Innovare Academic Sciences

International Journal of Pharmacy and Pharmaceutical Sciences

ISSN- 0975-1491 Vol 6, Issue 8, 2014

Review Article

GUAR GUM: A VERSATILE MATERIAL FOR PHARMACEUTICAL INDUSTRIES

JAY J. PATEL, MANDAR KARVE, NIRMAL K. PATEL*

***Department of Industrial Chemistry, Institute of Science & Technology for Advanced Studies & Research, V. V. Nagar – 388120 Gujarat, India.**
Email: drnirmalpatel@yahoo.com

Received: 25 Jun 2014 Revised and Accepted: 26 Jul 2014

ABSTRACT

Guar gum (GG) is galactomannan, derived from guar (*cyamopsistetragonolobus*) kernels which belong to family *Leguminosae*. The solution of guar gum in water has the highest viscosity amongst all the natural polysaccharide discovered till the date. Further it has better bio-degradability and bio-compatibility. Due to these properties, guar gum finds application in various industries like, Textile, Food, Petrochemical, Mining, Paper, Explosive etc. But due to uncontrollable rate of viscosity, uncontrollable rate of hydration, instability of its solution for a long time and susceptibility to microbial contamination restricts its use in pharmaceutical industries. To overcome these draw back guar gum should be chemically modified. Modified guar gum is widely used in pharmaceutical application due to its viscosity enhancing properties. Guar gum and derivatives are used as binders and disintegrate in tablet and also used as a control-released agent for the drug. In this review article we summarized different pharmaceutical applications of native guar gum and its derivatives.

Keywords: Guar gum, Extraction method, Guar gum derivatives, Pharmaceutical applications, Control- release.

INTRODUCTION

Guar gum (GG) is galactomannan, derived from guar (*cyamopsistetragonolobus*) kernels which belong to family *Leguminosae.* Guar gum is also known as cluster bean, Guaran, Cyamopsis, Guarina, Clusterbean, Calcutta lucern.

The guar plant is about 0.6m high and pods are 5-12.5cm long and contain an average 5-6 light brown seeds. Guar gum is insoluble in hydrocarbons, fats, alcohols, esters, ketones- in fact with a very few exceptions (e.g. formamide) in organic solvents in general. The only important solvent for guar gum is water [1]. The general structure of guar gum is shown in below figure.

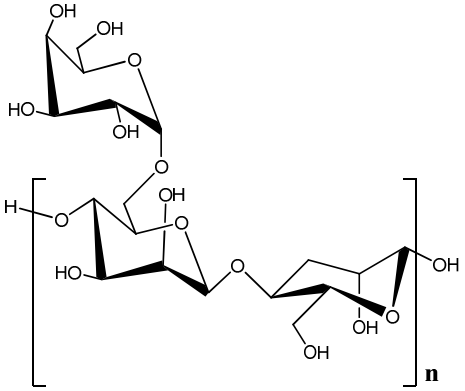

Fig.1: It shows the structure of guar gum

Guar gum has the ability to produce highly viscous, pseudo plastic aqueous solutions even at low concentrations due to the high molecular weight (up to 200,000 to 300,000 Daltons) and to the presence of the extended repeating unit formed by hydrogen bonding. This feature allows guar gum to be soluble and gel even in cold water.

Chemically guar gum has a linear chain of (1→4)-linked β-D-mannopyranosyl units with (1→6)-linked α-D-galactopyranosyl residues as side chains with mannose: galactose ratio is approximately 2:1. As it is non-ionic it is not affected by any pH. It is stable between pH ranges 5-7 and degrades on extreme pH and temperature [2, 3, 4, 5, 6].

Extraction of guar gum

Guar gum is extracted from guar kernels. Global demand for guar seed has increased over the year with a sudden rise in demand in the recent time on account of its increasing use in the petroleum industry and pharmaceutical industries. Exports of Indian guar gum have increased from mere 83,000 tons in 1995-96 to 205,000 tons in 2006-07. In the current year too, the exports are expected to inch higher to 210,000 tones as per trade estimates.

The extraction process of guar gum from guar seed is shown in below figure.

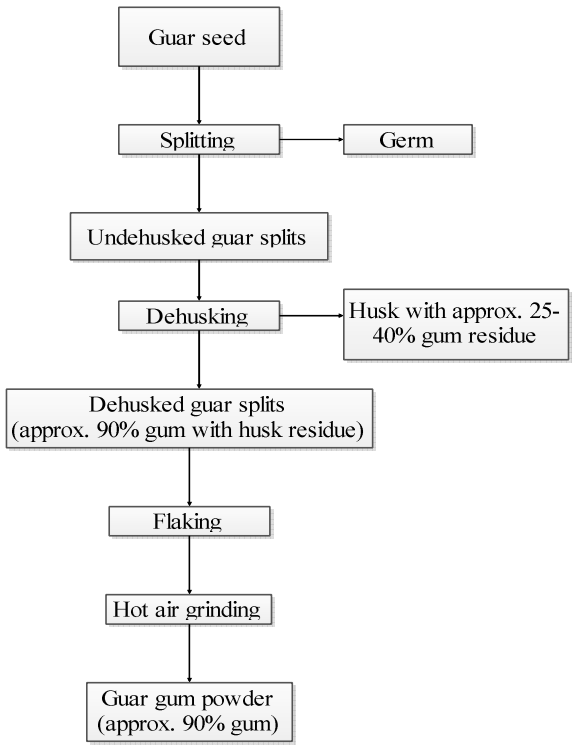

Fig. 2: It shows the extraction of guar gum from guar seed

The guar galactomannan has the unique property of imbibing large quantities of water, resulting in dispersions of extremely high viscosity. High viscosity coupled with the branched character of the polymer is responsible for adhesion of guar gum to hydrophilic surfaces. Guar gum products show a pronounced temperature thinning effect when their solutions are heated. This is caused by loss of water of hydration around the polymer molecule which makes the guar gum most applicable natural polymer [7]. Because of these properties, guar gum is used for a large number of industries viz. Textile, Petroleum, Paper, Explosive, Pharmaceutical and Food applications [8].

Guar gum is used to deliver drug to colon due to its drug release retarding property and susceptibility to microbial degradation in the large intestine. The gelling property retards release of the drug from the dosage form as well as it is susceptible to degradation in the colonic environment [9-11].

Guar gum and its derivatives are used as a binder and disintegrate in tablets to add cohesiveness to drug powder. Guar gum is also used as a controlled release agent for the drug due to high hydration rate (swelling in aqueous media)[12].

