



## PREPARATION OF COACERVATES COMPLEX FROM ISOLATE FENUGREEK SEED PROTEIN AND ITS GUM FOR CAPSULE SHELL PRODUCTION.

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### ABSTRACT

The isolate of fenugreek protein and fenugreek gum were extract previously obtained using steps conducted from Fenugreek seed. The fenugreek seed protein isolate (FPI) and Fenugreek seed gum (FG) were prepared as a coacervates complex as well as they were studied its characteristics. The best proportion of FPI-FG were optimized to obtain the highest production of (capsule shell) coacervates complex support by estimating of zeta potential and turbidity values. It was found the pH (4.0), FPI- to-FG proportion(6 protein to1 gum) had the best yield for complex production .The freeze-drying dried technique was ultilized to obtain the coacervates complex had the most stability particles by reducing its humidity. Therefore, the purpose of cross-linked formation between FPI-to-FG complex coacervates was obtained as a cover to protect against the sensitive effects of oxygen and heat factors whether food or medical supplies.

**Keyword:** fenugreek seed, complex coacervates, zeta potential, freeze dried.

### تحضير complex coacervates من معزول بروتين بذور الحبة وصمع بذور الحبة لعمل غلاف كبسولة

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### الخلاصة

تم عزل وتجهيز معزول بروتين الحبة ومستخلص صمع الحبة من بذور الحبة مسبقاً في المختبر المركزي التابع لكلية علوم الهندسة الزراعية - جامعة بغداد. استخلص معزول بروتين بذور الحبة (FPI) وصمع بذور الحبة (FG) وحضر منها Complex coacervates وتمت دراسة صفاتها. وقد درست النسبة الامثل لمعقد البروتين وصمع الحبة للحصول على أعلى إنتاج من (مادة الغلاف) معقد بروتين وصمع الحبة Complex coacervates من خلال تقدير قيمة زيتا والمعكار. حيث وجد ان الاس الهيدروجيني 4.0 ونسبة خلط بروتين : صمع 1:6 أعطت افضل حصيلة لانتاج المعقد، استخدمت تقنية التجفيف للحصول على مادة اكثر ثباتاً بتقليل نسبة رطوبتها. ان الغاية من تكوين هذا المعقد Complex coacervates بين معزول بروتين الحبة وصمع الحبة هو الحصول على غلاف للحماية من تأثيرات الأوكسجين والحرارة لمواد حساسة لهذه العوامل، سواء كانت مواد غذائية أو طبية.

الكلمات المفتاحية: بذور الحبة ، معقد complex coacervates ، تقنية زيتا ، التجفيف.

\* The article is taken from the doctoral thesis of the first researcher.



## INTRODUCTION

Fenugreek (*Trigonella foenum gracum* L.) is legume cereale belonging to Leguminosae or Fabaceae family. fenugreek is a pretty source of protein (27.5%) (Tavakoly *et al.*, 2018), (Aziz *et al.*, 2011) which was used to employed as health food in pharmaceutical and nutraceutical domain. (Dhull *et al.*, 2021). Due to its abundance of many nutritious components, including proteins, lipids, and carbohydrates, fenugreek (*Trigonella foenum-graecum* L.) has been a staple in most regions around the world for centuries. minerals, vitamins, carbs, and other nutrients (Yaseen *et al.*, 2011), there is a great interest in finding novel sources of plant proteins because of the paucity of animal proteins with equivalent nutritional and functional advantages in food systems (Al-Saddi *et al.*, 2009) Ingredients-wise, the seeds also have a lot of pharmacological and medical ingredients (AL-hadwany, 2004).

Fenugreek gum is component of galactomannans, its molecular structure is composed of a (1-4)- $\beta$ -D-mannan vertebral to single  $\alpha$ -D-galactopyranosyl groups. The polymer is rich in hydroxyl groups and have hydrogen bonds with water to viscous solution. (Salarbashi *et al.*, 2019). The research has focused on the characterizations of fenugreek gum of its potential applications in food, food products, pharma and different industrial uses (Yaseen, 2011), (Inas *et al.*, 2013).

