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Analytical Characterization of Guar and Guar Gum Produced in Sindh, Pakistan

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Research Article

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Abstract

The objective of this work was to study the quality of guar and guar gum produced in Sindh, Pakistan. Fresh guar, guar seeds and guar gum made in laboratory was analyzed for that purpose. For comparison purpose, analytical grade guar gum and industrial guar gum (prepared from guar split) was also studied. Results of proximate composition of guar seed revealed that it is mainly composed of Nitrogen free extract (45.7%) followed by protein (29.6%), moisture (12.4%), crude fiber (8.9%), ash (2.05%) and fat (1.30%). In contrast fresh guar had higher amount of moisture (36%)followed by Nitrogen free extract (23.2%), protein (15.9%), crude fiber (15.6), ash (5.97%) and fat (3.5%). while guar gum had highest nitrogen free extract (82.4%) as compared to fresh guar and seed. Tannin content was found in the range of 0.014-0.44%in fresh guar, its seedsand gum. Furthermore, galactomannan content was found higher (85.6%) in Analytical grade guar gum followed by Lab made (80%) and industrial made guar gum (77.9%). Mannose to Galactose ratio was quantified using gas chromatography in guar gum and was found to be 1.9:1.Hence guar produced in Pakistan are of good quality for human consumption and the guar gum produced from locally grown guar is of food quality as per EU standard and can be explored for commercial applications.

Keywords: Guar; Guar gum; Galactomannan; Tannin; Mannose; Galactose

Introduction

Guar or Cluster Bean (*Cyamopsis tetragonoloba*) is a coarse, upright, bushy & drought tolerant summer annual legume belonging to the family of Leguminosae (Fabaceae) [1]. The dicotyledonous seed of cluster bean consists of three major fractions, viz the husk or hull (14–17%), endosperm (35–42%) and germ (43–47%) [2]. the major world suppliers are Pakistan, India, with both producing around 80% of the world total guar [3] followed by United States & with limited acreages in Africa and Australia [4]. It grows well in arid to semiarid areas on a wide range of different soil types, preferably in fertile, medium-textured and sandy loam soils. Guar plant also produces nitrogen-rich biomass and improves soil quality [5]. *C. tetragonoloba* is a well-known in folklore medicine, it acts as an appetizer, cooling agent, laxative, and is useful in dyspepsia and anorexia. In addition anti-

ulcer, anti-secretory, cytoprotective and hypolipidemic effects have also been reported [6].

Due to its increasing uses, U.S.A. imports substantial quantity of guar every year from the Indo-Pak subcontinent [7]. It is economically the most important species of genus Cyamopsis, because it is a source of natural polysaccharide, commercially known as guar gum [8], which is extracted from the refined endosperm of cluster bean seeds [9]. Guar gum forms a viscous gel in cold water and used as an emulsifier, thickener, stabilizer in a wide range of food and industrial application [10] such as paper, laxatives, oil well drilling, textile, mining industry, canned food products, explosive and pharmaceuticals. It is also found to be effective in diabetes, bowel movements, heart disease, colon cancer [11], and osteoarthritis, transdermal drug delivery systems [12], as artificial cervical mucus [13] and for anticancer medicine in the treatment of colorectal cancer [14]. Guar gum attains nearly its full viscosity potential in cold water, while other gums (including the related locust bean galactomannan) require sometimes prolonged "cooking" [15]. Another reason for its popularity in the industry is its low cost. Its economical nature makes it popular in gums and stabilizers industry [11]. Cluster bean gum has emerged as the most important agro-chemical, which is non-toxic, eco-friendly and Generally Recognized as Safe (GRAS) by FDA [2]. The fraction remaining after extraction of guar gum, known as guar meal, is rich in protein and used in animal and poultry [16].