As discussed earlier due to uncontrolled rate of viscosity, uncontrollable rate of hydration, guar gum finds limited use in virgin forms. There so it has been chemically modified into various properties to expand its industrial applications such as in food, paint and pigments, oil field, mining, paper, water treatment, personal care, pharmaceutical and new types of superabsorbent. Natural polysaccharides like starch, cellulose, chitosan etc. are modified to carboxymethyl derivatives is the wide choice of researcher [13-15]. The most specific property of the guar gum and their derivatives is that they have hydroxyl groups, which makes them suitable for making changes in their structure formula and functionalization. A lot of research has been done on guar gum for the changing their physical and chemical properties by grafting, blending and compositing with synthetic and natural polymers. [16-19].

Some of the reported derivatives of guar gum are Carboxymethyl guar gum [16], Hydroxymethyl guar gum[20], Hydroxypropyl guar gum [21], O- Carboxymethyl- O-hydroxypropyl guar gum (CMHPG) [22], O-2-hydroxy-3- (trimethylammonia propyl) guar gum (HTPG), O-Carboyxymethyl-O-2-hydroxy-3-(trimethylammonia propyl) guar gum (CMHTPG) [23], Acryloyloxy guar gum [24], Methacryloyl guar gum[25], Sulfated guar gum[26], Guar gum esters [27].

Guar gum in pharmaceutical industries

Guar gum in control drug release system

Guar gum used as thickener and stabilizer in pharmaceutical formulation. When mixed with different ingredients in the formulation of tablets it form protective layer and consequently, drug releases out from the guar gum tablet in a sustained manner, achieving the desired kinetics effect, and masked unpleasant taste and odor of drugs and improve its stability and drug release properties.

K.L.K. Paranjothy et al prepared transdermal patches of verapamil HCl by using sodium carboxymethyl guar as a polymer matrix. A comparison of various polymers and plasticizers were also made. In vitro release studied through the mouse skin has shown that sodium carboxymethyl guar as a suitable polymer [28]. Y.V. Rama Prasad et al studied in vitro drug release of guar gum in the form of compression coat applied over indomethacin core tablets protects the drug from being released under conditions mimicking mouth to colon transit. The study clearly established that guar gum, in the form of compression coat, is a potential carrier for drug targeting to colon [29]. Ishihara N et al investigated the effect of partially hydrolyzed guar gum (PHGG) for treatment of the colonization of Salmonella enteritidis (SE) in young and laying. They concluded that ingestion of different rent dose of PHGG decreases the Salmonella enteritidis (SE) due to improvement in the balance of intestinal microflora. Feed supplemented with 0.025% PHGG was found the most effective [30]. Kumaresh S. Soppimath et al prepared Poly (vinyl alcohol)-guar gum interpenetrating network microspheres by cross-linking with glutaraldehyde. Nifedipine, an antihypertesive drug, was loaded into these matrices before and after cross-linking to study its release patterns. The in vitro release study indicated that the release from these microspheres is not only dependent upon the extent of cross-linking, but also on the amount of the drug loaded as well as the method of drug loading [31]. Soppimath K. S et al modified guar gum by grafting with polyacrylamide by emulsification. The drug loading capacity of modified guar microspheres were studied at different PH conditions using diltiazem hydrochloride and nifedipineas a model drug. The release followed non-Fickian transport in almost all the cases results show quick release in pH 7.4 buffer than observed in 0.1 N HCl [32].Y.S.R. Krishnaiah et al prepared three-layer matrix tablets of trimetazidinedihydrochloride by compressing on either side of guar gum matrix tablet granules of trimetazidinedihydrochloride. The three-layer matrix tablets were evaluated for hardness, thickness, drug content uniformity, and were subjected to in vitro drug release studies. The results clearly indicate that guar gum in the form of a three-layer matrix system is a potential hydrophilic carrier in the design of oral controlled drug delivery systems for highly soluble drugs [33].Y.S.R. Krishnaiah et al studied site-specific delivery of 5-fluorouracil to the colon without the drug being released in the stomach or small intestine using guar gum as a carrier. The study shows the guar gum compression-coated tablets released only 2.5–4% of the 5-fluorouracil in simulated GI fluids [34]. Toti U S et al prepared guar gum-g-polyacrylamidepolymer. *In vitro* drug release of diltiazem hydrochloride was studied. The effect of drug loading on release kinetics was evaluated. The nature of drug transport through the polymer matrices was studied by comparing with Higuchi, Hixson-Crowell and Kopcha equations [35].Narasimha Murthy S et al investigated the role of carboxymethyl guar gum for drug delivery systems. For this terbutaline sulfate (TS) was taken as model drug and the drug loading capacity of carboxymethyl guar gum films was observed at a different pH range [36].MuniraMomin et al prepared matrix tablet containing various proportions of guar gum by wet granulation technique using starch paste as a binder and sennosides as model drug. The results of study indicate that matrix tablet containing 50% guar gum and coated with 10% hydroxy propyl methylcellulose phthalate are most suitable for drug like sennosides which are mainly active in the lower GIT [37].M.K. Chourasia et al studied colon-targeting delivery of metronidazole using guar gum microspheres. *In vitro* drug release studies were performed in simulated gastric fluid and study shows 15.27±0.56% of the drug were released in 5 hrs. [38]. Pablyana L.R. Cunhaa et al prepared gel by cross-linking guar with glutaraldehyde. The reaction condition utilized leads to a guar gel with viscosity 40 times higher than the original gum viscosity and with 95.6% of water. Study shows that properties viz. low viscosity, small amount of remained glutaraldehyde, and thermal stability indicates that the guar gel has potential to be applied as biomaterial with specific rheological requirements [39]. MohiniChaurasia et al prepared guar gum microspheres containing methotrexate (MTX). MTX-loaded microspheres demonstrated high entrapment efficiency (75.7%). The in vitro drug release was investigated using a US Pharmacopeia paddle type (type II) dissolution rate test apparatus in different media. Guar gum microspheres showed adequate potential in achieving local release of drug in in vitro release studies, and this finding was further validated with in vivo studies [40]. SmitaRane et al prepared chemically modified guar gum for improving its film forming properties. The derivatives were evaluated as film coating material by coating dummy tablets. The coated tablets were studied for various tablet parameters such as hardness, friability loss, film adhesion and disintegration. Accelerated stability studies were carried out at 40^0C and at 75 % relative humidity for a period of 6 months [41]. Tiwari A et al prepared guar gum grafted with poly(epsilon-caprolactone) (GG-g-PCL). This derivative studied for drug-delivery carrier using microwave irradiation. The drug-release profile showed that the GG-g-PCL micelles provided an initial burst release followed by a sustained release of the entrapped hydrophobic model drug, ketoprofen, over a period of 10-68 hrs. These results suggest that the GG-g-PCL micelles could be used as a nano carrier for in vitro controlled drug delivery [42].GautamSena et al synthesized polyacrylamide grafted guar gum (GG-g-PAM) as matrix for controlled release of 5-amino salicylic acid. In vitro release of this drug from various grades of GG-g-PAM has been

