EXTRACTION OF GUM FROM ABELMOSCHUS ESCULENTUS: PHYSICOCHEMICAL PECULIARITY AND ANTIOXIDANT PREPATURENT

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INTRODUCTION

Gums are natural polysaccharides in which multiple sugar units are interconnected together to form large molecules. Gums possess the capability of forming extremely thick aqueous solution or dispersions. Gums in drug delivery have been explored for modifying the drug release rate. Gums have been explored for their use in controlled release dosage forms [1], buccal patches [2], medicated chewing gum [3], biodegradable microparticles [4], nanoparticles [5], stabilized submicron emulsions [6], ion activated in situ gel [7], and many more. Gums attract the attention of researchers because of biocompatibility, abundant availability, stability, hydrophilicity, and its nature of modifiable biopolymers.

Okra fruit gum (OFG) is procured from fruits of Abelmoschus esculentus (family - Malvaceae) and is cultivated in tropical, subtropical, and warm temperate regions worldwide. OFG contains D-galactose, L-rhamnose, and L-galacturonic acid [8,9]. The main structural elements of okra polysaccharide were described by Tomada, Shimada, Saito, and Sugi (1980) who concluded that it contained a repeating unit of alternating α-(1→2)-linked rhamnosyl and α-(1→4)-linked galacturonic acid residues with a disaccharide side chain of β-(1→4)-linked galactosyl moieties attached to O-4 of about half the L-rhamnosyl residues [10] and degree of acetylation up to 58 (DA = 58) [10,11]. Okra gums are used as thickeners and flavoring for different foods. Polysaccharides extracted from okra are also used as egg white substitute [12] and fat substitute in chocolate bars and frozen dairy desserts [13,14]. When extracted in water, it can produce highly viscous solution with a slimy appearance. Okra mucilage is also used as soothing emollient medicine in the treatment of diarrhea, dysentery, and gastric ulcer. A cupful of mucilage mixed with a ripe banana is given as a tonic food during the treatment of colitis, cystitis, hepatitis, and jaundice [15]. A gastroprotective effect of the methanolic extract of okra in ethanol-induced gastric ulcer in rats was reported [15,16]. OFG is inexpensive, consistent in quality, chemically inert, biodegradable, biocompatible in nature, and reliable in supply [8,17]. These attributes of OFG lead to usefulness as excipients in the development of various pharmaceutical formulations [2,8,17-21]. In addition, the highly viscous property of OFG leads the usefulness of it as a drug-release retarding polymer and it is used in the development of sustained-release drug delivery matrices [8,17].

Extraction of gum is usually done with hot water extraction, ultrasound-assisted extraction and microwave-assisted extraction, of which ultrasonic assisted extraction was chosen because of its lower energy consumption, lower consumption of solvents, higher extraction efficiency, and higher level of automation [22-24].

Till date, no thorough investigation occurred on the ultrasonic extraction process of gum from A. esculentus fruits. Therefore, in this study, okra gum is extracted from okra fruits using ultrasound assisted technology. Also in this study, physicochemical, functional and antioxidant performances of OFG were explored for its application in food and pharmaceutical industry.

MATERIALS AND METHODS

Materials

The fruits of A. esculentus (usually known as bhindi) were purchased from local market (Chandigarh, India). OFG samples being collected were stored in airtight jars in dessicator. All other chemicals used in extraction and characterization of gum were of analytical reagent grade.
Ultrasonic assisted extraction of OFG from *A. esculentus* fruits

OFG was extracted by modifying the method described by Wang *et al*, 2014 [22] using an ultrasonic device (AS3120A, Tin in Automatic Science Instrument Co., Ltd, China). Fruits were cleaned, sliced, and were mashed in 2% v/v glacial acetic acid solution to form a slurry and gum was extracted in distilled water in 100 ml beaker with a 1:1 ratio of water to raw material, 65 W ultrasonic power and 45 minutes extraction time at 65°C. After extraction, the slurry was filtered through muslin cloth to remove debris. Excess acetone was added for precipitating the gum. Finally, the precipitates were dried in vacuum oven at 50°C. The OFG sample was further purified by dialysis. Purified gum obtained by lyophilization and ground to OFG gum powder. Each OFG sample was weighed and yield was calculated. The extraction procedure of OFG is summarized in Fig. 1.