The type of polymers utilized, their ratio, concentration, and charge density all have an impact on the complex coacervation process. The complex coacervates process are affected in other factors such as pH, temperature, ionic strength, an emulsification technique (Siow *et al.*, 2013). For all mentioned reasons, the aforementioned components interact in vital to the coacervation process's optimization Between FPI and FG, respectively.

This study attempts to better isolate protein and gum from fenugreek seed, as well as examine some of its features, The goal of conducting future studies due to learn more about the health and nutritional advantages about the complex coacervation technique in Department of Food Science, College of Agriculture Engin. Science University of Baghdad, Iraq.

## MATERIALS AND METHODS

Fenugreek seeds were obtained from the Agricultural Research Department / Ministry of Agriculture, Iraq, and they were cleaned of impurities, purified, ground, sieved, and stored in opaque polyethylene bags in the refrigerator.

The isolate protein prepares from defatted fenugreek seed the method used with some modifications (Ayoub *et al.*, 2023). The isolate protein dried by freeze-drying method. The gum prepares from defatted fenugreek seed the method used (Ayoub *et al.*, 2023) (shukla *et al.*, 2022) and dried by air oven at 50°C

### 1- Preparation the Transglutaminase enzyme solution

Dissolve 1 g of transglutaminase enzyme (Turkish origin) in 50 mL of sterile distilled water and mix.

### 2- Preparation sodium azide solution

To prepared 0.2% sodium azide solution (weight: volume) added to both protein and gum solutions to protect them from the growth of microbes, (Capitani *et al.*, 2013).

### 3-Preparation the protein solution

In the first step the protein isolate from fenugreek seed were prepared by dissolving 25 g of protein isolate powder in 500 mL distilled water at pH8 and mixing in shaker at a speed of 100 rpm for one hour at ambient temperature. The solution was kept in refrigerator at 4°C until



the subsequent steps were completed. Then it was left for overnight to ensure the moisturizing and melting process has been completed (Ayoub *et al.*, 2023), (Oomah *et al.*, 1994).

#### 4- Preparation the gum solution

In the sconed the gum solution from fenugreek seed was prepared by dissolving 2.6 g of gum extract powder in 500 ml of distilled water at pH=7. Then, the solution was mixed using the shaker at speed around 100 rpm for one hour at room temperature. The solution was stored at refrigerator temperature for overnight until all steps were ended (Pratibha, 2016). The sodium azide solution was added to both of solutions (the protein and glue solution) at a concentration 0.2% (W/V) from the volume of the prepared solution. When, the protein and glue solution were mixed, the transglutaminase enzyme solution was added at a concentration 2%, with an addition rate around 5% of the total solution volume.

#### 5- Determine the optimal pH and ratio of protein isolate to gum

The complex coacervates was prepared by mix 300 ml of 0.1% protein isolate solution (weight: volume) at speed 1000 rpm using a magnetic stirrer for 2 minutes. The prepared gum solution is 50 mL at a concentration of 0.1% (weight: volume). Add it slowly to the protein solution while mixing on the mixer, take the solution to settle for 2 h at room temperature. Add the 5% Transglutaminase enzyme solution (weight: volume) prepared with distilled water and a temperature of 5°C. The protein-gum solution was added to the bonding process and took place after 2 hours at ambient temperature (Xiao *et al.*, 2013).

#### 6- Effect of pH on zeta potential

The zeta potential was measured in the laboratories of the Ministry of Science and Technology The zeta potential is estimated according to the method (Timilsena *et al.*, 2016) from the protein-gum solution diluted using distilled water containing 1 mg/mL protein, and the same to the gum. 0.2M citric acid or 1M NaOH was added to measure the pH values. Zeta potential for pH values were 5-1. The different proportion of protein-gum solutions was prepared from 2:1,1:1,1:2,4:1,6:1 and 8:1. The zeta potential was estimated using the scattered light technique at 25°C.

#### 7- Optical density (Turbidity) measurement

Optical density is measured according to the method followed (Timilsena *et al.*, 2016) for the protein-gum solution at a concentration of 0.1% (W/V) for both prepared solutions and based on the pH estimated in method 2-6 using a UV spectrometer with a wavelength of 600nm.