studied by USP dissolution method (paddle type). The effect of percentage grafting on the rate of drug release has been investigated [43].Amit. S. Yadav et al formulatedthe oral controlled release zidovudine matrix tablets by using guar gum as rate controlling polymer and to evaluate drug release parameters as per various release kinetic models.The in vitro dissolution study was carried out for 12 hrs.using paddle (USP type II) method in phosphate buffer (pH 6.8) as dissolution media. Selected formulation was subjected to stability studies for 3 months, which showed stability with respect to release pattern [44]. RishabhaMalviyaet al developed sustained release matrix tablets of diclofenac sodium using guar gum as release modifier. The tablets were evaluated for their hardness, friability, weight variation, and an *In-vitro* release of drug was performed in phosphate buffer saline pH 7.4 for 24 hrs. Dissolution studies shows the release profile of diclofenac sodium from matrix tablets prepared using guar gum was retarded approximately 24 hrs. Thus guar gum stands as a good candidate for sustained release formulation [45].H.V. Chavda et al prepared oral controlled drug delivery system for sparingly soluble diclofenac sodium (DCL) using guar gum as triple-layer matrix tablets. Matrix tablets of diclofenac sodium were prepared by compressing three layers one by one. The results clearly indicate that guar gum could be a potential hydrophilic carrier in the development of oral controlled drug delivery systems [46].P. J. Subrahmanyam developed an oral colon targeted drug delivery system, which consists of theophylline matrix tablets prepared using guar gum and borax cross linked guar gum as rate controlling polymers in different concentrations. These tablets were evaluated for weight variation, friability, hardness uniformity of content and in vitro drug release under specified conditions. The dissolution data revealed that the tablets containing guar gum and borax cross linked guar gum in higher concentrations each (120mg) showed 87.567±0.42% and 76.186±0.17% of drug release respectively. Selected tablets of borax cross linked guar gum were subjected to in vitro drug release study in presence of rat caecal content medium. Results clearly indicate that there is an increase in the release of the drug to 98.930±0.38% [47].Vipul V. Jambukiya et al studied the effect of Guar gum (GG) and Modified guar gum (MGG) on the oral bioavailability of a poorly water-soluble drug, Ibuprofen (IBU). Prepared mixtures were evaluated for solubility study and *In vitro* dissolution studies using USP XXIII Dissolution apparatus. From the results, it was concluded that the co-grinding mixture with modified guar gum could be useful in developing a dosage form with improved dissolution rate and oral bioavailability of poorly water-soluble drugs [48].

Guar gum in treatment of diabetes

The role of guar gum and its derivatives to control blood sugar is well known. Studies showed that guar gum reduced the postprandial rise in blood glucose and insulin concentrations.

David J.A. Jenkins et al reported that when nine diabetic patients supplemented either their normal home diets (four patients) or metabolic ward diets (five patients) with 25 gm guar gum daily for 5 or 7 days their mean urinary glucose excretion fell by 46% ($P<0.05$) and 54% ($P<0.01$), respectively. Gel-forming, unabsorable carbohydrate may therefore be a useful adjunct to antidiabetic therapy, irrespective of the type of treatment or insulin dosage used [49]. Biesenbach G et al used combination of pectin and guar gum for treatment of hyperlipidemia. They reported that the total-cholesterol level and triglyceride concentration in blood serum is lowered but HDL-cholesterol level remained approximately the same in 15 female patients (52-70yrs) having type-2 diabetes with hypercholesterolemia(total-chol> 240 mg/dl and LDL-chol> 130 mg/dl). Females were taken fiber mixture at dose level of (17 gm + 5.9 gm water-soluble fiber) dissolved in 250 ml water for the 9 weeks after 3 weeks in dieteticsrun-in-phase. PHGG is considered as safe and good to use as a food supplement products for lowering of lipids in patients suffering from hyperlipidemia [50]. Gatenby S J et al investigated the blood glucose, plasma insulin, C-peptide, and gastric inhibitory polypeptide (GIP) of 14 patients of non-insulin dependent diabetes (NIDDM) after and before intake of modified partial depolymerized guar meal. Results indicate the reduction in the rise in blood glucose, plasma insulin, butno reductions in postprandial plasma C-peptide levels were observed [51].Suzuki T et al concluded that guar gum hydrolysate (GGH) increases glucose intolerance and low hypertriglyceridemia in rats fed high-fructose diets. Possible mediators of these beneficial effects of GGH are the SCFAs produced by microbial fermentation of GGH in the large intestine [52]. Samarghandiansaeed et al studied the antihyperglycemic and antihyperlipidemiceffects of guar gum on streptozotocin-induced diabetes in male rats. Study result shows that guar gum diet significantly decreased the serum concentration of cholesterol, triacylglicerols and LDL-C and atherogenic index. The most significant result in this study was the reduction of blood glucose in diabetic rats treated with the guar gum diet after 28 days versus non- and glibenclamide-treated rats. The gum promoted a general improvement in the condition of the diabetic rats in body weight and food intake in comparison with non-treated rats [53].ValescaDall'Alba et al studied the effect of soluble fibre from partially hydrolysed guar gum (PHGG) on the MetS and cardiovascular risk factors in patients with type 2 diabetes.In these study randomized controlled clinical trial, 44 patients with type 2 diabetes and the MetS underwent clinical, laboratory and dietary evaluations at baseline, 4 and 6 weeks. All patients followed their usual diet and the intervention group received an additional 10 gm/day of PHGG. In patients with type 2diabetes and the MetS, the addition of PHGG to the usual diet improved cardiovascular and metabolic profiles by reducing WC, HbA1c, UAE and trans-FA [54].

Guar gum in treatment of Cancer

Guar gum and its derivatives are also helpful in cancer therapy especially colorectal cancer most common form of cancer due to intestinal disorder.

