# Production, optimization and validation of fig gum products for Extended shelf-life

**Abstract**: The purpose of this study was to improve the sensory qualities of fig gum jelly by optimizing its formulation using Response Surface Methodology (RSM) and mixture design. To assess how important ingredients affected the sensory qualities of fig gum jelly, an experimental design technique was used. The investigation was carried out at Instituto Superior de Engenharia, Universidade Do Algarve, Faro Portugal. Fig paste (x1), k-carrageenan (x2), and honey (x3) were used as independent variables in the mixture design. Ten trained assessors of both sexes participated in the sensory evaluation, rating six sensory attributes: overall acceptability (Y1), openness (Y2), fragrance (Y3), texture A (Y4), texture B (Y5), sweetness A (Y6), sweetness B (Y7), mouthfeel A (Y8), and mouthfeel B (Y9). For every response, polynomial regression models were created. The optimal formulation was found by numerical optimization. It was discovered that a composition of 55 % fig paste, 15 % k-carrageenan, and 30 % honey produced the best fig gum jelly. Validation by the sensory panel confirmed this formulation with a desirability score of 0.3, indicating strong alignment with consumer preference.

**Keywords***:* K-carrageenan, fig, fig gum jelly, shelf life & RSM.

1. **INTRODUCTION**

Although its origin is unknown, figs have been a staple in the diets of people of the Middle East and Mediterranean region since ancient times due to their lifespan [1]. Out of all the fig species, *Ficus carica* is the most important commercially [2]. With approximately 800 species of epiphytes, trees, and shrubs in tropical and subtropical climates worldwide, it is one of the largest genera of Angiosperms and an evergreen tree of the mulberry family *moraceae* with significant nutritional value [3]. In the Mediterranean and Middle East regions, figs are part of their staple diet since the ancient years and it has been considered because of the sign of longevity [1, 14]. Because figs are low in fat and cholesterol and abundant in amino acids and phenolic compounds, they are utilized as a delicious source of minerals, vitamins, carbohydrates, and dietary fiber [4,5].

Fig fruits can be consumed raw, dried, canned, or preserved in various ways, such as jam and sweets, which can be consumed right away or used to make cakes and other treats. According to USDA data, among dried fruits, dried figs have the greatest nutrient score since they are a significant source of vitamins and minerals [6]. Iron, protein, calories, and fiber are all abundant in figs. Compared to milk, it has the highest calcium content. According to Gani et al. [7], fig has nutritive index of 11, as against 9, 8 and 6 for apple, raisin and date, respectively

According to Villalobos et al. [8], the fig is classified as a climacteric fruit with a moderate rate of ethylene production and respiration. The fruit's commercial quality is mostly determined by the maturity stage at which it is picked. Figs are extremely perishable, just like other fruits and vegetables. Numerous packing methods created by researchers have the potential to increase the shelf life of figs by up to 21 days following harvest. Due to the afore-mentioned facts, a large portion of the figs that are collected are often processed into dried figs. Currently, this approach is evolving because of growing market demand.

According to a recent study [9], some packaging forms can quadruple the shelf life of fresh figs, extending the shelf life of fig varieties. Their use of ultrasonic pre-treatments to save drying times and enhance fruit handling is one of their most intriguing advances [16]. Unlike typical sun drying methods, which need an average of fifteen days, the fruit can be dried in as little as one to three days.

Because the thin fruit skin can easily rupture, causing rapid loss of nutritional contents and increased permeability for microbial invasion, figs are extremely perishable and difficult to handle and store after harvest [17]. Only a small percentage of figs can occasionally be sold as fresh fruits while maintaining all their nutritional and sensory qualities [15].

Traditionally, to extend the shelf life, figs are dried and eaten in this manner or in snack bars or cookies. [10]. This study aims to add value by producing fig gum jelly which can be available all year round with longer shelf life and evolution of new products.

