The Pharma Innovation Journal 2022; 11(6): 689-694

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(6): 689-694

www.thepharmajournal.com
Received: 17-02-2022
Accepted: 31-05-2022

Rajvinder Kour
School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

Corresponding Author:
Rajvinder Kour
School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

A study of the utilization of hydrocolloids in Food

Rajvinder Kour

Abstract
Hydrocolloids are broadly used in food industries in various food preparations for quality and timeframe of realistic usability. Hydrocolloid is used to increase the thickness and gelling property of the food system. In this review four hydrocolloids are selected and then there study is done on deep fried sweet to final oil uptake of the product during frying. According to different studies among all used hydrocolloid guar gum exhibited the best oil uptake ratio. To enhance the nutritional benefits of the product addition of Hydrocolloid is done for increasing the fiber content of the final product.

Keywords: Hydrocolloid, oil uptake, xanthan, guar gum, carrageenan, gum Arabic

1. Introduction

Hydrocolloids also called as gums and are known to be long chained polymers. Hydrocolloids when dispersed in water have strong tendency to form gel or any thick viscous dispersion. Back in time these hydrocolloids were extracted from bushes and trees, these hydrolloids were also widely extracted from seaweed. Hydrocolloid have strong affinity to have binding with water molecules this property is due to the presence of hydroxyl group in large quantity which is why hydrocolloids are considered to be good options in hydrophilic compounds. Hydrocolloid tend to form an intermediate dispersion which is in between the consistency of a true solution and a suspension this exhibits the property of a colloidal component, Because of these two properties these are named as "hydrocolloids" and "hydrophilic colloids" (Galatas and Armisen, 2000).

Hydrocolloids are loaded with functional properties among these are thickening, emulsifying, stabilization, gelling, coating and etc. hydrocolloids can be used in different proportions. These proportions are decided on the bases of the hydrocolloid used for example the proportion size of the hydrocolloid ranges from few part per million when carrageenan is used and when acacia gum, gelatin or starch is used hydrocolloid is used in high levels. Hydrocolloid have great tendency to modify rheological characteristic of any food sample which is the reason for its ample use in food industry (Burey *et al*, 2008) [3]. Amongst various rheological properties alter by addition of hydrocolloid two basic properties these are viscosity and texture these property alter the flow behavior of the food system and mechanical solid property, these modifications helps to differ sensory properties of the food material considering these changes in food system hydrocolloids are also widely used as food additives to make specific changes in food system. When desired consistency in flow is required in food systems such as gravies or in soups and salad dressings, toppings hydrocolloids is considered as a good additive and when there is need for improved texture in food system hydrocolloid is preferred in food system like jams, jelly, cakes, ice cream or any other gelled desserts. Gum Arabic, Gum Tragacanth, Gum ghatti are all botanical sources of commercially important hydrocolloid available in market these hydrocolloids are derived from exudates gums from trees. Various other hydrocolloids from botanical sources are cellulose, Guar Gum, Tara gum, tamarind gum, Konjac mannan these hydrocolloids are obtained from sources such as plants, trees, seeds and tubers (Glicksman, 2000). Hydrocolloids are also derived from algal sources main algal sources are from brown and red seaweeds these weeds helps in extractions of alginate and carrageenan agar, microbial sources of hydrocolloid extraction gives curdlan, cellulose, gellan gum, xanthan gum and gelatin, egg white protein, chitosan are derived from animal sources. Even the concentration of the used hydrocolloid in food system is less than 1 percent on whole but due to its diverse nature of changing textural, viscous properties of food hydrocolloids are extensively used in food industry in recent years. In modern era the use of hydrocolloid is increasing with the increase in demand of fiber rich low fat food products. In many food systems hydrocolloids are used as a replacement of fat (Azmoon *et al*., 2021) [1].