#### 8- The yield of protein-gum solution measurement

The protein-gum solution was prepared in the proportions ranging between 1:2, 1:1, 2:1, 3:1, 4:1, 5:1, 6:1, 8:1, 10:1 and 12:1, respectively. It was left for 2 hours to stabilize at ambient temperature. The separation process was carried out using centrifugation, then it was dried at 105°C until the weight was stabled (Timilsena *et al.*, 2016).

The yield for different pH was obtained in the protein-gum solution at a ratio of 1:6. This ratio was found to be the result of linking the protein-gum solution (complex solution) with the highest ratio. Calculating by equation below:

$$CY\% = (m_i/m_0) \times 100\%$$

CY = Yield of coacervates %

$m_i$  and  $m_0$  mass(mg) of dried coacervates and total mass of both FPI, FG.

#### 9- Drying of the protein-gum complex solution

The freeze-drying technique was used to dry the protein-gum complex solution using a (CHRIST freeze-drying) at a temperature of -81°C.

## 10- Fourier transform infrared spectroscopy (FTIR)

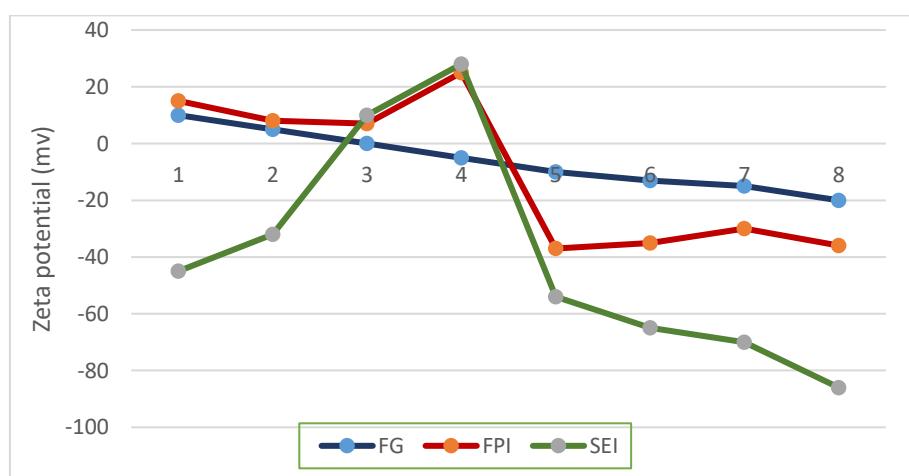
The FTIR fourier transform infrared spectroscopy device to diagnose the protein-gum complex by making tablets using a mortar with KBr, where 40 mg of the sample is weighed with 120 mg of KBr. After 10 min, weigh 40 mg of the mixture and compress it under a pressure 8 bar for 60 seconds with the compressor of the IR device. The tablets drying in an oven at 80°C for 16 h and analyzed with an FTIR device at a frequency of 650-4000 cm<sup>-1</sup> (Timilsena *et al.*, 2016).

## RESULTS AND DISCUSSION

### Isolate protein - gum ratio and effect of pH on zeta potential

pH plays the most important role in the process of cohesion of complex coacervates between the fenugreek gum solution and the fenugreek isolate protein solution because it controls the degree of functional ionization (amine groups in the protein with carboxyl groups in the polysaccharide of the gum) and the strength of the electrostatic interaction between the charged parts. Bonding strength is important because the physical, mechanical, and thermal properties of the complex coacervates are governed by the extent of interaction between the shell polymers and the degree of cross-linking (Huang *et al.*, 2012).