Chaurasia M et al evaluated the effect of glutaraldehydecrooslinked guar gum containing methotrexate for treatment of colorectal cancer (colon cancer). Colorectal cancer is the third most serious type of cancer having 665,000 deaths per year all around the world. They prepared guar gum microsphere crosslinked by emulsification with glutaraldehyde and then characterized for local release of drug in the colon which is necessary for the treatment of colorectal cancer. The research shows that crosslinked guar has high entrapment efficiency along with methotrexate (MTX) investigation of in vitro drug release was tested by US Pharmacopeia paddle type(type-2)dissolution rate test apparatus, which shows different drug release result by changing amount of guar gum and glutaraldehyde[55].Sakata Y et al investigated that how much amount of partially hydrolyzed guar gum (PHGG) ingestion can enhances bowel movement and can stop risk of colorectal cancer. They investigated the effect of PHGG intake upon 9 healthy female students by observing weight, moisture and hardness of feces. The result shows increase in fecal moisture and texture with some variation. The benefit of bowel movements provided by the PHGG intake has variation among different female students [56].Gamal-EldeenA M et al prepared the gum c-glycosylated derivative (GG), and its sulphated derivative (SGG) and observed their cancer chemopreventive and anti-inflammatory properties. They reported that modified guar gum has potential to prevent cancer and must be taken as supplement in foods. Results conclude that derivative of guar gum has ability to inhibited the carcinogen activator enzyme, cytochrome P450 1A (CYP1A), and also promote the carcinogen detoxification enzymes glutathione-S-transferases (GSTs) [57].E. Chandra Sekhar et al prepared chitosan and guargum-g-acrylamide (CH-GG-g-AAm) semi interpenetrating microspheres (semi IPNMs) by water-in-oil (w/o) emulsion process by using glutaraldehyde as a crosslinker. 5-fluorouracil (5-FU) is an anticancer drug was successfully loaded in these semi IPNMs. *In-vitro* release studies were performed in basic (pH 7.4) buffer medium. The release pattern depended on graft polymer composition, effect of cross linker and drug content in the polymer matrices. In vitro release studies indicated the release of 5-FU more than 12 hrs. [58].Elias E. J et al studied a suitable polymer (guar gum) based matrix tablet for curcumin with sufficient mechanical strength and promising in vitro mouth-to-colon release profile. Three formulations of curcumin were prepared using varying concentrations of guar gum containing 50 mg curcumin by the wet granulation method. Tablets were subjected to evaluation by studying parameter like hardness, friability, drug content uniformity, and in-vitro drug release. In vitro

drug release was evaluated using simulated stomach, intestinal and colonic fluids. The susceptibility of guar gum to colonic bacteria was also assessed by a drug release study with rat caecal contents. The 40% guar gum containing formulation (F-1) showed better drug release (91.1%) after 24 hrs in the presence of rat caecal contents in comparison with the 50% guar gum containing formulation (F-2) (82.1%). Curcumin could, thus, be positively delivered to the colon for effective colon cancer treatment using guar gum [59].

Guar gum as hydrogel

Hydrogels are prepared by crosslinking guar gum with different monomer. These hydrogels are incorporated with different drugs to study their release pattern. Guar gum hydrogels are also useful in the control drug delivery system.

Gliko-Kabir I et al prepared a crosslinked low swelling guar gum (GG) hydrogel by reacting it with trisodiumtrimetaphosphate (STMP) and its function as possible colon-specific drug carriers was analyzed in the rats. They concluded that crosslinked guar (biodegraded enzymatically) is an effective vehicle for colon specific drug delivery systems [60]. Soppirnath K S et al studied drug release ability of polyacrylamide-guar gum copolymer, crosslinked with glutaraldehyde. These guar gum hydrogel microspheres were incorporated with two antihypertensive drugs, verapamil hydrochloride (water-soluble) and nifedipine (water-insoluble) to investigate their controlled drug release capacity. In vitro study shows dependence of drug release on the extent of crosslinking of guar copolymer, concentration of drug, type of drug molecule and method of drug loading [61].Das A et al examined the effect of glutaraldehyde crosslinked guar gum for delivery of colon specific drug system. The ability of this hydrogel discs for drug loading capacity, buffer intake ability, drug release efficiency were investigated in different medium and pH. They concluded that crosslinking decreases swelling (buffer intake) of guar gum. % drug release capacity increased with increasing glutaraldehyde concentration [62].M. George et al prepared pH sensitive alginate-guar gum hydrogel crosslinked with glutaraldehydefor the controlled delivery of protein drugs. The crosslinked alginate-guar gum matrix is novel and the drug loading process used in the study was mild and performed in aqueous environment. The release profiles of a model protein drug (BSA) from test hydrogels were studied under simulated gastric and intestinal media. Protein release from test hydrogels was minimal at pH 1.2 (~20%), and it was found to be significantly higher (~90%) at pH 7.4. Presence of guar gum and glutaraldehyde crosslinking increases entrapment efficiency and prevents the rapid dissolution of alginate in higher pH of the intestine, ensuring a controlled release of the entrapped drug [63].Tiwari A et al prepared photo polymerized guar gum-methacrylate derivative having molecular weight range from 74-210 Da and different degree of methacrylation. These hydrogels exhibit excellent endothelial cell proliferation capacity just like that of matrigel control. The human endothelial cell line EA.hy926 was photo-encapsulated in the GG-MA hydrogels. Cells remained viable at low macro monomer concentrations, but cell viability decreased sequentially as the macro monomer concentration increased [64].ShiwaliThakura et al synthesized acryloyl guar gum (AGG) and its hydrogel materials for use as carrier and slow release devices of two pro-drugs, l-tyrosine and 3,4-dihydroxy phenylalanine (l-DOPA). The hydrogel materials responded to the change of pH of the swelling medium, and exhibited reversible transitions in 0.9% saline solution. These were loaded with two pro-drugs, and their cumulative release behavior was studied at pH 2.2 and pH 7.4. The hydrogel materials exhibited structure-property relationship in the release of these pro-drugs. The % cumulative release of l-tyrosine was the maximum from the AGG-g-poly (methacrylic acid), while the maximum release of l-DOPA was observed from AGG-g-poly (AAc) in both the media [65].Anita G. Sullad et al prepared pH-sensitive hydrogel blend of poly(vinyl alcohol) with acrylic acid-graft-guar gum. Microspheres with a size of 10 μm were produced by the water-in-oil (w/o) emulsification method for investigating the controlled release of an anti-tuberculosis drug, isoniazid. These novel carriers were analyzed for surface morphology, size, effect of pH, swelling, drug loading, and in vitro release of isoniazid in pH 1.2 and 7.4 media. The kinetics of drug release was analyzed using empirical equations. Release times of the drug were increased to 8 h from its nascent plasma half-life of 0.5-1.6 hrs. [66].Kumaresh S. Soppimath et al prepared new spherically shaped cross-linked hydrogels of polyacrylamide-grafted guar gum by the emulsification method. The derived micro gels were responsive to pH and ionic strength of the external medium. The swelling of micro gels increased when the pH of the medium changed from acidic to alkaline. Transport parameters, viz., solvent front velocity and diffusion coefficients were calculated from a measurement of the dimensional response of the microgels under variable pH conditions. Swelling was reversible and pulsatile with the changing environmental conditions. The pH-sensitive micro gels were loaded with diltiazem hydrochloride and nifedipine (both antihypertensive drugs) and their release studies were performed in both the simulated gastric and intestinal pH conditions [67].Ghanshyam S. Chauhan et al prepared guar gum (GG)based hydrogel, by grafting GG with acrylic acid (AAc) using simultaneous gamma radiation technique. Swelling behavior of hydrogels was studied at various temperature, pH, and the salt sensitivity of the hydrogels was studied by swelling the hydrogels in 0.9% NaCl solution. The hydrogels exhibited fast swelling and stimuli-responsiveness at the technologically significant pH or temperature. These stimuli-responsive hydrogels being cost-effective, biocompatible, and biodegradable are easy to synthesize. The hydrogels are technologically important and have potential applications in drug delivery and separation processes [68].