The selection of hydrocolloid for particular food depends on various points in consideration of organoleptic changes that are required of any specific food products pricing of the hydrocolloid is also a major influence, this is also the reason why starch are the most commonly used hydrocolloids in food industry and are mainly used as thickeners. Per annum the hydrocolloid market in the world is estimated to be around $4.4 billion which equals to be around 260,000 to 280,000 tonnes of total volume. The growth rate of the hydrocolloid market is around 4-5% in these recent years. There are various hydrocolloid in food industry these hydrocolloids are classified on the basis of property of adhesiveness and non-adhesiveness. This property is classified on the hydration of the hydrocolloids when placed in water. Adhesive hydrocolloids are those hydrocolloids which are sticky upon hydration and non-adhesive hydrocolloids are those hydrocolloids which forms a slippery mucilage upon hydration In addition to various attributes of hydrocolloids properties and its usage in food industry there are various functional properties that are associated with hydrolloids which makes hydrocolloid the most used food additives in food industry. These functional property of hydrocolloids are thickening property, viscosity enhancing property, gelling property, emulsifying property, edible coting, fat replacing property (Glicksman, 2020) [11].

2. Review of Literature

Gums are considered to be the colloidal system. In these colloidal systems particles are in network form which spans volume of liquid. The physical form of gels are similar to liquid so the density of gum is similar to the density of liquid solutions. Structurally gels resembles solid this resemblance is due to tight network of particles this is why gels appear to be jelly like product. These gels are edibles and they are also referred as "edible gel composition". Gels are considered to be shelf stable even without refrigeration. Because of this property gels don't get degrade physically even at room temperature. Fruit particles are also incorporated in edible gels likes pears, cherries, grapes, peaches and oranges. These hydrocolloids have good gelling properties, thickening properties making it very popular food additive to use (Galatas and Armisen, 2000). These hydrocolloids have various health benefits and these health benefits depend on how they are added to food products. By addition of hydrocolloid in food system some food become fiber rich and some food become less oily. Hydrocolloids carbohydrates are naturally present in plant food these can be present in cell wall as in hemicellulose and pectin. Hydrocolloids also have specific role within plant they are present in such as being a storage polysaccharides and bring a husk polysaccharides as in ispaghula. Some hydrocolloids are also bacterially produced these hydrocolloids are gellan gum and xanthan. Some hydrocolloids are added in food in small amount as fats substitutes, emulsifiers and stabilisers. Addition of hydrocolloids in food system is less that is why it becomes quite difficult to have epidemiological studies for identification of health benefits. Guar gum is usually incorporated less than 1% when used in food products and health benefits of Guar gum is achieved when used in higher levels of 3-5%. Guar gum is partially hydrolysed and has low viscosity so it has higher potential to be used in variety of food products (Ellis *et al*., 1985) [9]. For uses as therapeutic agent in diet hydrocolloids have to be used in large quantities or doses. To be beneficial against constipation ispaghula is used with medication such as Regulan or iso gel. Hydrocolloid when indigested have specific mechanism of action in large intestine. They have impact on microbiota present in intestine and have effect on products made by fermentation of plasma lipids. Hydrocolloids are rich in fiber this property of hydrocolloid helps in weight management, plasma lipid and appetite control as well. Some food components are not digestible by human body because they lack specific enzymes which are responsible for their complete breakdown aiding in digestion process (Yanes *et al*., 2002) [26]. Food hydrocolloids are also considered non-digestible food component along with the mucilage which are found in oats, beans, fruits and barley. Hydrocolloids are thus considered to form viscous solution or gels which when added to food increase the fiber content of the food product but being remained as a non-digestible food component. Analogous carbohydrates or the edible portion of the plant are digestion resistance and absorption in small intestine in humans. Dietary fiber on the whole constitutes of oligosaccharides, lignins, polysaccharides and other plant substances. Dietary fiber when used in human diet have shown to promote good physiological effects which includes good blood circulation, blood glucose attenuation and laxation. Non digestible carbohydrates which contain more than three or three sugars are researched to be beneficial for health when consumed. Hydrocolloids are good source of dietary fiber the definition of dietary fiber was selected by (Panel on the Definition of Dietary Fiber and the Standing Committee on the Scientific Evaluation of Dietary Reference Intakes 2001) as non-digestible carbohydrates which consists of lignin. The added fiber constitute of non-digestible carbohydrates, isolates which have positive physiological effects when consumed. Total fiber in food is termed as total sum of dietary fiber and added fiber. The effect of hydrocolloid and non-starch polysaccharides on intestinal track are dependent upon the physico chemical properties of the hydrocolloids (Ben & Nussinovitch *et al*., 1997) [2]. Physico chemical properties of the hydrocolloid include the water holding ability, to regulate high viscosity and their ability to hold on to small molecules for binding. Hydrocolloids such as guar gum if digested in high amount for increasing the viscosity of small intestine and gastric contents may result in delay in the process of gastric emptying and also results in the inhibition of the effects of contraction of small intestine which further results in the passive delivery in nutrients for the absorptive epithelium resulting in slow absorption. It also reduces the level of glucose and lipids in body. Hydrocolloids has different effect on large intestine which mainly depends upon the water holding capacity of the hydrocolloid. In cases where water holding capacity (WHC) is maintained their hydrocolloids act as a catalyst and speeds the transfer of stool through the colon. In fermentation process of colonic micro flora the water holding capacity of hydrocolloid is lost and difficult to maintain. Fermentability in carbohydrates is the cause of loss of WHC. Ispaghula and gellan when ingested in bulk amount in animals for testing resulted in slower passage of stools causing health complications. Epidemiological studies have reported the constructive association in reduction of chronic diseases and consumption of high amount of dietary fiber. Chronic diseases which are benefitted with the consumption of high dosage of fiber are type 2 diabetes, colorectal cancer and