Table 1 is a summary of the nutritional content of both fresh and dried figs.

**Table 1 - Nutritional content of fresh and dried figs**

**Source:** USDA FoodData Central https://fdc.nal.usda.gov/ [11]

|  |  |  |
| --- | --- | --- |
| 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 |

This crop could be valued by producing a fig product with nutritional properties close to fresh fruit but with longer shelf life which is the basis of this research.

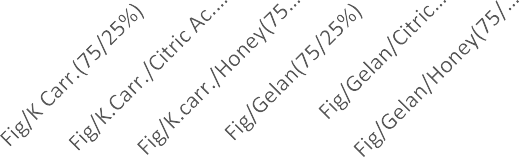
# MATERIALS AND METHODS

Three distinct hydrocolloids K-carrageenan, gellan gum and sodium alginate were first evaluated to see how well they improved viscosity, stability, and texture to make fig gum with a longer shelf life. Because of its superior gel-forming ability, consistency, and stability in the finished product, K-carrageenan was chosen as the optimal thickener based on preliminary trials.

**Preparation of Fig Gum with K-Carrageenan**

The final formulation contained K-carrageenan at a concentration of 1.0% (w/w). To avoid clumping, the hydrocolloid was first diluted 1:10 in cold distilled water. After which the mixture was heated to 80°C while being constantly stirred to achieve complete dissolution. The formulation's pH was kept between 6.0 and 7.0 to ensure optimal gel formation. To ensure appropriate gelation, the solution was cooled progressively to 40 to 50°C, allowing proper gelation. The formulated fig gum was evaluated for texture, viscosity, and shelf stability, confirming its suitability for extended storage. To create fig gums, fig was mixed with different natural food ingredients in different proportions until an optimum design was produced. To determine the product's ideal texture, firmness was examined. This is shown in Fig. 1A & B.

A B



400

350

300

250

200

150

100

50

0

1200

1000

800

600

400

200

0

**Fig. 1 A, B - Textural analysis of fig gum using flat end and knife edge probe, respectively.**

Through the investigation to develop fig gum jelly, the best result was obtained as shown in Table 2.

**Table 2 - Constitution of Kappa carrageenan solution.**

|  |  |
| --- | --- |
| **Water(mL)** | **Gum(g)** |
| **92.5** | **7.5** |

**Mixture Design**

Four ingredients were used to create fig jelly gum: water, honey, k-carrageenan, and fig paste. The K-carrageenan always contained water at a fixed percentage (92.5%). Each component's minimum and maximum levels were determined, as shown in Table 3.

**Table 3 - Minimum and maximum limits for x1; x2 and x3 to establish the mixture design**

|  |  |  |
| --- | --- | --- |
|  | Mínimum (%) | Máximum (%) |
| *x1 Fig paste* | 55 | 75 |
| *x2* k-carrageenan | 15 | 35 |
| *x3 Honey* | 10 | 30 |

According to Anderson and Whitcomb [12], to choose the optimal amount of experience, polynomial was chosen to obtain a prediction model for the result obtained. In this instance, we chose Scheffée's quadratic polynomial model:

*Yi*= *β1x1* + *β2x2* + *β3x3* + *β12x1x2* + *β23x2x3* + *β13x1x3* eq. (1**)**

Where *Yi* is the value of the dependent variable of parameter *I and x1, x2* and *x*3 *represent* the three components of the film; *β1, β2* and *β3* represent the linear regression coefficients; *β12*, *β23* and *β13* are the quadratic regression coefficients [12].

First, it selected each component's lowest and maximum values based on Table 3. To fit the selected polynomial model, the software then produced a design with several surplus points. In order to minimize the standard deviation error in the most central region, which was of the greatest interest, and 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 the lack of adjustment of the model to the experimental points (*g.l*. 3; Table 3, 4 and Figure 2), an evaluation was conducted after the design was obtained.