**Physical characterization of OFG sample**

**Swelling index**

The OFG sample (100-250 mg) was filled into micropipette tips for evaluating swelling index. The tip outlet was blocked with nylon fiber swab to avoid leakage of the powder during the testing. OFG sample was tapped 10 times by dropping on a hard surface from a 10 cm height to avoid the same bed packing. The plastic tip was weighed (W1) and then dipped into a 2-3 mm layer of deionized water, phosphate buffer pH 1.2, 6.8 and 7.4, respectively, for 24 h. The plastic tip was weighed (Wf) and then dipped into a 2-3 mm layer of deionized water, phosphate buffer pH 1.2, 6.8 and 7.4, respectively, for 24 h. After the bed was wetted with liquid, the tip was again weighed (W2) to find the amount of the liquid taken in by the powder. The swelling index was estimated using the formula:

\[
SI = \frac{W_f - W_i}{W_i} \times 100
\]

Average value was taken for calculation after repeating the experiment for 6 times.

**Solubility**

Powdered OFG (2 g) was added to 200 ml of distilled water and left undisturbed (10-12 hrs), allowing it to swell totally. After stirring at room temperature (25-30°C) and elevated temperature (55-65°C) for approximately 50 minutes, the solution was cooled and centrifuged at 5000 × g for 45 minutes extraction time at 65°C. After extraction, the slurry was filtered through muslin cloth to remove debris. Excess acetone was added for precipitating the gum. Finally, the precipitates were dried in vacuum oven at 50°C. The OFG sample was further purified by dialysis. Purified gum obtained by lyophilization and ground to OFG gum powder. Each OFG sample was weighed and yield was calculated. The extraction procedure of OFG is summarized in Fig. 1.

**Solubility**

Solubility (%) of OFG was estimated using the formula:

\[
\text{Solubility} = \frac{S_2 - S_1}{S_2} \times 100
\]

Where, S1 is the sediment fraction (mg) while S2 is the initial concentration of the solution (mg). Solubility of OFG was also investigated in other solvents such as ethanol, acetone, and chloroform, and in buffers of pH 2.0, 3.0, 4.5, 5.0, 5.5, 6.8, 7.4, 10.0.\nonumber

**Water sorption time (WST)**

The OFG (50 mg) was soaked in distilled water, HCl (0.1 N) or phosphate buffer pH 1.2, 6.8 or 7.4, respectively (100 cc) for 24 hrs. The time taken by the liquid to reach to top of powder bed was estimated as WST [25,26].

**Packaging and flow properties of OFG**

**Angle of repose**

The fixed funnel and free standing cone method were employed in which a funnel is secured with its tip at a given height, H, above graph paper that is placed on a flat horizontal surface. OFG powder was precisely weighed and vigilantly introduced into the funnel until the peak of the conical stack just touches the funnel tip. Angle of repose was calculated using the following equation:

\[
\tan \alpha = \frac{H}{R}
\]

Where, R is the radius of the base of the conical stack.

**Bulk and tapped density**

A known amount of the powdered OFG sample (M) was placed in a measuring cylinder (100 mL) and the volume (Vt) occupied by the powder bed was noted as bulk volume. The cylinder was then tapped, and the volume occupied after 100 taps was noted as tapped volume (Vt). The bulk and tap densities were calculated using the equation:

\[
\text{Bulk density} = \frac{M}{V_b}
\]

and

\[
\text{Tapped density} = \frac{M}{V_t}
\]

**Hausner’s ratio (H)**

H was calculated as the ratio of tap density to bulk density of the sample.

\[
H = \frac{T}{B}
\]

**Compressibility index (C %)**

C % was calculated using the following equation:

\[
C\% = \frac{T - B}{T} \times 100
\]

