024315	0.429401	655.9	0.445284	-0.00308	0.017956	0.446827
0.051172	0.288149	601.9	0.383209	-0.00529	0.029477	0.385852	593.8	0.421382	-0.00574	0.030713	0.424255	654.7	0.44264	-0.00264	0.015391	0.443962
0.002079	0.279596	599.7	0.378153	-0.00032	0.001762	0.380681	600.7	0.437899	0.001032	-0.00552	0.429641	643.4	0.41774	-0.00156	0.009058	0.43019
0.01919	0.274283	598.2	0.374706	-0.00345	0.019224	0.376429	599.1	0.434069	-0.00383	0.020475	0.435984	642.6	0.415978	-0.00176	0.01026	0.416859
0.031983	0.269099	595.4	0.368271	-0.00643	0.035885	0.371489	596.9	0.428803	-0.00527	0.028154	0.431436	641.3	0.413113	-0.00286	0.016673	0.414545
0.026866	0.263138	594.3	0.365743	-0.00253	0.014098	0.367007	594.7	0.423537	-0.00527	0.028154	0.42617	636.2	0.401875	-0.01124	0.06541	0.407494
0.010234	0.25938	593.2	0.363216	-0.00253	0.014098	0.364479	593	0.419467	-0.00407	0.021755	0.421502	631	0.390417	-0.01146	0.066693	0.396146
0.005117	0.257825						591.9	0.416834	-0.00263	0.014077	0.418151	627	0.381603	-0.00881	0.051302	0.38601
							590.8	0.414201	-0.00263	0.014077	0.415518	624.9	0.376975	-0.00463	0.026934	0.379289
0.010234	0.255233	a	0.35839	-0.00161	0.008971	0.179195	580.4	0.389307	-0.02489	0.13309	0.401754	623.5	0.373891	-0.00308	0.017956	0.375433
0.021748	0.250956	590.2	0.356321	-0.00207	0.011535	0.357355	576.9	0.380929	-0.00838	0.04479	0.385118	621.5	0.369484	-0.00441	0.025651	0.371687
0.009435	0.233461	580.2	0.333341	-0.00144	0.00801	0.344831	561.4	0.343826	-0.00232	0.012397	0.362378	608.2	0.340177	-0.00183	0.010661	0.35483
0.025586	0.215577	578	0.328285	-0.00506	0.028196	0.330813	559	0.338081	-0.00574	0.030713	0.340954	606.5	0.336431	-0.00375	0.021803	0.338304
0.030703	0.209875	574.9	0.321161	-0.00712	0.03973	0.324723	554.7	0.327788	-0.01029	0.055028	0.332935	604.2	0.331363	-0.00507	0.029499	0.333897
0.01919	0.204821	573.7	0.318403	-0.00276	0.015379	0.319782	552.5	0.322522	-0.00527	0.028154	0.325155	603	0.328719	-0.00264	0.015391	0.330041
0.016631	0.201193	572.4	0.315416	-0.00299	0.016661	0.316909	536.6	0.284462	-0.03806	0.203474	0.303492	591.4	0.303158	-0.02556	0.148777	0.315938

0.010234	0.198471	572	0.314496	-0.00092	0.005126	0.314956	535.2	0.281111	-0.00335	0.017916	0.282787	590.7	0.301615	-0.00154	0.008978	0.302387
							529	0.26627	-0.00495	0.026447	0.273691	589.7	0.299412	-0.00073	0.004275	0.300514
							526.7	0.260765	-0.00551	0.029433	0.263517	588.4	0.296547	-0.00286	0.016673	0.29798
							524.5	0.255499	-0.00527	0.028154	0.258132	587.1	0.293683	-0.00286	0.016673	0.295115

Moisture content for fresh figs

Sample	Weight of dish (g)	Dish +sample (g)	Weight of sample (g)	Dish weight +dried sample (g)	Final weight (g)	Weight of moisture (g)	% of moisture (%)	Average % of moisture (%)	Stanard Deviation
Fresh Fig	44.0681	49.2166	5.1485	45.3203	1.2522	3.8963	75.6784	76.1718	0.6301
	45.9369	50.974	5.0371	47.1014	1.1645	3.8726	76.8815		
	38.8142	43.8436	5.0294	40.0235	1.2093	3.8201	75.9554		

Moisture content for fig gum jelly Products

Sample	Weight of dish(g)	Dish +sample (g)	Weight of sample (g)	Dish weight + sample (g)	Final weight(g)	Weight of moisture (g)	% of moisture (%)	Average % of moisture (%)	Standard Deviation
Fig Jelly	38.995	44.023	5.028	41.4197	2.4247	2.6033	51.7761	51.6244	0.31796
	48.5549	53.5653	5.0104	50.968	2.4131	2.5973	51.8382		
	41.2376	46.2812	5.0436	43.6959	2.4583	2.5853	51.259		
Carob Fig	40.7532	45.7752	5.022	43.9955	3.2423	1.7797	35.4381	39.4515	3.48763
	41.3735	46.3887	5.0152	44.3239	2.9504	2.0648	41.1708		
	39.2689	42.8858	3.6169	41.3759	2.107	1.5099	41.7457		
chocofig	41.815	46.8639	5.0489	45.1833	3.3683	1.6806	33.2865	33.9932	1.63138
	41.0139	46.0269	5.013	44.2293	3.2154	1.7976	35.8588		
	39.3383	44.3483	5.01	42.7033	3.365	1.645	32.8343		

Ash content of fig jelly

	Crucible weight	Dish + sample	Wt of sample (g)	Average of sample wt	Dish wt +dried sample(g)	Wt of ash (g)	Average of ash (g)	% ash (%)
	26.6704	28.6774	2.01	2.04	26.69	0.02	0.0354	1.7399
	26.0171	28.0725	2.06		26.05	0.03		
Fig gum Jelly	24.3924	26.445	2.05		24.45	0.06		
	29.6464	31.7214	2.08	2.04	29.67	0.03	0.0539	2.6481
	21.387	23.4106	2.0236		21.42	0.03		
Carob Fig gum jelly	26.9963	29.0038	2.0075		27.10	0.10		

Colour of fig gum jelly

	L	a	b	c	h°
	41.49	0.07	9.47	9.47	89.61
	38.11	0.06	6.81	6.81	89.46
Average	39.8	0.07	8.14	8.14	89.54
Std	2.39	0.01	1.88	1.88	0.11

Water activity of fig product

Sample	aw		Average	Std
Fig gum jelly	0.86	0.881	0.8705	0.014849
choco fig gum jelly	0.87	0.869	0.8695	0.000707

Brix

Brix	52.5
	46.5
	48
Average	49
Std	3.122499

Texture for fig gum jelly

Peak loads	196
	216.8
	239.6
	244.2
	210.4
	166.6
	182.6
Average	208.0286
std	28.56371

Microbial result for unrefrigerated samples of fig jellies

Time (days)	**unref. Fig**	**unref. chocofig**	**unref. Carobfig**
0	1.67E+01	4.00E+01	7.00E+01
4	1	3.50E+01	7.50E+01
8	75	2.00E+01	130
11	40	5.50E+01	180
18	1285	5.00E+01	90
21	5	6.00E+01	80
25	uncountable	uncountable	uncountable

Microbial result for refrigerated samples of fig jellies

Time (days)	**ref. Fig (CFU)**	**ref.chocofig (CFU)**	**ref. Carobfig(CFU)**
0			
4	1.00E+01	3.00E+01	1.60E+02
8	20	15	90
11	10	35	100
18	30	70	40
21	50	20	20
25	50	90	120
28	uncountable	uncountable	uncountable