Because the studies were conducted on three separate days, the design was split into three blocks to minimize or eliminate error. To assess the pure error, the center and vertices were duplicated. A total of eighteen experiences were used to obtain a design.

**Table 4- Mixture Design**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  | Component 1 | Component 2 | Component 3 |
| Std | Run | Block | A: Fig pastes | B: carrageen | 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 2 - Standard Error estimation within the design triangular area and experimental points distribution**

**Sensory Evaluation**

The judges were asked to rate how much they liked or disliked the product using six points on the hedonic scale.

Ten trained assessors of both sexes who are experts in sensory evaluation from the department of food engineering participated in the sensory evaluation, rating six sensory attributes: overall acceptability, openness, fragrance, texture, sweetness and mouthfeel. This was carried out in a controlled environment at the sensory laboratory. Six-point hedonic scale method was used.

**Optimization of Fig jelly gum**

Through experimental design and sensory research, the optimal formulation of fig jelly gum was optimized. The numbers of independent parameters that produce the least variation on the desired quality were chosen using an experimental methodology.

To learn more about the system, it was also utilized to fit experimental data to an empirical function. Following the establishment of objectives and constraints (minimum and maximum) for every response, the estimates were transformed to produce a desired range (13).

**Validation of the optimum formulation**

Desirability, a multiple response technique, was used to optimize. A process for defining the connection between expected answers on a dependent variable and the attractiveness of the responses was included in this optimization approach, along with preferences and priorities for every variable created.   
The same sensory panel used the optimal value and a close-to-optimal but deviant choice to confirm the optimal formulation. The optimal value was then maintained with the higher value after the mean and standard deviation were computed.

**RESULTS AND DISCUSSION**

1. **Fig Gum Jelly Prediction Models**

Table 5 shows the prediction models for: Y1 Y2, Y3, Y4, Y5, Y6, Y7, Y8 and Y9. The graphs for each response are shown in the contour plots in Figure 3, showing the responses in the actual components.

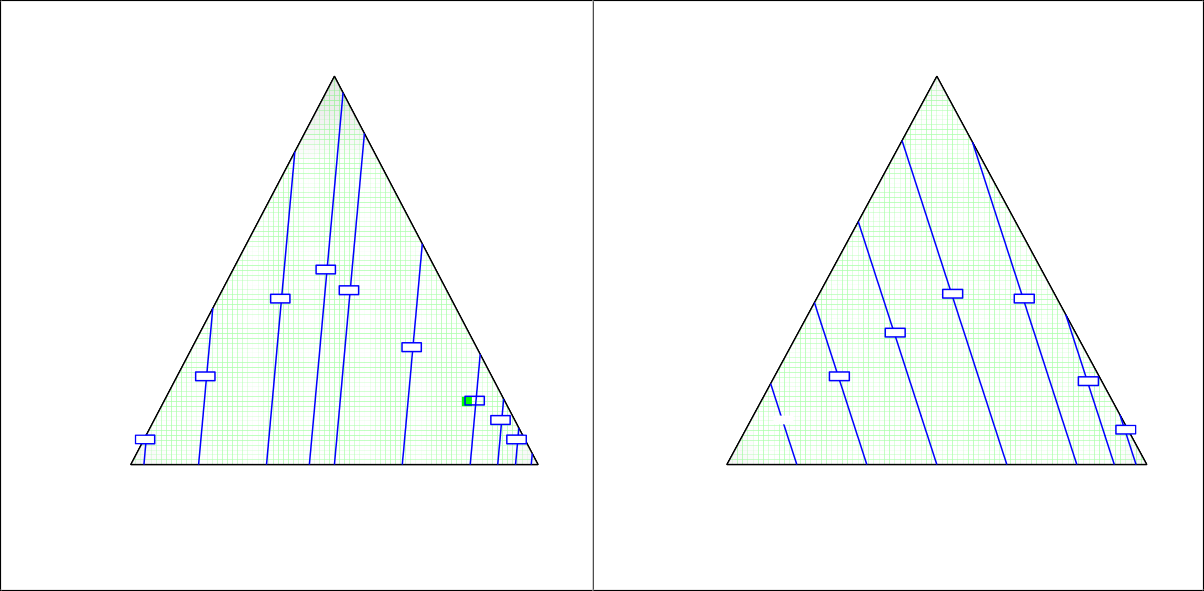
**Table 5 - Predicted models for responses in actual components**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Mode l | Reduced Quadratic | Reduced Quadratic | Reduced Quadratic | Linear | Linear | Linea r | Linea r | Linea r | Linea r |
| Coefi  . | *Y*1 | *Y2* | *Y*3 | *Y*4 | *Y*5 | *Y*6 | *Y7* | *Y8* | *Y9* |
| β1 | 0.066 | 0.045 | 0.067 | 0.038 | 0.044 | 0.043 | 0.038 | 0.04 | 0.0  4 |
| β2 | 0.017 | 0.035 | 0.228 | 0.012 | -2.278E- 3 | - 0.013 | - 0.016 | -6.31E- 3 | -  0.0  1 |
| β3 | 0.351 | 0.193 | 0.034 | 0.075 | 0.056 | 0.085 | 0.073 | 0.08 | 0.0  8 |
| β12 | ------ | ----- | -3.896E-3 | ----- | ---- | ---- | ---- | ---- | ---- |
| β13 | -5.772  E-3 | -2.59E-3 | ------ | ----- | ---- | ---- | ----- | ---- | ---- |
| β23 | ------- |  | -2.499E-3 | ----- | ---- | ---- | ---- | ---- | ---- |