Several research studies have been done on guar, guar gum and its derivatives. There is also wider biological application as drug delivery carriers & in electrochemical biosensor. The ion exchangers based on guar gum (synthesized) has also been utilized for removal and recovery of toxic metal ions from industrial waste water. Comparative studies between guar & oat gum related properties, applications and their effect on glycemic index has been assessed [17,18].

Previously guar characterization has been done from India and Sudan with different environmental locations, nutritive index and properties. Although Pakistan is one of the most important guar producing countries with 70,000 tons of guar production ranging between 50,000 to 110,000 tons per year [4], but until now no such work addressing characterization of guar & gum has been done. Hence current study is step towards physicochemical characterization of guar and guar gum properties and the functionalities produced in Pakistan.

Material and Methods

Sample Collection

Fresh guar and guar bean samples (n=25) were collected from the local markets of Hyderabad. Guar splits were a kind gift from the local industry of Hyderabad. Analytical standard of guar gum was purchased from Duksan (Korea).

Preparation of guar gum in laboratory

Guar gum was prepared as reported earlier by Taha et al. [19]. Where guar seeds were macerated in water for 12-16 hours, hand pounded and endosperm was separated. Afterwards endosperm was dried and grounded to pass a 0.2mm sieve and stored in polyethylene bag.

Analysis of Proximate Composition

Moisture & ash Content were determined via AOAC [20]. For protein the procedure of Kjeldahl (EN ISO 3188) [21] was applied and factor 6.25 was used for the conversion of nitrogen to protein. While Crude Fiber and Lipid were assessed through reported methods of Abara et al. [22] and Caprioli et al. [23]. Nitrogen Free extract was calculated by difference.

Tannin Content

Modified vanillin-HCl of Price et al. [24] was applied for tannin's estimation. Vanillin and 8% HCl were used as solvent, while d (+) catechin was utilized for standard curve preparation.

Galactomannan Determination and quantification

The total galactomannan contents was calculated by Rathore et al. [25] method, while individual quantification of mannose & galactose was done by gas chromatographic analysis after silylation procedure as reported earlier by Dhakal and Armitage [26].

Results & Discussion

Proximate composition

The proximate composition of guar seeds and its constituents, fresh guar, guar gum is shown in Table 1

Samples	Moisture %	Protein %	Crude Fiber %	Ash %	Fat %	NFE % (CHO)
Fresh Guar	35.90	15.87	15.60	5.97	3.50	23.16
Guar Seed	12.40	29.64	8.90	2.05	1.30	45.71
Hull	12.16	2.89	53.90	2.30	0.09	28.66
Endosperm	12.20	5.80	2.10	0.50	0.20	79.20
Germ	24.90	40.04	4.10	5.50	2.90	22.56
Guar Gum (Analytical Grade)	7.80	3.92	1.71	1.00	0.20	85.37
Guar Gum (Industrial)	10.85	5.03	1.61	0.65	0.10	81.76
Guar Gum (Lab Made)	8.70	4.50	2.50	1.20	0.20	82.40
EU standard for guar gum quality (% max)*	14.00	7.00	2.50	1.50	0.80	75 (min)

Table 1: Proximate Composition of Fresh guar, guar seed and guar gum analyzed.
**Commission regulation (EU) No 231/2012 of 9 March 2012*

Results shows that moisture content of guar seed was 12.40%, which is consistent with the range (10 to 15%) reported by Whistler and Hymowitz [27], however higher moisture values i.e. 7.25-10.66% were reported by Eldirany et al. [28]. The possible reason for such variation is genetic differences and relative humidity of the surrounding atmosphere at harvest and during the storage time.

The average of protein content in guar seed was 29.64% which is similar to the results (22.9 -30.6%), reported by Kays et al. [29]. On the contrary Elsiddig and Khalid [30] have reported but higher values (16.7 - 20.5%), where they to observe the response of guar to inoculation and its impact on seed quality in Sudan. In addition, Badr et al. [31] reported 33.25% protein along with some Anticancer Activities in guar. The variation in protein content of the genotypes in this study may be attributed to genetic factors and environmental conditions.