Guar gum in treatment of other disease

Guar gum and its derivatives also used in treatment of other disease like, cholera, functional constipation, and diarrhea. Guar gum and its solution also used in eye-drop formulations.

Lampe J W et al had given 11 healthy men three different fed enzymatically modified guar gum, maltodextrin and soy polysaccharides for 18 days trial. They demonstrated improvement in gastrointestinal function [69].Takahashi H et al confirmed the role of partially hydrolyzed guar gum (PHGG) for prevention of constipation on 15 constipated women for 3 weeks. Mostfavored reason for constipation is lack of dietary fibers in our diet. In the experiment female were taken an average diet of 9.7+/-0.1 gm/day then weight, texture, moisture and bacterial flora ion feces were observed. Results confirmed beneficial effect of PHGG for treatment of constipation [70].Alam N H et al evaluated the effect of partially hydrolyzed guar gum (BENEFIBER) on the rate of normal absorption of glucose, amino acid (arginine) and fat and their side effects was also investigated. 10 healthy male volunteers in a double blind trial were given to two different dietary supplements (with fibers, without fibers) for a period of two weeks. The results of the study demonstrated that PHGG did not interfere with the normal absorption of glucose, amino acid and fat and shows no side effects so its use is safe for health [71]. Heini A F et al evaluate the effects of hydrolyzed guar gum on fasting and postprandial hormone levels, respiratory quotient (RQ) and postprandial satiety during a controlled weight-loss program and found it useful for weight reduction [72].Yamada K et al observed the role of partially hydrolyzed guar gum (PHGG), glucomannan, highly methoxylated (HM) pectin and water-insoluble cellulose on the serum lipid level and immunoglobulin (Ig) production of Sprague-Dawley. They reported decrease in serum total cholesterol, phospholipids and triglyceride levels and increase in immunoglobulin IgA productivity in rats fed on water soluble dietary fibers (guar gum, pectin) as compared to cellulose (water insoluble fiber) [73].Watanabe O et al investigated the effect of phosphorylated guar gum hydrolysate (P-GGH) on intestinal calcium absorption of overiectomized (OVX) rats. Rats were fed on P-GGH (50gm/Kg of diet) for six week. Result shows that in the condition of estrogen deficiency P-GGH may be useful for prevention of the reduction of intestinal calcium absorption and bone [74].Kovacs E M et al reported the effect of modified guar on appetite and body weight loss. For this purpose 28 fatty male (age 19-56) were given semisolid meal along with modified guar gum in different amount for specified time period. GG addition to a semisolid meal prevented an increase in appetite, hunger and desire to eat, which was increase in the other treatments as a result significant decrease in body weight taken place

[75].Parisi G et al also observed useful effects of partially hydrolyzed guar gum for treatment of irritable bowl syndrome in an open clinical trial different dose of PHGG was given to different patients and their gastrointestinal symptoms GSRS), physiochemical symptoms (HADS) and quality of life (SF-36) was observed in six month. Results show beneficent effect of this modified guar gum on patient's health [76].Stewart M L et al observe fruitful physiological effects of partially hydrolyzed guar gum (PHGG) to human health. They investigated the variation in intestinal fermentability by changing molecular weight of modified guar gum. For trial guar gum of four different molecular weights (15, 20, 400, and 1,100 kDa) was fermented using a batch *In vitro* fermentation system. The result shows the molecular weight of guar gum was positively influenced on the acetate production and negatively influenced on the propionate production. They conclude that 400-kDa guar gum is suitable for intestinal fermentability[77].De CássiaFreitas K et al reported the effect of partially hydrolyzed guar gum towards intestinal iron absorption in rats with iron deficiency. 24 male wistar rats having iron deficiency anemia was divided in three groups and fed with partially hydrolyzed guar (100Kg/day) diet, cellulose (100kg/day) diet, and without dietary fiber diet for each group respectively. Maximum intestinal absorption of iron, regeneration of hemoglobin and hepatic levels of iron observed in first group fed on PHGG containing diet [78]. Foulks G N. studied the role of HP-Guar as gelling agent in polyethylene glycol (PEG)400/propylene glycol9(PG) eye drops used for the treatment of dry eye diseases. A literature review prior to 2007 july was conducted and founded efficacy of HP-Guar as gelling agents in PEG/PG eye drops [79].Nakamura S et al studied the role of dietary fiber especially partially hydrolyzed guar gum on transitory diarrhea caused by ingestion of malitol and lacitol (sugar substitute).PHGG effect was evaluated by injection of different dose of malitol to volunteers female until they experienced diarrhea. Then observation confirmed suppressive effect on diarrhea of partially hydrolyzed guar [80].Zhu Y et al prepared sulfonated degraded guar gum by reaction of guar gum with chlorosulfonic acid under different conditions. Structure of this modified guar was confirmed by infrared spectrometry. They concluded that about 2500mg/L concentration of sulfated guar can reduces about 60-66% cholesterol, about 76-89%LDL and almost 100% of fibrinogen [81].Belo G M et al evaluated the effect of partially hydrolyzed guar gum for treatment of functional constipation among different hospitalized patient. They found it beneficial for reduction of functional constipation [82].Kuo D C et al evaluated the role of partially hydrolyzed guar gum for prevention of $FeCl_3$-induced arterial thrombosis and hyperlipidemia in the high fat-diet fed hamsters. Based on their results, they conclude that PHGG supplement can increase antioxidant protein expression and thus decrease oxidative stress induced arterial injury [83].