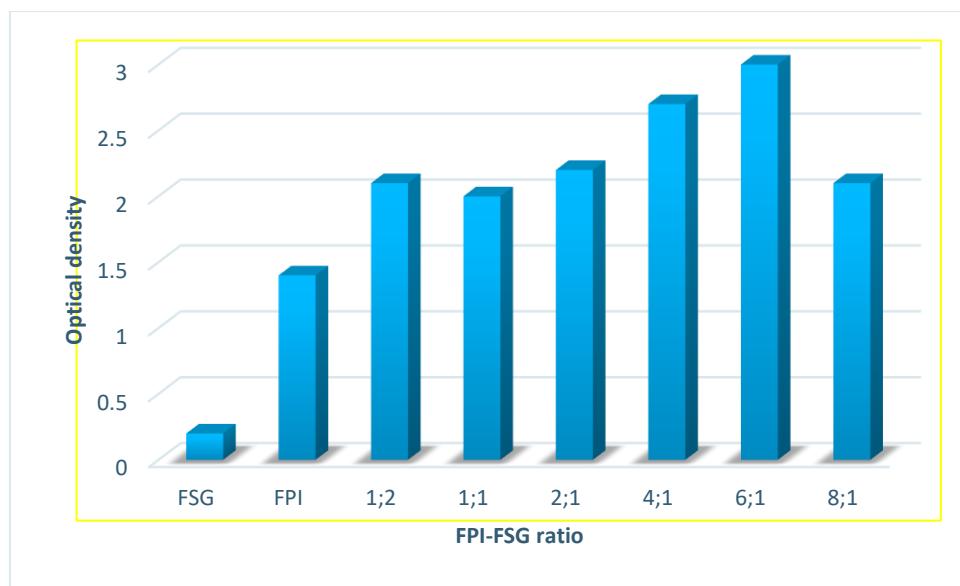
The zeta potential of the gum solutions and the fenugreek isolate protein was estimated within a pH range between 1-8. We note from Figure (1) that the dispersion of the gum solution is a result of the weak negative charge in the pH range due to the carboxyl group in the ionic acid, and at pH 2 it became dispersion. The gum solution is positively charged, but as for the protein isolate at pH 4, the negative charge began to decrease as the pH decreased, reaching the Iso electric point at which the charge becomes neutral. Below that, the charge is positive because the protein isolate contains an amine group (NH<sub>2</sub>). The carboxyl group (COOH) is below the electrical neutrality point, as the number of amine groups (NH<sub>3</sub>) increase of carboxyl groups(COO<sup>-</sup>), the charge is positive, and exactly the opposite at a pH higher than the electrical neutralization point. (Amirafshar *et al.*, 2021).



**Figure (1):** Effect of pH on zeta potential to complex coacervates between the fenugreek gum solution (FG), the fenugreek isolate protein solution (FPI) and Strength Electrostatic Interaction (SEI).

### Optical density (Turbidity) measurement

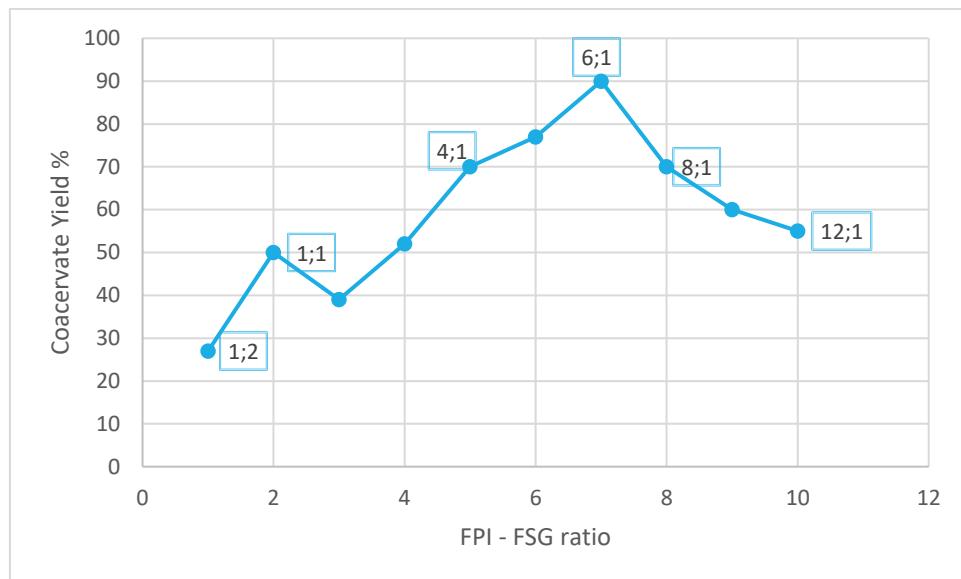
Figure (2) shows the variation in optical density (turbidity) of complex coacervates between the fenugreek gum solution and the fenugreek isolate protein solution with different proportions of them. As the figure shows, the turbidity increases gradually with an increase in the mixing ratio between the gum solution and the protein isolate solution, reaching the ratio of 6:1 protein: gum, while when the proportion of protein isolate is increased to the gum, a mixing ratio of 8:1 led to a significant decrease in turbidity. The reason for the decrease in turbidity is attributed to the inability of the excess protein to bind to the gum (polysaccharide), with the amount of free protein in the solution (Timilsena *et al.*, 2016), who conducted a similar study on chia seeds. It was concluded that the best mixing ratio of protein isolate and gum is 6:1.