The crude fiber content of guar seed was 8.90%, which is similar to the results (7.47 to 8.95%) reported by Elsiddig and Khalid [30] but lower than results (10.87%) reported by Al-Hafedh and Siddiqui [32]. The ash was found to be 2.05% for guar seed, which is lower than earlier reported data [33]. The differences are possibly due to different soil and climatic conditions. Results showed that the fat content of guar seeds (1.30%) resembles well with the findings (0.87 to 5%) of Thomas et al. [34] study of guar gum in India. The variation in the oil content may be controlled by hereditary as well as ecological environments.

Lower carbohydrate content were reported Eldirany et al. [28] earlier i.e. 30 to 35.8%, for new genotype of guar seed, than present findings of carbohydrates (45.71%) as evident from Table 1. Al-Hafedh and Siddiqui [33] assessed and determined the nitrogen free extract as 48.95. Discrepancy in carbohydrate (as glactomanan) content among the different genotypes might be ascribed to genetic variation and environmental conditions.

Guar seed's components were analyzed separately for their proximate composition. The moisture content in hull, germ and endosperm were found as 12.16%, 24.90%, and 12.20% respectively. These values were moisture contents are higher than reported earlier by Eldaw [35] from Khartoum, which is a dry area with little to low humidity such results were to be expected. Here environmental conditions play a major role, hence the reason for deviations in results.

Protein content in germ is highest with the value of 40.04%, followed by 5.80% in endosperm and 2.89% in hull, which was less than what Duke [36] reported for hull and germ. Crude fiber varies in amount in different parts of guar seeds was maximum in hull with 53.90% followed by 4.10% in germ and 2.10%in endosperm. Whistler and Hymowitiz [29] reported numbers were higher than our study in case of germ and endosperm but in hull they reported 36% of crude fiber much lower than our value.

Ash content in hull was 2.30%, in germ was 5.50% and in endosperm it was 0.50% , while fat content of hull, germ and endosperm was found as 0.09%, 2.90% and 0.20% respectively. Comparable results of ash (0.6 -4.6%) and fat content (0.3-5.2%) were reported earlier by Nemade and Sawarkar [37] for Indian guar varieties**.** Table 1 show that 28.66% Carbohydrates was present in hull, 22.56% in germ & 79.2% in endosperm. These results were less than what Duke JA [36] has reported.

Moreover guar gum quality analyzed in present study lies within recommended levels as prescribed by EU standard.

Fresh guar was mainly composed of moisture i.e. 35.9%, followed by 23.2% of carbohydrates. It possesses same amount of protein and crude fiber approx. (15-16%), while ash and fat were minor constituent comprising 5.97% and 3.50% respectively. To best of our knowledge no literature/data is available regarding proximate composition of fresh guar.

For guar gum quality purposes, locally produced (lab made) guar gum was compared with industrial guar gum along with analytical grade guar gum in present study. As evident from (Table 1), guar gum has moisture content of 8.70%, which is less than industrial grade (10.85%) but higher than analytical grade guar gum (7.80%). Similarly Kawamura [38] has reported moisture in between 4-12%. However, Taha et al. [20] has reported guar gum's moisture as 6.70%, lower than our results. There was variation for protein content in guar gum, with analytical grade guar gum had less content of protein (3.92%) than lab made guar gum (4.50%), while industrial grade had higher amount of crude protein i.e. 5.03%. Kawamura [38] reported protein content ranging from 2-6%, which support the values obtained in this study.

Similar crude fiber was found in analytical and industrial grade (1.71% & 1.61% respectively), whereas higher amount was detected in lab made guar gum (2.50%). Sabahelkheir et al. [39] and Eldaw [36] reported the crude fiber to be between 1.4-2.0% & 0.99-1.72% respectively.