FUTURE ASPECT

All these research shows that guar gum and its derivatives finds application as drug binder, control-release agent and as dietary fiber. Guar gum and its derivatives have potential to use in many pharmaceutical applications without any side effects.

CONFLICT OF INTERESTS

Declared None

REFERENCES

1. RJ Chubzikowski. Guar gum and its applications. J Soc Cosmet Chem 1971;22:43-60.
2. Wang Q, PREllis, SB Ross murphy. Dissolution kinetics of guar gum powders-II. Effects of concentration and molecular weight. J Carbohydrate Polym 2003;53(1):75-83.
3. Veeran GK, Gure VB. Water Soluble Polymers for Pharmaceutical Applications. J Polymers 2011;3(4):1972-2009.
4. KN Venugopal, Abhilash M. Study of Hydration Kinetics and Rheological Behaviour of Guar gum. Int J of Pharm Sci and Res 2010;1(1):28-39.
5. A Srichamroen. Influence of Temperature and Salt on Viscosity Property of Guar Gum. Naresuan University J 2007;15(2):55-62.
6. DN Iqbal, EA Hussain. Physiochemical and pharmaceutical properties of Guar gum derivatives. J Report and Opinion 2010;2(10):77-83.
7. TT Reddy, S Tammishetti. Free radical degradation of guar gum. J Polymer Degradation and Stability 2004;86(3):455-9.
8. H Prabhanjan, MM Gharia, HC Srivastava. Guar gum derivatives. Part I:Preparation and properties. J Carbohydrate Polymers 1989;11(4):279-92.
9. CE Bayliss, AP Houston. Characterization of plant polysaccharide-and mucin-fermenting anaerobic bacteria from human feces. J Applied and Environmental Microbiology 1984;48(3):626-32.
10. J Tomolin, JS Taylor, NW Read. The effect of mixed faecal bacteria on a selection of viscous polysaccharide *in vitro*. J Nutr Rep Int 1989;39:121-35.
11. GT Macfarlane, S Hay, S Macfarlane, GR Gibson. Effect of different carbohydrates on growth, polysaccharidase and glycosidase production by Bacteroidesovatus, in batch and continuous culture. J Appl Bacteriol 1990;68:179-87.
12. R Malviya, P Srivastava, M Bansal, PK Sharma. Formulation and Optimization of Sustained Release Tablets of Diclofenac Sodium Using Guar Gum as Release Modifier. Int J of Pharm Sci and Res 2010;1(6):82-8.
13. B Yaacob, Mohd CairulIqbal Mohd Amin, KHashim. BABakar. Optimization of Reaction Conditions for Carboxymethylated Sago Starch. Iranian Polymer J 2011;20(3):195-204.
14. S Kamel, N Ali, K Jahangir, SM Shah. AA El-Gendy.Pharmaceutical significance of cellulose:A review Express. J Polymer Letters 2008;2(11):758-78.
15. PD Koninck, D Archambault, F Hamel, F Sarha, MA Mateescu. Carboxymethyl-Starch Excipients for Gastrointestinal Stable Oral Protein Formulations Containing Protease Inhibitors. J Pharm and Pharmaceut Sci 2010;13(1):78-92.
16. JJ Patel, M Karve, NK Patel, A novel approach to synthesize carboxymethyl guar gum via friedel craft acylation method. MMAIJ 2014;10(1):18-22.
17. G Dodi, D Hritcu, MI Popa. Carboxymethylation of guar gum:synthesis and characterization. J Cellulose Chem Technol 2011;45 (3-4):171-6.
18. P Adhikary, S Krishnamoorthi, RP Singh. Synthesis and Characterization of Grafted Carboxymethyl Guar Gum. J of Applied Polymer Sci 2011;120(5):2621-6.
19. JZ Yi, LM Zhang. Biodegradable Blend Films Based on Two Polysaccharide Derivatives and Their Use as Ibuprofen-Releasing Matrices. J of Applied Polymer Sci 2007;103(6):3553-9.
20. R Lapasin, S Pricl, P Tracanelli. Rheology of hydroxyethyl guar gum derivatives. J Carbohydrate Polymers 1991;14(4):411-27.
21. R Lapasin, S Pricl, LD Lorenzi, G Torriano. Flow properties of hydroxypropyl guar gum and its long-chain hydrophobic derivatives. J Carbohydrate polymers 1995;28(3):195-202.
22. HY Shi, MZ Li. New grafted polysaccharide based on O-carboxymethyl-O-hydroxypropyl guar gum and N-isopropylacrylamide:synthesis and phase transition behaviour in aqueous media. J Carbohydrate polymer 2007;67(3):337-42.
23. Li-Ming Z, Jian-Fang Z, SH Peter. A comparative study on viscosity behavior of water-soluble chemically modified guar gum derivatives with different functional lateral groups. J of the Sci of Food and Agriculture 2005;85(15):2638-44.
24. MA Shenoy, DJ D'Melo. Synthesis and Characterization of Acryloyloxy Guar Gum. J of Applied Polymer Sci 2010;117(1):148-54.
25. Xiao, W., Dong, L. Novel excellent property film Prepared from Methacryloyl chloride-graft-Guar Gum Matrixes. Conference Location:Xian Ning, Date of Conference:16-18 April 2011,1442-45.
26. NM Mestechkina, AV Egorov, VD Shcherbukhin. Synthesis of Galactomannan Sulfates. J Applied Biochemistry and Microbiology 2010;42(3):326-30.
27. C Dong, B Tian. Studies on Preparation and Emulsifying Properties of Guar Galactomannan Ester of Palmitic Acid. J Appl Polym Sci 1999;72(5):639-45.
28. KLKParanjothy, PP Thampi. Development of Transdermal Patches of Verapamil Hydrochloride using Sodium Carboxymethyl guar as a Monolithic Polymeric matrix and