CVD (Schulze *et al*. 2007) [22]. Higher fiber diets are also associated with good stool movement and speeder gut transfer. This high requirement to fiber in diet can be fulfilled by intake of hydrocolloid incorporated food sample (Dukas *et al*. 2003) [8]. Hydrocolloids have various metabolic effect these effects are changes in insulin sensitivity, changes in fecal bile acid excretion, low density lipoprotein synthesis changes, changes in fat absorption, hepatic glucose production depletion, increasing in satiety of the food, changes in enzyme production in the system. If these changes occur in body due to different physiological actions which are caused due to use of hydrocolloid in human diet. Some common physiological action taken by hydrocolloid are increase in distension of gastric, the output of faecal sterol is increase, and transit time of gut is increased. These changes may vary as per different properties of hydrocolloids are acting.

2.1 Properties of hydrocolloid

2.1.1 Thickening property

Among various uses of hydrocolloids the best use of hydrocolloid in food industry is to modify the rheological attributes of the food system.to perform specific function in food system hydrocolloids are used in ample amount its helps in modification of texture of food by changing its thickness. The effect of the formed thickness in food system is depended upon the types of hydrocolloid used and the concentration in which that particular hydrocolloid is used. pH and temperature of the food system are also important when considering the desired thickness in any food product (Saha and Bhattacharya, 2010) [20].

2.1.2 Gelling Action

Hydrocolloids used in food system also helps in achieving swollen particulate which further forms gel in food products. These swollen structures formed after addition of hydrocolloid have good flow ability. This property of hydrocolloid is advantage in replacing any chemical treatment which is applied for formation of gel, this property helps to eliminate chemical processing of cross linked starches which is depended upon the processing and structuring. (Burey *et al*., 2008) [3].

2.1.3 Emulsifying Properties

This property of hydrocolloid is most diverse. This property of the hydrocolloid resembles with the phenomena of the solid particle retardation, oil droplet decreased creaming rate, aggregation of particles prevention. The hydrocolloids once added to food system absorbs very slowly and because of this hydrocolloid is divided into various category on the action of the activity at the interface. Various hydrocolloid used in food industry have different affinity to the interface of the food system (Garti and Leser, 2001) [10].

2.1.4 Edible coating and Film

Hydrocolloids are extensively used in food industry in form of edible film or coating in the food product. This property of hydrocolloid helps in the action of absorption of oil from the food products. Edible films are considered to be very thin layer which is applied or coated on the food product. These edible coating are applied to any food product to make a barrier within food and the surrounding. The function served by application of edible film around food product is to inhibit moisture, aroma or migration of lipid from food to surrounding atmosphere (Salehi, 2020) [21].

2.1.5 Fat Replacers

Due to awareness in presence era there is a need to replace fat from diet and finds its healthy alternatives. This has also given rise in production of ready to serve products and novelty products. With introduction of new processing techniques in food industry there is rapid rise in development of low fat high fiber food products in markets. Many hydrocolloids are specifically used in industry for replacing fat from food products. For e.g. In Italian pasta recipe xanthan gum is added as a thickener which has eliminated the use of traditional thickener which where high in fat (Azmoon *et al*., 2021) [21].