As specified in table 1 analytical grade and lab made guar gum has similar amount of ash, but industrial grade had low amount of ash (1-1.20 vs. 0.65%). Taha et al. [20] has described the ash of guar gum to be in the range of 0.60-0.70%. The smallest constituent of guar gum was fat, containing 0.10-0.20% in all three types of guar gum. The results are in accordance with findings of Naoumkina et al. [10].

Sugars were found as largest part of guar gum with highest concentration in analytical grade guar gum (85.4%) followed by lab made guar gum (82.4%) and industrial grade guar gum (81.7%). Sabahelkheir et al. [39] support the values obtained in this study. The wide variation in the proximate composition is most probably due to different varieties, location and environmental conditions.

FTIR

The overlaid IR spectra of lab made guar gum, analytical grade guar gum and industrial guar gum is shown in Figure 1. The presence of medium and broad absorption band at 3332, 3341, 3371cm^{-1} is assigned to OH bond stretching, While the small absorption band located at 2923, 2924, 2925 cm^{-1}, may be attributed to CH group stretching. The absorption band appearing at 1650, 1651, 1654 cm^{-1} is due to the OH bond belonging to water molecules. CH_2 group bending is assigned to an absorption band located at 1457 cm^{-1}, and the bending of CH_2–O–CH_2 appears in the 1025 cm^{-1} frequency region. Small peaks at 1650, 1651, 1654 cm^{-1} are assigned to C-O (carbonyl) stretching. Absorption bands around 1618 and 1430 cm^{-1} are typical of carboxylate groups of the galacturonic acid residues. The 1200-700 cm^{-1} spectral region encompasses the carbohydrate region (1200-900 cm^{-1}), the "fingerprint" or anomeric region of carbohydrates (900-700 cm^{-1}).

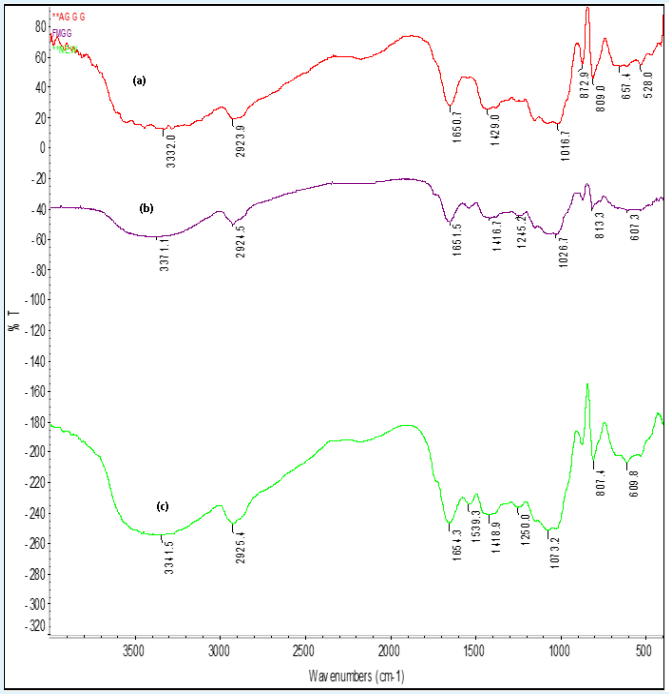

Figure 1: FTIR Spectra of (a) Analytical Grade (b) Industrial grade &(c) Lab Made guar gum.

Tannin Content

Tannin is an astringent, polyphenolic bimolecular that binds to and precipitates proteins and various other organic compounds including amino acids and alkaloids.

Most legumes contain tannins. Red-colored beans contain the most tannin, and white-colored beans have the least. Chickpeas (garbanzo beans) have a smaller amount of tannins.

As shown in Table 2 the tannin content of guar seeds was 0.044%, which resembles with the findings of Eldirany et al. [28]. While lab made guar gum has tannin content of 0.014%, which is higher than analytical grade guar gum.