there *in vitro* release studies. Indian J Pharm Sci 1997;59(2):49-54.
29. YSR Krishnaiah, S Satyanarayana, YV Rama Prasad, S NRao. Evaluation of guar gum as a compression coat for drug targeting to colon. Int J of Pharm 1998;171(2):137-46.
30. N Ishihara, DC Chu, SAkachi, LR Juneja. Preventive effect of partially hydrolyzed guar gum on infection of Salmonella enteritidis in young and laying hens. J Poultry Sci 2000;79(5):689-704.
31. KS Soppimath, AR Kulkarni, TM Aminabhavi. Controlled release of antihypertensive drug from the interpenetrating network poly(vinyl alcohol)–guar gum hydrogel microspheres. J of Biomaterials Sci Polymer Edition 2000;11(1):27-43.
32. KS Soppimath, AR Kulkarni, TM Aminabhavi. Chemically modified polyacrylamide-g-guar gum-based crosslinked anionic microgels as pH-sensitive drug delivery systems:preparation and characterization. J of Controlled Release 2001;75(3):331-45.
33. YSR Krishnaiah, RS Karthikeyan, VG Sankar, V Satyanarayana. Three-layer guar gum matrix tablet formulations for oral controlled delivery of highly soluble trimetazidinedihydrochloride. J of Controlled Release 2002;81(1-2):45-56.
34. YSR Krishnaiah, V Satyanarayana, BD Kumar, RSKarthikeyan. *In vitro* drug release studies on guar gum-based colon targeted oral drug delivery systems of 5-fluorouracil. European J of Pharm Sci 2002;16(3):185-92.
35. US Toti, TM Aminabhavi. Modified guar gum matrix tablet for controlled release of diltiazem hydrochloride. J of Controlled Release 2004;95(3):567-77.
36. SN Murthy, SR Hiremath, KL Paranjothy. Evaluation of carboxymethyl guar films for the formulation of transdermal therapeutic systems. Int J of Pharmaceutics 2004;272(1-2):11-8.
37. M Momin, K Pundarikakshudu. *In vitro* studies on guar gum based formulation for the colon targeted delivery of Sennosides. J Pharm Pharmaceut Sci 2004;7(3):325-31.
38. MK Chourasia, SK Jain. Potential of Guar Gum Microsphere for Target Specific Drug Release to Colon. J of Drug Targeting 2004;12(7):435-42.
39. PLRCunhaa, RR Castro, FAC Rocha, RCM de Paula, JPA Feitosa. Low viscosity hydrogel of guar gum:Preparation and physicochemical characterization. Int J of Biological Macromolecules 2005;37(1-2):99-104.
40. M Chaurasia, MK Chourasia, NK Jain, A Jain, VSoni, Y Gupta *et al.* Cross-Linked Guar Gum Microspheres:a viable approach for improved delivery of anticancer drugs for the treatment of colorectal cancer. J AAPS Pharm Sci Tech 2006;7(3):E143-E51.
41. S Rane,V Kale. Evaluation of modified Guar Gum as film coating material. Int J of Chem Tech Res 2009;1(2):180-2.
42. A Tiwari, MPrabaharan. An amphiphilicnanocarrier based on guar gum-graft-poly(epsilon-caprolactone) for potential drug-delivery applications. J Biomater Sci Polym Ed 2010;21(6):937-49.
43. G Sen, S Mishra, UJha, S Pal. Microwave initiated synthesis of polyacrylamide grafted guar gum (GG-g-PAM)-Characterizations and application as matrix for controlled release of 5-amino salicylic acid. Int J of Biol Macromolecules 2010;47(2):164-70.
44. AS Yadav, Ashok Kumar P, Vinod R, BS Rao, SV Kulkarni. Design and Evaluation of Guar Gum Based Controlled Release Matrix Tablets of Zidovudine. J of Pharm Sci and Technology 2010;2(3):156-62.
45. R Malviya, P Srivastava, M Bansal, PK Sharma. Formulation and Optimization of Sustained Release Tablets of Diclofenac Sodium Using Guar Gum as Release Modifier. Int J of Pharm Sci and Res 2010;1(6):82-8.
46. HV Chavda, MS Patel, CN Patel. Preparation and *in vitro* evaluation of guar gum based triple-layer matrix tablet of diclofenac sodium. J Res in Pharm Sci 2012;7(1):57-64.
47. PJ Subrahmanyam. Design and development of guar gum and borax cross-linked guar gum matrix tablets of theophylline for colon specific drug. J of Chemical Pharm Res 2012;4(2):1052-60.
48. VV Jambukiya, RB Parmar, AV Dudhrejiya, Dr. HM Tank, VD Limbachiya. Enhancement of Solubility and Dissolution Rate of Poorly Water Soluble Drug by Using Modified Guar Gum. Asian J Res Pharm Sci 2013;3(1):25-30.
49. DJA Jenkins, T Derek, R Hockaday, RHowarth, EC Apling, TMSWolever, *et al*. Treatment of Diabetes with Guar Gum:Reduction of Urinary Glucose Loss in Diabetics. J Lancet 1977;310(8042):779-80.
50. G Biesenbach, P Grafinger, P Janko, W Kaiser, U Stuby, E Moser. The lipid lowering effect of a new guar-pectin fiber mixture in type II diabetic patients with hypercholesterolemia. J Leber Magen Darm 1993;23(5):207-09.
51. SJ Gatenby, PR Ellis, LM Morgan, PA Judd. Effect of Partially Depolymerized Guar Gum on Acute Metabolic Variables in Patients with Non-insulin-dependent Diabetes. J Diabetic Medicine 1996;13(4):358-64.
52. T Suzuki, H Hara. Ingestion of Guar Gum Hydrolysate, a Soluble and Fermentable Nondigestible Saccharide, Improves Glucose Intolerance and Prevents Hypertriglyceridemia in Rats Fed Fructose. The J of Nutr 2004;134(8):1942-7.
53. S Saeed, HM Al-Reza, AN Fatemeh, D Saeideh. Antihyperglycemic and antihyperlipidemic effects of guar gum on streptozotocin-induced diabetes in male rats. J Pharmacognosy Magazine 2012;8(29):65-72.
54. V Dall'Alba, FM Silva, JP Antonio, T Steemburgo, CP Royer, JC Almeida. *et al*. Improvement of the metabolic syndrome profile by soluble fibre-guar gum in patients with type 2 diabetes:a randomized clinical trial. J British J of Nutrition 2013;110(09):1601-10.
55. M Chaurasia, MK Chourasia, NK Jain, A Jain, V Soni, Y Gupta, *et al*. Cross-linked guar gum microspheres:A viable approach for improved delivery of anticancer drugs for the treatment of colorectal cancer. J AAPS Pharm Sci Tech 2006;7(3):E143-E51.
56. Y Sakata, S Shimbo. How much does partially hydrolyzed guar gum affect the weight, moisture and hardness of feces. J Nippon Koshu Eisei Zasshi 2006;53(4):257-64.
57. AM Gamal-Eldeen, H Amer, WA Helmy, Cancer Chemopreventive and anti-inflammatory activities of chemically modified guar gum. J Chemico-Biological Interactions 2006;161(3)229-40.
58. E Chandra Sekhar, KSV Krishna Rao, RR Raju. Chitosan/guargum-g-acrylamide semi IPN microspheres for controlled release studies of 5-Fluorouracil. J of Applied Pharm Sci 2011;1(08):199-204.
59. EJ Elias, S Anil, S Ahmad, A Daud. Colon Targeted Curcumin Delivery Using Guar gum. J Natural Product Communications 2010;5(6):915-8.
60. IG Kabir, B Yagen, M Baluom, ARubinstein. Phosphatedcross-linked guar for colon-specific drug delivery:II. *In vitro* and *in vivo* evaluation in the rat. J Controlled Release 2000;63(1-2):129-34.
61. KS Soppirnath, TM Aminabhavi. Water transport and drug release study from cross-linked polyacrylamide grafted guar gum hydrogel microspheres for the controlled release application. Eur J Pharm Biopharm 2000;53(1):87-98.
62. A Das, S Wadhwa, AK Srivastava. Cross-Linked Guar Gum Hydrogel Discs for Colon-Specific Delivery of Ibuprofen:Formulation and *In Vitro* Evaluation. J Drug Delivery 2006;13(2):139-42.
63. M George, TEAbraham. pH sensitive alginate-guar gum hydrogel for the controlled delivery of protein drugs. Int J of Pharm 2007;335(1–2):123-9.
64. A Tiwari, JJ Grailer, S Pilla, DA Steeber, S Gong. Biodegradable hydrogels based on novel photopolymerizable guar gum–methacrylate macromonomers for in situ fabrication of tissue engineering scaffolds. J Acta Biomater 2009;5(9):3441-52.
65. S Thakur, GS Chauhan. Synthesis of acryloyl guar gum and its hydrogel materials for use in the slow release of l-DOPA and l-tyrosin. J Carbohydrate Polymers 2009;76(4):513-20.
66. AG Sullad, LS Manjeshwar, TM Aminabhavi. Novel pH-Sensitive Hydrogels Prepared from the Blends of Poly(vinyl alcohol) with Acrylic Acid-graft-Guar Gum Matrixes for Isoniazid Delivery. J Ind Eng Chem Res 2010;49(16):7323-29.
67. KS Soppimath, AR Kulkarni, TM Aminabhavi. Chemically modified polyacrylamide-g-guar gum-based crosslinked anionic microgels as pH-sensitive drug delivery