A: Fig A: Fig







A: Fig 75.00

A: Fig 75.00

10.00

3.8

3.9

15.00

10.00

15.00

3.7

3.7

3.9

3.5

1

3.3

4.0

4.4

4.0

3.3

4.5

35.00

B: Carrageenan

55.00

30.00

C: Honey

35.00

B: Carrageenan

55.00

30.00

C: Honey

Texture A Texture C

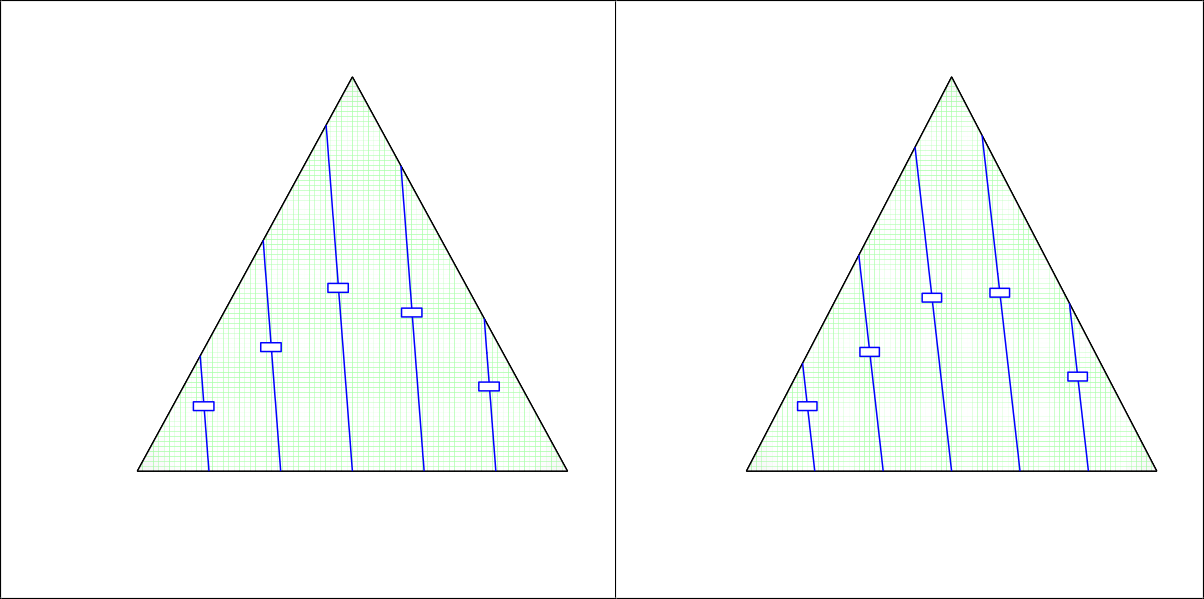
3.5

3

4.

4.

3.1



A: Fig 75.00

A: Fig 75.00

10.00

3.7

15.00

10.00

3.2

3.5

15.00

4.0

3.4

4.4

2.6

35.00

B: Carrageenan

55.00

30.00

C: Honey

35.00

B: Carrageenan

55.00

30.00

C: Honey

Sweetness A Sweetness B

3.1

3.7

2.9

A: Fig

A: Fig

**Figure 3 - Contour plots of the response Y1, Y2, Y3, *Y4*, *Y5*, Y6, Y7, Y8 and Y9 respectively.**

**Optimization**

Optimization and validation of the parameters with higher effect on the model were considered as restrictions. For each response, a restriction was imposed according to the requirements for the film developed. This restriction was either minimum or maximum value (Table 6). In the optimization of the best formulation, a desirability value (di) (Equation 1) was obtained for each response, through the transformation of the Yi responses (14).

**Table 6- 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 4 - Response Surface of the optimization result.**

The percentage value for the optimized fig jelly product is shown in Table 7

**Table 7 - Percentage value of the optimized fig jellies components.**

|  |  |  |  |
| --- | --- | --- | --- |
| Components | fig | K.carrageenan | honey |
| % | 55 | 15 | 30 |

The ANOVA for the optimized fig jelly product and the 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 8 - Statistical analysis of variance (ANOVA) for responses and the of optimum versus another 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 |  |  |  |  |

The figure 5 below shows the radar representation of the sensory characteristics of the optimized and other sample, which is close to the optimized product, in terms of responses.



Brilliance A

6