**Figure (2):** Optical density of complex coacervates between the fenugreek gum solution and the fenugreek isolate protein solution.

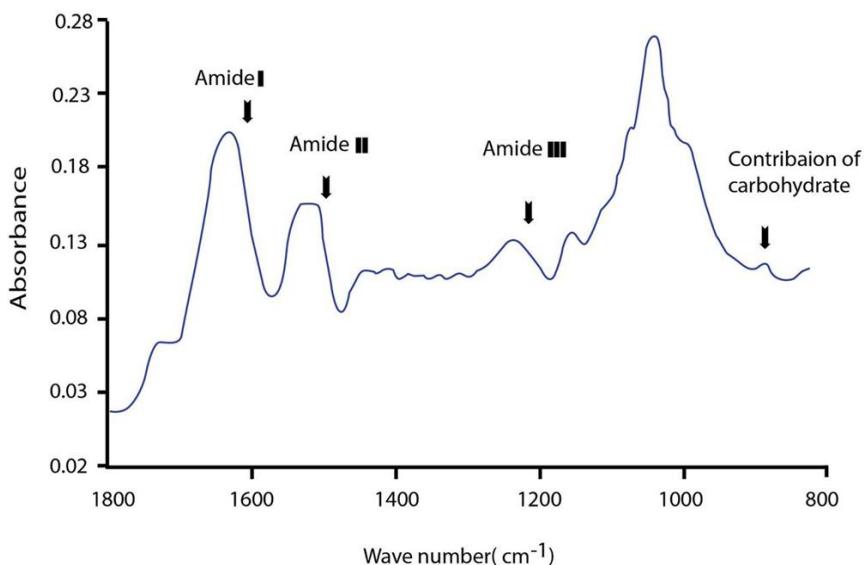
### Effect of pH and Mixing Ratio on the Yield of complex coacervates

Estimating the yield depends on two factors: the mixing ratio of the gum and protein isolate and the pH. The yield was calculated based on different mixing ratios. It was found that the highest yield was at a ratio of 6:1 protein: gum, where the yield reached 90%, as the ratio of protein to polysaccharides affects in the mixture, the charge balance of the multiple ions and thus the method of complex formation (Eratte *et al.*, 2014). Figure (3) shows an increase in the yield values with increasing mixing ratios, reaching a ratio of 6:1, after which the yield decreases as the mixing ratio increased because more free protein solution did not interact with gum solution to bind to it and form the required complex coacervates, meaning that the process of balancing the proportions between the solutions led to a decrease in the yield after reaching a concentration higher than 6:1 protein:gum (Su *et al.*, 2022).



**Figure (3):** Yield of complex coacervates between the fenugreek gum solution and the fenugreek isolate protein solution ratio mixing.