Samples	Amount (%)
Fresh Guar	31.2
Guar Seed	52.3
Hull	6.7
Endosperm	77.9
Germ	10.7
Guar Gum (Analytical grade)	85.6
Guar Gum (Industrial)	77.9
Guar Gum (Lab made)	80.0

Table 2: Tannin content (%) of fresh guar, guar seed and guar gum

Glactomanan Determination and quantification

Galactomannanare polysaccharides consisting of a mannose backbone with galactose side groups and are present in different ratios of mannose-to-galactose in various legumes. The glactomanan was calculated for fresh guar, guar seeds and its component along with guar gum and are shown in Table 3. Results showed that guar gum of analytical grade had the highest amount of glactomanan followed by locally produced lab made guar gum.

Sample	Amount %
Fresh guar	0.058
Guar Seed	0.044
Hull	0.256
Endosperm	N.D
Germ	0.091
Guar gum (analytical grade)	N.D
Guar Gum (Industrial)	0.075
Guar gum (lab made)	0.014

Table 3: Glactomanan content (%) of fresh guar, guar seed and guar gum.

Glactomanan samples were further subject to GC analysis; Figure 2a shows the chromatogram of mannose and galactose standards which are major part of glactomanan. In analytical grade guar gum, mannose and galactose were present in 2:1 ratio (Figure 2b), which is in consistent with earlier reported data for guar gum [38]. Whereas industrial grade guar gum as shown in Figure 2c has the ratio of 1.77:1 for mannose to galactose. However lab made guar gum has better quality as evident from mannose to galactose ratio i.e. 1.90:1.

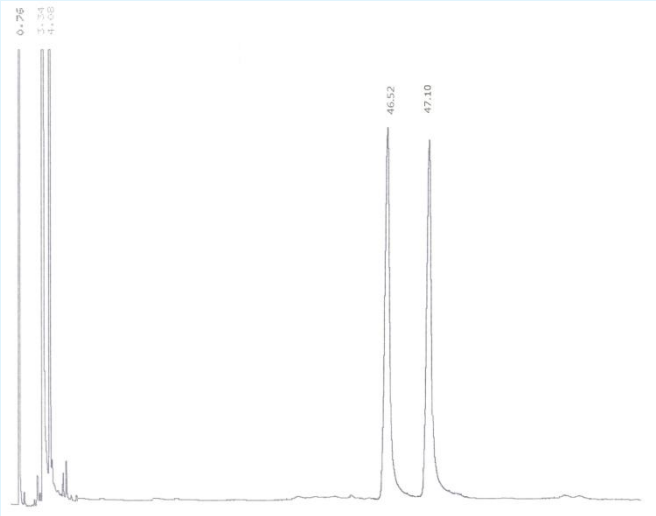

Figure 2a: GC-FID Chromatogram of silyl derivative of Mannose & Galactose.

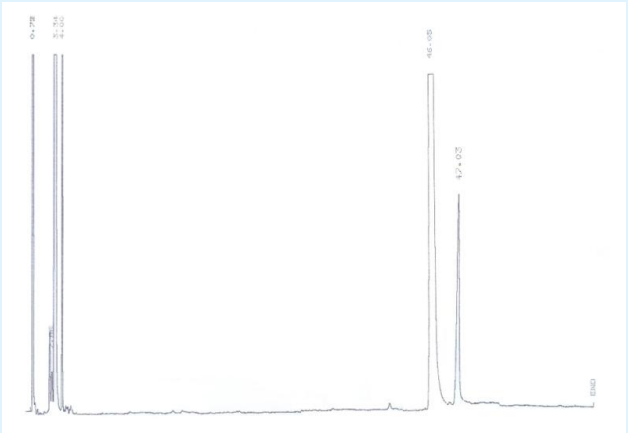

Figure 2b: GC-FID Chromatogram of silyl derivative of Analytical Standard guar gum.