2.2 Types of hydrocolloid

2.2.1 Xanthan Gum

Xanthan gum is derived microbialy with the secretion of *Xanthomonas campestris.* Xanthan gum s a polysaccharide. Xanthan gum has good solubility with cold water and the solution prepared with the mixing of xanthan gum and cold water has good pseudo plastic flow behavior. Xanthan gum shows wide stability in various pH ranges, temperature. Xanthan gum is highly resistance with the degrading of enzymatic reaction. With various other hydrocolloids xanthan gum shows good synergistic interaction. Among these hydrocolloids are guar gum, glucomannan and locust bean gum (LBG) (Sworn, 2021) [23].

2.2.1.2 Preparation process and Rheology

Hydration process is very important factor in the preparation of gums. For optimum working of the xanthan gum proper hydration process of the xanthan gum is required. The hydration process of the gum is dependent mainly on 4 factors: particle size, solvent composition, rate of agitation of solvent and size of particle. When the gum is poorly dispersed formation of clumps is common during mixing these swollen lumps are also called fish eyes at times. When lumps are present in large numbers proper hydration of the xanthan gum is hindered thus reducing its functionality. For proper mixing and hydration process proper conditions of shear mixing should be maintained. Solution of xanthan gum is pseudo plastic in nature. Xanthan gum molecules form intermolecular aggregates with help of hydrogen bonding and polymer entanglement. Viscosity of the xanthan gum is dependent upon various factors these are effect of salt, pH and temperature (Casas *et al*., 2000) [5].

2.2.1.3 Application of xanthan gum

Xanthan gum is widely used in food industry as an additive but it also helps in various sectors of food industry like in bakery and dairy industry. Xanthan gum helps in the reduction of flour sedimentation when used in wet flour, it also aids in the gas retention and gives a uniform coating on the flour.in other application in bakery industry is that it helps in making process of pancakes. When xanthan gum is added to the pancake mix it helps in the better spread control. In bakery industry it is important to maintain the moisture content of the food product xanthan gum helps in the retention of the moisture. This retention of moisture helps in cake making as any fluctuation in cake making can leads to lumpy cake base and cake may also collapse once baked. In dairy industry blend of xanthan gum is used as stabilisers and helps in providing long term stability to food system also helps to improve heat transfer during processing (Katzbauer, 1998) [12].

2.2.2 Gum Arabic
Gum Arabic is also called as Gum Acacia. This gum is a tree exudate and is used for consumption from long back. This gum is obtained from Acacia Senegal species primarily from Africa this gum is present on the stems and branches of the tree. The average height of the tree is about 7-8 meters. Its extraction process is unique the stimulation of the extraction is done by tapping the branch and then removal of the branch section which has gum in this removal is done carefully so that no harm to the tree is made. This gum when not picked or extracted from the branch of tree on time often dries on the branch itself and then it is carefully handpicked (William and Phillips, 2021) [25].

2.2.2.1 Properties
Arabic gum has good affinity with water. Gum Arabic dissolves completely in water and gives a complete clear solution the color of the dissolved solutions varies from yellow pale to very light orange brown color. The pH of the dissolved solution is 4.5. The structure of the gum Arabic is very branched with various linkage. The branched structure of the gum Arabic mainly Acacia Senegal often gives a structure which is very compact packed in molecule. The hydrodynamic volume of the gum is very small in this structure which results on the viscous nature of the gum. Gum Arabic with this compact nature only becomes viscous in high temperature. Gum Arabic is polyelectrolyte in mature, the viscosity of the solution decreases when electrolyte are present in the solution. In presence of the low pH range the carboxyl group present in the gum becomes undissociated. Among various other functional property of the gum Arabic it also act as an emulsifier when added in food system having flavors and essential oil. Food system which are high in protein absorb more on the surface of oil droplet (William and Phillips, 2021) [25].

2.2.2.2 Application of Gum Arabic
Gum Arabic has major role in confectionery sector in food industry. Gum Arabic is added to marshmallows, toffees and pastilles to add chewiness to the confectioneries. These gums are added in the concentration of 40-55% to these confectionaries. In the preparation process of the gum it is dissolved in water the temperature is maintained at 60 degree Celsius. This low temperature is maintained so that any precipitation is avoided. This also helps in the formation of turbid solution because no proteinaceous component is precipitated from the solution. For addition of this gum in the solution the gum mixture is added to the pre boiled solution of sugar followed by the addition of flavor and color to get the desired taste of the confectionary. When gum are added to this boiling solution it is allowed to stand so that the bubble inside the solution rise and any formation of the scum is removed. This solution incorporated with gum is then stored in stoving room for 4-6 day in the specific moulds. For making soft confectionary the stoving period is reduced to 2-3 days. In different confectionary the use of gum Arabic is different. In marshmallow it is used as a foam stabilisers where as in toffees it is used to emulsify fat. When used on nuts gum Arabic is used to form a shiny glaze to make it attractive (Patel and Goyal, 2015) [18].