Overall Opinion

Mouthfeel

5

4

3

2

1

0

Transparency A

[Aroma B]

Optimum

Non-optimum

[Sweetness B]

Texture A

Sweetness A

Texture C

**Figure 5 - Radar representation for comparison of the optimum and non-optimum points**

**Statistical Analysis**

Statistical analysis was conducted using Design-Expert Software (version 13, Stat-Ease Inc., Minneapolis, USA). Analysis of variance (ANOVA) was performed to assess the significance of model terms, screen for vital factors, and determine optimal process settings for peak performance. The software facilitated response surface modeling (RSM) to optimize the formulation parameters and evaluate interactions between variables. Model adequacy was verified through diagnostic plots and statistical significance tests.

**CONCLUSIONS**  
Figs are highly nutritious fruits that should not go to waste. Processing figs extends their shelf life and creates value-added products like fig gum jelly, which is enjoyable and promotes good health. This study found that blanching and solar oven drying accelerated the drying process. Kappa carrageenan, combined with fig paste and honey, was the best formulation for superior sensory quality.

Using Response Surface Methodology (RSM) and mixture design, fig paste (x1), k-carrageenan (x2), and honey (x3) were optimized. A sensory panel evaluated six attributes, leading to an optimal composition of 55 % fig paste, 15 % k-carrageenan, and 30 % honey. The validated formulation aligned with panelists’ preferences. Fig gum jelly demonstrated a shelf life of 25 days refrigerated and 21 days at room temperature, significantly longer than fresh figs. Future studies could explore advanced packaging techniques, such as modified atmosphere packaging, to extend shelf life further. The product is in figure 6.

A close up of food

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Figure 6 - Fig gum jelly product

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