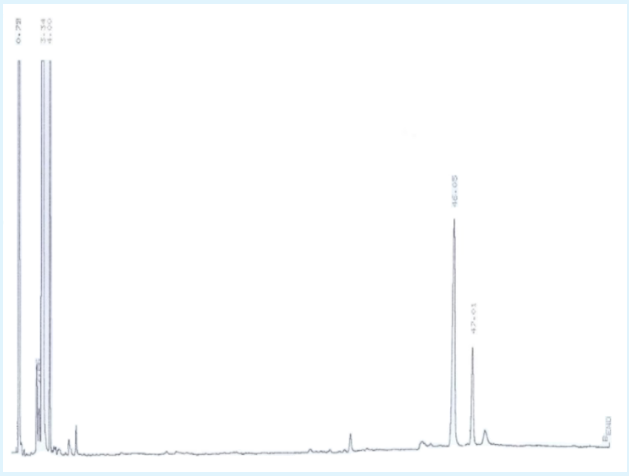

Figure 2c: GC-FID Chromatogram of silyl derivative of Industrial sample of guar gum.

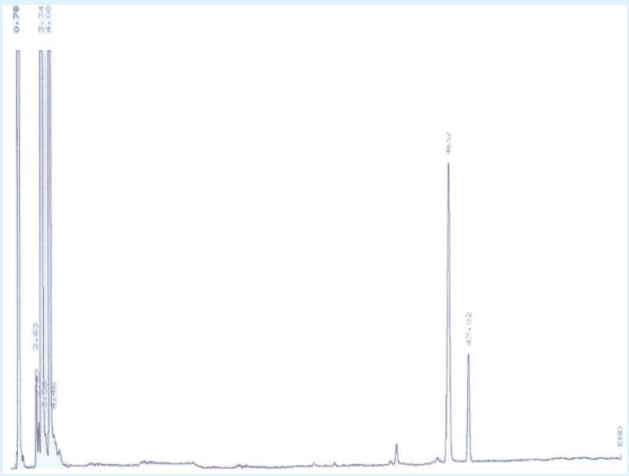

Figure 2d: GC-FID Chromatogram of silyl derivative of Industrial sample of guar gum Lab made Guar gum.

Conclusion

Present study showed that fresh guar was mainly composed of moisture (35%) followed by nitrogen free extract (23%), while guar seed contain higher nitrogen free extract (45%) followed by protein (28%). Glactomanan was major part of guar gum constitute ≈80% of total composition. Guar gum extracted from locally grown guar exhibited good index of nutrient composition when compared with analytical and commercially produced guar gum. In addition higher Glactomanan content and lower protein (<5%) assures that guar gum extracted from locally grown guar exhibits food grade quality, thus locally grown guar has great potential to be explored commercially.

Conflict of Interest

Author declares no conflict of interest.

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1. Gendy AS, Said-Al Ahl HA, Mahmoud AA, Mohamed HF (2013) Effect of nitrogen sources, bio-fertilizers and their interaction on the growth, seed yield and chemical composition of guar plants. Life Science Journal 10(3): 389-402.

2. Pathak R, Singh M, Henry A (2011) Genetic diversity and interrelationship among clusterbean (Cyamopsis tetragonoloba) genotypes for qualitative traits. Indian Journal of Agricultural Sciences 81(5): 402-406.

3. Bahar AH, Ismail MA, Sulaiman AH, Siddig AMA (2015) Characteristic Evaluation of Some Guar (*Cyamopsis tetragonoloba* (L) *Taub*) Genotypes Grown under Rain-fed Conditions at Zalingei Area. ARPN Journal of Science and Technology 5(5): 215-218.

4. Sultan M, Zakir N, Rabbani MA, Shinwari ZK, Masood MS (2013) Genetic diversity of guar (Cyamopsis tetragonoloba L.) landraces from Pakistan based on RAPD markers. Pakistan Journal of Botany 45(3): 865-870.