Gum Arabic is widely used in beverages industry because this gum is stable in acidic condition and is used as emulsifier. Gum Arabic is used to maintain the concentration of citrus and cola flavored soft drinks. Arabic gum is helps in inhibition of the flocculation of oil droplets this property of the gum helps to increase the shelf life of the food products. This gum has very vital role in the flavor encapsulation. In process of microencapsulation food flavors are transformed from liquid which is volatile in nature to the powder form which further can be incorporated into dry food system. For the process of encapsulation gum Arabic is used as an emulsifier.in the formulation of the flavor encapsulation gum Arabic is used in 28% to the flavor of 7% of the total percentage of the product (Daugan and Abdullah, 2013) [6].

2.2.3 Carrageenan
Carrageenan has a long and illustrious history in Asia and Europe. The word "carrigan" or "carrageen" is most likely derived from "carrigan" or "carrageen," the Irish word for Chondrus crispus, or Irish Moss, as it is generally known, and was coined in Ireland in the 1820s. Carrageenan's gelling potential was first addressed scientifically in 1819 by English botanist Dawson Turner, who was examining what he thought was the brown seaweed Fucus crispus, but was actually Chondrus crispus (Anderson *et al*., 2002). The plants are not more than 50 cm. Extracted carrageenan from these species have both lambda and kappa. Both these carrageenan do not grow on the same plant, but on different plants which are cultivated together. Carrageenan behaves as a multifunctional ingredient when mixed in water and milk system. When mixed in water mixture it exhibits the hydrocolloid properties which are gelling and thickening and when same is mixed in milk mixture then it reacts with protein to have additional stabilizing abilities. At room texture Carrageenan have ability to blend into wide variety of textures in gel form which can be explained as rigid, clear, turbid, elastic, tough, tender, thermally reversible or heat stable. This specific hydrocolloid can also exhibit the property of being used in low/high melting point and different gelling temperatures. Under its various industrial applications Carrageenan is also used as emulsifying, gelling, suspending and stabilizing agent. It also works as great water retaining agent (Dai *et al*., 2007).

2.2.3.1 Structure
Carrageenan has high molecular weight and it is a structure of polysaccharide which comprises of galactose unit in repeat format and the sulphate and non-sulphate 3,6-anhydrogalactose is linked by glycosidic linkages. Carrageenan is available in various forms among these the main form of carrageenan are lambda, kappa and iota. All these different types of carrageenan are prepared with the help of extraction process. The selection of extraction process is specified to which form of hydrocolloid is being prepared. For the production of kappa and iota carrageenan chemical modification with the help of alkali is made which has resultant MU and NU carrageenan as their precursor structure. These different form of carrageenan are differentiated on the bases of different structure of 3,6-anhhydrogalactose which are present in carrageenan (Millane *et al*., 1998) [16].

Table 1: Types of carrageenan

Carrageenan type	Properties	References
KAPPA	Has high gel strength Thermo reversible Syneresis effect	(Opoku *et al*., 2006)
IOTA	It is elastic gel Thermo reversible Has no syneresis effect	(Karbowiak *et al*, 2006)
LAMBDA	Shows no gelling action Has high viscosity Cold soluble	(Wang *et al*.,2006)

2.2.3.2 Applications

Carrageenan's main uses are (i) processed meats, (ii) dairy, and (iii) sweets and jellies. It's easy to see why application is best suited to these locations, given its unique set of functional features (as mentioned above). The iota, lambda, and kappa grades have distinct gelling and thickening qualities, allowing them to be used in a variety of applications and product areas that require a variety of textures, such as dairy desserts. When utilized in chocolate milk and ice cream, kappa's reactivity with milk protein gives it an incomparable economic advantage, and the flexibility to employ SRC in meats and dairy also saves money. The usage of Carrageenan in these major areas will be the subject of the following section. The next section will concentrate on Carrageenan's applications in these key areas; however, it should be noted that Carrageenan is used in a broader range of food products, including infant formula, various dairy products, yoghurts, soft cheeses and cheese analogues, dressings, syrups, fruit preps, and jams, though to a lesser extent (Hotchkiss *et al*., 2016).