systems:preparation and characterization. J of Controlled Release 2001;75(3):331-45.

68. R Dharela, LRaj, GS Chauhan. Synthesis, characterization, and swelling studies of guar gum-based pH, temperature, and salt responsive hydrogels. J of Applied Polymer Sci 2012;126(S1):E260-E5.
69. JW Lampe, ME Effertz, JL Larson, JL Slavin. Gastrointestinal Effects of Modified Guar Gum and Soy Polysaccharide as Part of an Enteral Formula Diet. J Parenteral and Enteral Nutrition 1992;16(6):538-44.
70. H Takahashi, N Wako, T Okubo, N Ishihara, J Yamanaka, T Yamamoto. Influence of Partially Hydrolyzed Guar Gum on Constipation in Women. J of Nutritional Sci and Vitaminology 1994;40(3):251-9.
71. NH Alam, R Meier, T Rausch, B Meyer-Wyss, P Hildebrand, H Schneider. *et al*. Effects of a partially hydrolyzed guar gum on intestinal absorption of carbohydrate, protein and fat:a double-blind controlled study in volunteers. J Clinical Nutrition 1998;17(3):125-9.
72. AF Heini, C Lara-Castro, H Schneider, KA Kirk, RV Considine, RL Weinsier. Effect of hydrolyzed guar fiber on fasting and postprandial satiety and satiety hormones:A double-blind, placebo-controlled trial during controlled weight loss. Int J of Obesity 1998;22(9):906-9.
73. IG Kabir, B Yagen, A Penhasi, A Rubinstein. Phosphatedcross-linked guar for colon-specific drug delivery:I. Preparation and physicochemical characterization. J of Controlled Release 2000;63(1-2):121-7.
74. Watanabe, H Hara, Y Aoyama, T Kasai, Improving Effect of Feeding with a Phosphorylated Guar Gum Hydrolysate on Calcium Absorption Impaired by Ovariectomy in Rats. J Biosci Biotechnol and Biochem 2001;65(3):613-8.
75. EMR Kovacs, MS Westerterp-Plantenga, WHM Saris, I Goossens, P Geurten, F Brouns. The effect of addition of guar gum to a low-energy semisolid meal on appetite and body weight loss. Int J of Obesity 2001;25(3);307-15.
76. G Parisi, E Bottona, M Carrara, F Cardin, A Faedo, D Goldin. *et al*. Treatment Effects of Partially Hydrolyzed Guar Gum on Symptoms and Quality of Life of Patients with Irritable Bowel Syndrome. A Multicenter Randomized Open Trial. J Digestive Diseases and Sci 2005;50(6):1107-12.
77. ML Stewart, JL Slavin. Molecular weight of guar gum affects short-chain fatty acid profile in model intestinal fermentation. J Molecular Nutrition and Food Res 2006;50(10):971-6.
78. KC Freitas, OM Amancio, NF Novo, UF Neto, MB Morais. Partially hydrolyzed guar gum increases intestinal absorption of iron in growing rats with iron deficiency anemia. J Clinical Nutrition 2006;25(5):851-8.
79. GN Foulks. Clinical evaluation of the efficacy of PEG/PG lubricant eye drops with gelling agent (HP-Guar) for the relief of the signs and symptoms of dry eye disease:a review. J Drugs Today (Barc) 2007;43(12):887-96.
80. S Nakamura, R Hongo, K Moji, T Oku. Suppressive effect of partially hydrolyzed guar gum on transitory diarrhea induced by ingestion of maltitol and lactitol in healthy humans. Eur J of Clinical Nutrition 2007;61(9):1086-93.
81. Zhu Y, Fang B, Huang L, Guan C, Yang G. Study on the selective removal of plasma low-density lipoprotein and fibrinogen by degraded guar sulfate. J Sheng Wu Yi Xue Gong Cheng XueZa Zhi 2008;25(5):1135-40.
82. BGM da Silva, DA da Silva, APC Pereira. Effect of partially hidrolized guar-gum in the treatment of functional constipation among hospitalized patients. J Arq Gastroenterol 2008;45(1):93-5.
83. DC Kuo, SP Hsu, CT Chien. Partially hydrolyzed guar gum supplement reduces high-fat diet increased blood lipids and oxidative stress and ameliorates $FeCl_3$-induced acute arterial injury in hamsters. J of Biomedical Sci 2009;16:15:1-10.