An FTIR test was conducted for the fenugreek gum complex and the protein isolate, where the figure (4) shows the infrared absorption peaks, at the formation of the complex, the amine groups in the protein isolate interact with the carboxyl groups in the gum to a complex coacervates that contains an amide bond and includes the characteristic peaks of amides. and the first peak is Amide I ( $\text{C=O, C-N}$ ) at  $1600 \text{ cm}^{-1}$ , Amide II (N-H, C-N)  $1544 \text{ cm}^{-1}$ . Amide III (C-N, N-H) at  $1150 \text{ cm}^{-1}$  the FTIR of the protein isolate, we find that the frequency range between  $1200 \text{ cm}^{-1}$  -  $1350 \text{ cm}^{-1}$  represents the binding of NH with the C-N stretches in Amide II and it appears clearly at the frequency  $1230 \text{ cm}^{-1}$  and the frequency  $1300 \text{ cm}^{-1}$ . Amide I and Amide II are specialized for the infrared spectrum of the protein (Abdalah, 2011). The frequency is  $2850 \text{ cm}^{-1}$  -  $2950 \text{ cm}^{-1}$  associated with the extended bonds - CH, as the frequency  $2850 \text{ cm}^{-1}$  falls within them. The frequency  $1600 \text{ cm}^{-1}$  -  $1700 \text{ cm}^{-1}$  is attributed to Amide I, as it is characterized by  $\text{C=O}$  and  $\text{C-N}$  groups and its vibration is stretched, and this explains the peak at  $1684 \text{ cm}^{-1}$ , we find that the infrared spectrum in examining the complex between the gum and the protein made the readings move to the right because this type of transformation of the amides is a characteristic of distinguishing the random coil and the  $\alpha$ -helix, as well as the lamellar structure of the protein, the  $\beta$ -sheet, which represents the structure of the protein, which is attributed to the high ratio of the complex components, i.e. the ratio of isolated protein: gum. Regarding the carboxyl group ( $\text{C=O}$ ), we find that  $1010 \text{ cm}^{-1}$ , in the FTIR test of fenugreek gum previously that the bond  $1155 \text{ cm}^{-1}$  refers to the carbonyl group C-O-C present in the rapinose ring (pyranose ring) (Cerqueira, et.al, 2011), so the frequency  $1050 \text{ cm}^{-1}$  represents the C-O-C bond, which is of the  $\alpha$  1-4 glycosidic bonds as well as the C-O-H bond that crosses the characteristic bonds of polysaccharides (Fonseca et al., 2011), it is worth noting that the strong bond bond at  $1400 \text{ cm}^{-1}$  in the structure of the gum protein complex is similar to N. The infrared rays present in the glue test as well as the protein isolate test, which represents an indicator of the binding interaction during complex formation (Timilsena et al., 2016).



**Figure (4):** FTIR of complex coacervates between the fenugreek gum solution and the fenugreek isolate protein solution.

## CONCLUSIONS

- 1-Possibility of preparing complex materials used for micro encapsulation for food packaging purposes.
- 2-The complex showed positive effects for preserving the fortified material in food
- 3- Preparing the complex from fenugreek protein and gum resulted in obtaining a natural coating material

## REFERENCES

- 1- Abdalah, M. E. (2011). The study of Antibacterial activity of fenugreek (*Trigonellafoenum-graecum*) Seeds extract. *Iraqi Journal of Market Research and Consumer Protection.*,3(6),145 – 155.
- 2- Al-Aubadi. I., M. & Al-Jobouri A. H. (2013). Accessing the Physiochemical and Functional Properties of Flaxseed Mucilage, *The Iraqi Journal of Agricultural Sciences* .44(6),745 – 753
- 3- AL-hadwany A. K. (2004), *Effect of Fertilization and Spraying of Some Nutritional Elements on Quantitative and Qualitative Properties of Some Active Medicinal Components in Two Fenugreek Seed (*Trigonella foenum-graecum L.*) Cultivars.*ph. D. Theses , college of Agriculture , University of Baghdad. Iraq.
- 4- Al-Saddi, N. H., Al-Jumaily, E. F. & Al-Rawi, A. M. (2009). The Antimicrobial Activity of the Fenugreek Seeds and Corn Silk Extracts. *Iraqi Journal Biotechnology*. 8(1),457-464
- 5- Amirafshar A., Iraj K., SaniSajad P. & Abbas T. (2021) Production and Characterization of Nanocomposite Film Based on Whey Protein Isolated/Copper Oxide Nanoparticles Containing Coconut Essential Oil and Paprika Extract. Springer. *Journal of Polymers and the Environment*.29(1),335 – 349. DOI: 10.1007/s10924-020-01882-w