5. Ayare KS, Golatkar V, Komal S (2014) Evaluation of arbuscular mycorrhizal interactions with Cyamopsis Psoralioides D.C. Bionano Frontier 7(1): 154-156.

6. Mukhtar HM, Ansari SH, Bhat ZA, Naved T (2006) Antihyperglycemic activity of Cyamopsis tetragonoloba. Beans on blood glucose levels in alloxan-induced diabetic rats. Pharmaceutical biology 44(1): 10-13.

7. Ashraf MY, Akhtar K, Sarwar G, Ashraf M (2002) Evaluation of arid and semi-arid ecotypes of guar (*Cyamopsis tetragonoloba L.*) for salinity (NaCl)

tolerance. Journal of arid environments 52(4): 473-482.

8. Khalil MM (2001) Biochemical and technological studies on the production of isolated guar protein. Nahrung 45(1): 21-24.

9. Dodi G, Hritcu D, Popa MI (2011) Carboxymethylation of guar gum: Synthesis and characterization. Cellulose chemistry and technology 45(3-4): 171-176.

10. Naoumkina M, Torres-Jerez I, Allen S, He J, Zhao PX (2007) Analysis of cDNA libraries from developing seeds of guar (*Cyamopsis tetragonoloba (L.) Taub*). BMC plant biology 7(1): 62.

11. Mudgil D, Barak S, Khatkar BS (2014) Guar gum: processing, properties and food applications-A Review. Journal of food science and technology 51(3): 409-418.

12. Murthy SN, Hiremath SRR, Paranjothy KLK (2004) Evaluation of carboxymethyl guar films for the formulation of transdermal therapeutic systems. International Journal of pharmaceutics 272(1): 11-18.

13. Burruano BT, Schnaare RL, Malamud D (2002) Synthetic cervical mucus formulation. Contraception 66(2): 137-140.

14. Shyale S, Chowdary KPR, Krishnaiah YSR, Bhat NK (2006) Pharmacokinetic evaluation and studies on the clinical efficacy of guar gum-–based oral drug delivery systems of albendazole and albendazole-β-cyclodextrin for colon-targeting in human volunteers. Drug development research 67(2): 154-165.

15. Chudzikowski RJ (1971) Guar gum and its applications. Journal of Society of Cosmetic Chemistry 22(1): 43-60.

16. Rodge AB, Sonkamble SM, Salve RV, Hashmi SI (2012) Effect of hydrocolloid (guar gum) incorporation on the quality characteristics of bread. Journal of Food Processing & Technology 3: 136.

17. Singh AV, Sharma NK (2011) Characterization and applications of synthesised cation exchanger guar gum sulphonic acid (GSA) resin for removal and recovery of toxic metal ions from industrial wastewater. Water SA 37(3): 295-302.

18. Wood PJ, Braaten JT, Scott FW, Riedel D, Poste LM (1990) Comparisons of viscous properties of oat and guar gum and the effects of these and oat bran on glycemic index. Journal of Agricultural and Food Chemistry 38(3): 753-757.

19. Taha KK, Elmahi RH, Hassan EA, Ahmed SE, Shyoub MH (2012) Analytical study on three types of gum from Sudan. Journal of Forest Products & Industries 1(1): 11-16.

20. AOAC (2000) Official Methods of Analysis of the Association of Official Analytical Chemists International 17th Ed. Published by the Association of Official Analytical Chemists International, Suite 400 2200 Wilson Boulevard, Arlington, Virginia, 22201-3301.

21. International Starch Institute (1999) Determination of Protein by Kjeldahl. Retrieved February 24, 2015.

22. Abara AE, Tawo EN, Obi-Abang ME, Obochi GO (2011) Dietary fibre components of four common Nigerian Dioscorea species. Pakistan Journal of Nutrition 10(4): 383-387.

23. Caprioli G, Giusti F, Ballini R, Sagratini G, Vila-Donat P, et al. (2016) Lipid nutritional value of legumes: Evaluation of different extraction methods and determination of fatty acid composition. Food chemistry 192: 965-971.