2.2.4 Guar gum

Guar gum is derived from *Cyamopsis Tetragonoloba* which is a drought tolerant plant belonging to the Leguminose family (Prem *et al*., 2005). Guar gum is considered to be the cheapest source of Galactomannan. Various names of guar gum are Guaran, Cluster bean, Cyamopsis and Calcutta lucern. Guar gum has high molecular weight. Guar gum has yellowish to white appearance and when mixed with water it is odorless. The maximum height attain by guar gum plant is about 0.6m with the length of pods being about 5-12.5 cm. during the time of germination plant of guar gum acts as a reserve for food to the embryo. India accounts for 650 thousand tons for production of guar gum. Among all the various solvent for guar gum water is considered the best. Hydrocarbon, alcohol, fat, ester and ketone are not compatible for dissolving with guar gum. Guar gum remains insoluble to these solvents (Poorna *et al*., 2016) [19]. Guar gum concentration and viscosity have proportional relationship when there is increase in the guar gum concentration in any food system or any aqueous solution there is increase in the viscosity of the system this happens due to the inter molecular chain interactions. Over wide pH range guar gum shows non-toxic nature which helps in stable nature of the food system. pH shows no effect on the final viscosity of the system when guar gum is added. At the pH around 8-9 highest hydration rate is attained and the pH less than 4 shows the lowest hydration rate. At higher temperature guar gum attends maximum viscosity prolonged heating to guar gum solution effects the water molecule order system which results in reducing the viscosity of the system (Tripathy *et al*., 2008) [24].

2.2.4.1 Application of guar gum

Guar gum is used vastly in food industry. Guar gum is consider to be valuable aid in providing variety of application in food industry. Its ability to form viscous system in dispersion and in gel gives it potential to be used for various application in food industry. This gum is easy to digest by human body because of the presence of glycosides' linkage in the structure of guar gum the microbial enzyme action in large intestine make it degrade easily. With the presence of hydroxyl group in the structure of guar gum making it suitable for chemical reactions. With high swelling ratio of the guar gum it is used for delivery of drugs in transportation. When used as a delivery agent in drug in tablet form it is used as a disintegrating agent and as a binder giving the cohesive nature to the applied drug (Kumar *et al*., 2018) [13]. Guar gum is widely used in cosmetic industry due to high solubility in hot and cold water solution, resistance to wide pH range, stability in wide range of solutions, non-toxicity nature and its relative cheap price makes its applicable in cosmetic industry. Common application of guar gum in cosmetic industry is in toothpaste. Guar gum provides flowing nature to the paste. So, that the paste is easily transferred in and out of the tube. It is also used in shaving creams as a stabilizer (Patel *et al*., 2014) [17]. Cosmetic industry includes creams, lotion and sunscreen which are daily used by consumers in these emulsion system guar gum is used to avoid the phase separation by maintaining stability in the solution and averting water loss.

3. Conclusion

In this review four hydrocolloid are studies on the bases of their oil uptake and their fat reduction in final product. Among the selected hydrocolloid guar gum, gum Arabic, xanthan and carrageenan were studied. It was found from various studies that guar gum has least oil uptake when introduced in frying method to any food product. Guar gum helped in reducing the fat percentage of the final fried product by up taking least oil. The main properties of hydrocolloids are thickening, gelling, emulsifying and fat replacing thus being very useful in food industry.