- 6- Ayoub. A. A, & Abdulrahman. S.M. (2023). Study of the Physiochemical and Functional Properties of Fenugreek Protein Isolate. *IOP Conf. Series: Earth and Environmental Science*. 1262(6), 206-214.
- 7- Ayoub. A. A., Abdulrahman. S. M. (2023). Study of the Physiochemical and Functional Properties of Fenugreek Gum. *IOP Conf. Series: Earth and Environmental Science*. 1252(1), 217-225.
- 8- Aziz L. S., and Salman, D.D. (2011). Extraction and Studying of some Physiochemical Properties of Fenugreek Gum. *The Iraqi Journal of Agricultural Sciences*, 42(3), 89-98.
- 9- Capitani, M. I., Ixtaina, V. Y., Nolasco, S. M., & Tom.as, M. C. (2013). Microstructure, chemical composition and mucilage exudation of chia (*Salvia hispanica L.*) nutlets from Argentina. *Journal of the Science of Food and Agriculture*, 93(15), 3856-3862
- 10- Dhul, S. B., Punia, S., Kumar, R., M., Nain, K. B., Jangra, K., & Chudamani, C. (2021). Solid state fermentation of fenugreek (*Trigonella foenum -gracum*): Implications on bioactive compounds, mineral content and in vitro bioavailability. *Journal of Food Science and Technology*, 58(5), 1927-1936.
- 11- Hugan, G-Q., Sun. Y. -T., Xiao, J. X., & Yang. J. (2012). Complex coacervation of soy-bean protein isolate and chitosan. *Journal Food Chemistry*. 135(2), 534-539.
- 12- Oomah, B. D.; Mazza, G.; and Cui, W. (1994). Optimization of protein extraction from flaxseed meal. *Journal of the Food research international*, 27(4). 355-361.
- 13- Pratibha K. B. E, M.Tech . (2016). *Microencapsulation of omega3 fatty acids from flaxseed oil in flaxseed protein and flaxseed gum-based matrix*. phD. Theses, Federation University AustraliaPO Box 663. University Drive, Mount Helen Ballarat, Victoria 3353, Australia
- 14- Salarbashi, D., Bazeli, J., & Fahmideh -Rad, E.(2019). Fenugreek seed gum: Biological properties, chemical modifications, and structureal analysis -A review. *International Journal of Biological Macromolecules*, 138(2), 386-389.
- 15- Siow, L-F &C. (2013). Effect of pH on garlic oil encapsulation by complex coacervation. *Journal of food processing and technology*.4(1), 199-203
- 16- Su M. S., Jaturanpinyo M. & Limwirkant. W. (2022). Effects of Wall Material on Medium-Chain Triglyceride (MCT)Oil Microcapsules Prepared by Spray Drying. Mahidol University, Bangkok 10400, Thailand. *Pharmaceutics*. 14(6), 1281-1289.
- 17- Tavakoly, R., Maracy, M. R., Karimifar, M., & Entezari, M. H. (2018). Dose fenugreek (*Trigonella foenum gracum*) seed improve inflammation, and oxidative stress in patients with type 2 diabetes mellitus? A parallel group randomized clinical trial. *European Journal of Integrative Medicine*, 18(1), 13-17.
- 18- Timilsena, Yakindra P., Bo, W., Raju, A., Benu, A. (2016) A. Preparation and characterization of chia seed protein isolate-chia seed gum complex coacervates. *Journal Food Hydrocolloids*, 52(2) , 554-563.
- 19- Xiao, Z., Liu, W., Zhu, G., Zhou, R., & Niu, Y. (2013). A review of the preparation and application of flavour and essential oils microcapsules based on complex coacervation technology. *Journal of the Science of Food and Agriculture*, 94(8), 1482-1494.
- 20- Yaseen, S. M. (2011). Effect Interaction of Gibberellic Acid and Urea Fertilizer on some Growth Characteristic of Fenugreek Plant (*Trigonella foenum-graecum L.*). *Ibn Al-Haitham Journal for Pure and Applied sciences*.24 (2), 184-193.