24. Price ML, Hagerman AE, Butler LG (1980) Tannin content of cowpeas, chickpeas, pigeon peas, and mung beans. Journal of Agricultural and Food Chemistry 28(2): 459-461.

25. Rathore SS, Saxena SN, Kakanic RK, Singh B (2013) Rapid and mass screening method for galactomannan content in fenugreek seeds. International Journal of Seed Spice 3(2): 91-93.

26. Dhakal B, Armitage RA (2013) GC-MS Characterization of Carbohydrates in an Archaeological Use Residue: A Case Study from the Coahuila Desert. In Armitage RA & Burton JH (Eds.) Archaeological Chemistry VIII 1147: 157–170 American Chemical Society.

27. Whistler RL, Hymowitz T (1979) Guar: agronomy, production, industrial use, and nutrition.

28. West Lafayette, Indiana, USA: Purdue University Press 1-96.

29. Eldirany AA, Nour AA, Khadir KI, Gadeen KA, Mohamed AM (2015) Physicochemical Properties of for New Genotypes of Guar Seeds (*Cyamopsis Tetragonoloba L.*). American Journal of Food Science and Health 1(3): 76-81.

30. Kays SE, Morris JB, Kim Y (2006) Total and soluble dietary fiber variation in *Cyamopsis tetragonoloba (L.) Taub*.(guar) genotypes. Journal of Food Quality 29(4): 383-391.

31. El-Siddig AE, Khalid AI (1999) In the effect of Bradyrhizobium inoculation on Yield and Seed quality of guar (*Cyamopsis tetragonoloba*). Food Chemistry 19: 8-19.

32. Badr SEA, Abdelfattah MS, El-Sayed SH, El-Aziz, Sakr D (2014). Evaluation of anticancer, antimycoplasmal activities and chemical composition of guar (*Cyamopsis tetragonoloba*) seeds extract. Research Journal of Pharmaceutical, Biological and Chemical Sciences 5(3): 413-423.

33. AI-Hafedh YS, Siddiqui AQ (1998) Evaluation of guar seed as a protein source in Nile tilapia, *Oreochromis niloticus* (L.), practical diets. Aquaculture research 29(10): 703-708.

34. Kobeasy I, Abdel-Fatah M, El-Salam SMA, Mohamed, ZEOM (2011) Biochemical studies on *Plantago major* L. and *Cyamopsis tetragonoloba* L. International Journal of Biodiversity and Conservation 3(3): 83-91.

35. Thomas TA, Dabas BS, Chopra DD (1980) Guar gum has many uses. Journal of Indian Farming. 30(9): 19-22.

36. Eldaw GE (1998) A study of guar seed and guar gum properties (*Cyamopsis tetragonoloba* L). M.Sc Thesis University of Khartoum, Sudan.

37. Duke JA (1981) Handbook of Legumes of World Economic Importance. Plenum Press, New York 345.

38. Nemade SN, Sawarkar SB (2015) Recovery and Synthesis of Guar Gum and its Derivatives. International Journal of Advanced Research in Chemical Science 2(5): 33-40.

39. Kawamura Y (2008) Guar Gum: Chemical and Technical Assessment. In Compendium of food additive specifications (pp. 31-34). Rome, Italy: 69th Joint FAO/WHO Expert Committee on Food Additives (JECFA).

40. Sabahelkheir MK, Abdalla AH, Nouri SH (2012) Quality Assessment of Guar Gum (Endosperm) of Guar (Cyamopsis tetragonoloba). ISCA Journal of Biological Sciences 1(1): 67-70.

41. Chattopadhyay H, Biswajit A, Sur T, Sana S, Datta S (2016) Accentuated transdermal application of glucosamine sulphate attenuates experimental osteoarthritis induced by monosodium iodoacetate. Journal of Materials Chemistry B 4(25): 4470-4481.