4. Reference

1. Azmoon E, Saberi F, Kouhsari F, Akbari M, Kieliszek M, Vakilinezam A. The effects of hydrocolloids-protein mixture as a fat replacer on physicochemical characteristics of sugar-free muffin cake: Modeling and optimization. Foods. 2021;10(7):1549.
2. Ben-Zion O, Nussinovitch A. Physical properties of hydrocolloid wet glues. Food Hydrocolloids. 1997;11(4):429-442.
3. Burey P, Bhandari BR, Howes T, Gidley MJ. Hydrocolloid Gel Particles: Formation, Characterization, and Application. Critical Reviews in Food Science and Nutrition. 2008;48(5):361-377.
4. Casas JA, Santos VE, Garcıa-Ochoa F. Xanthan gum production under several operational conditions: molecular structure and rheological properties. Enzyme and microbial technology. 2000;26(2-4):282-291.
5. Da Silva Dias JC. Nutritional and health benefits of carrots and their seed extracts. Food Nutr. Sci. 2014;5(22):2147.
6. Dauqan E, Abdullah A. Utilization of gum arabic for industries and human health. American Journal of

Applied Sciences. 2013;10(10):1270.
7. Dias JS. Major classes of phytonutriceuticals in vegetables and health benefits: A review. J Nutritional Therapeutics, 2012a.
8. Dukas L, Willett WC, Giovannucci EL. Association between physical activity, fiber intake, and other lifestyle variables and constipation in a study of women', Am. J Gastroenterol. 2003;98(8):1790±1796.
9. Ellis PR, Apling EC, Leeds AR, Peterson DB, Jepson EM. Guar bread and satiety: effects of an acceptable new product in overweight diabetic patients and normal subjects', J. Plant Foods. 1985;6(4):253-262.
10. Garti N, Leser ME. Emulsification properties of hydrocolloids. Polymers for advanced Technologies. 2001;12(1- 2):123-135.
11. Glicksman M. Functional properties of hydrocolloids. In Food hydrocolloids. CRC Press, 2020, 47-99pp.
12. Katzbauer B. Properties and applications of xanthan gum. Polymer degradation and Stability. 1998;59(1-3):81-84.
13. Kumar A, Rana A, Sharma G, Sharma S, Naushad M, Mola GT, *et al*. Aerogels and metal–organic frameworks for environmental remediation and energy production. Environmental Chemistry Letters, 2018.
14. Kumar N, Sarkar BC, Sharma HK. Mathematical modelling of thin layer hot air drying of carrot pomace. Journal of food science and technology. 2012;49(1):33-41.
15. Kumar V, Singh C. Cluster Bean: A Novel Alternative for Commercial Guar Gum Production. In Indian Farmer, 2018, 383-387.
16. Millane RP, Chandrasekaran R, Arnott S, Dea IC. The molecular structure of kappa-carrageenan and comparison with iota-carrageenan. Carbohydrate research. 1988;182(1):1-17.
17. Patel JJ, Karve M, Patel NK. Guar gum: a versatile material for farmaceutical industries. International Journal of Pharmacy and Pharmaceutical Sciences. 2014;6(8):13-19.
18. Patel S, Goyal A. Applications of natural polymer gum arabic: a review. International Journal of Food Properties. 2015;18(5):986-998.
19. Poorna KSV, Singh A, Rathore A, Kumar A. Novel cross linked guar gum - g- poly (acrylate) porous superabsorbent hydrogels : Characterization and swelling behaviour in different environments. Carbohydrate Polymers. 2016;149:175-185.
20. Saha D, Bhattacharya S. Hydrocolloids as thickening and gelling agents in food: a critical review. Journal of food science and technology. 2010;47(6):587-597
21. Salehi F. Edible coating of fruits and vegetables using natural gums: A review. International Journal of Fruit Science. 2020;20(2S):S570-S589.
22. Schulze MB, Schulz M, Heidemann C, Schienkiewitz A, Hoffmann K, Boeing H. Fiber and magnesium intake and incidence of type 2 diabetes: a prospective study and meta-analysis', Arch. Intern. Med. 2007;167(9):956± 965.
23. Sworn G. Xanthan gum. In Handbook of hydrocolloids. Woodhead Publishing, 2021, 833-853pp.
24. Tripathy J, Mishra DK, Srivastava A, Mishra MM, Behari K. Synthesis of partially carboxymethylated guar gum-g-4-vinyl pyridine and study of its water swelling, metal ion sorption and flocculation behaviour. Carbohydrate Polymers. 2008;72(3):462-472
25. Williams PA, Phillips GO. Gum arabic. In Handbook of hydrocolloids. Woodhead Publishing, 2021, 627-652pp.
26. Yanes M, Durán L, Costell E. Effect of hydrocolloid type and concentration on flow behaviour and sensory properties of milk beverages model systems. Food hydrocolloids. 2002;16(6):605-611.