**Effective pore radius (R_{eff.p})**

The R_{eff.p} of OFG powder was predictable according to the method reported by Jindal *et al*, 2013 [25]. Micropipette tip was filled with OFG powder and weighed (W1). Then, n-hexane (surface tension (γ) 18.4 N/m, θ=0°) was added dropwise to the top of packed bed till the solvent filtered out at the bottom of the tip. The tip was weighed again weighed (W2). The R_{eff.p} was calculated using formula:

\[
R_{eff.p} = \frac{W_B - W_A}{2\pi\gamma}
\]

**Loss on drying (LOD%)**

OFG sample (2 g) was positioned in a tarred Petri dish and dried in oven at 105°C, till constant weight was obtained [2,27,28]. The sample was
then removed, weighed and moisture content was determined using the equation:

\[ \text{LOD\%} = \frac{W_i - W_f}{W_i} \times 100 \]

Where, \( W_i \) is the initial weight of sample and \( W_f \) is the final weight after drying.

**Total ash content**

Total ash content of powder was estimated according to the method reported by Jindal et al., 2013 [25]. The gum sample (1.0 g) was weighed into a preheated and preweighed crucible, and transferred into a furnace at ignition temperature 550°C for 24 hrs. The recovered ash was transferred into a desicator for equilibration to room temperature before weighing. The resultant ash from the above was mixed with distilled water, boiled, filtered, and the filter was rinsed. Both filter paper and residue were transferred into the crucible and ignited for 24 hrs until a constant weight was reached. Thereafter, cooling was carried out in a desiccator and the product was weighed. Percent total ash was calculated from the formula:

\[ \% \text{Total ash} = \frac{\text{Ash weight}}{\text{Original sample weight}} \times 100 \]

**pH determination**

OFG dispersion 1% w/v was stirred constantly in water for 5 minutes and pH meter was used to determine pH.

**Electrical properties**

**Zeta potential and conductivity studies of OFG sample**

The zeta potential and conductivity studies of OFG were conducted using Zetasizer (Malvern Instrument Ltd., UK). The zeta potential measurements were performed using an aqueous dip cell in an automatic mode maintaining the temperature of samples at 25°C and diluting the samples with triple distilled water and placing in the capillary measurement cell. Each sample was analyzed in triplicate and results were recorded as the average ± standard deviation of the experimental values.

**Particle size measurement**

After diluting OFG samples with triple distilled water, it was measured for particle size and polydispersity index (PI) using a Zetasizer 4 (Malvern Instrument Ltd., UK) at 25°C, scattering angle 90°, 180 seconds. The mean diameter was determined in triplicate. Cumulative analysis was used for generating the mean hydrodynamic diameter.

**Scanning electron microscopy (SEM) of OFG**

OFG samples were mounted on a clean aluminum stub with silver PAG-915 and coated with gold particles in the presence of argon gas. The OFG sample was then pictured using scanning electron microscope (LEO 435VP, Cambridge, UK) using a 15 kV accelerating voltage, a 1-10 μm working distance and probe current of 3×10⁻¹³ Å.

**Chemical properties of OFG sample**

**Degree of esterification (%DE)**

The titrimetric method was used to determine the degree of esterification of OFG sample. OFG sample (500 mg) was sprinkled with 2 ml of ethanol and dissolved in 100 ml of HPLC water. Few drops of phenolphthalein were then added to the dissolved sample and titration was done with 0.5 M sodium hydroxide. The volume of sodium hydroxide consumed was recorded as the initial titer, \( I \). Thereafter, 10 ml of 0.5 M sodium hydroxide was added; the sample was robustly shaken and left uninterrupted for 10 minutes. 0.5 M hydrochloric acid (10 ml) was added, accompanied with shaking, until the disappearance of pink color. Titration of solution containing Phenolphthalein (five drops) was done with 0.5 M sodium hydroxide till the appearance of a faint pink color that persisted after vigorous shaking (final titer, \( F \)). The volume of titration was recorded as the saponification titer (the final titer). Each ml of 0.5 M sodium hydroxide used in the saponification titer and the total titration (sum of initial titer and saponification titer) was equivalent to 97.07 mg of galacturonic acid. The degree of esterification of OFG was calculated from the following formula:

\[ \% \text{DE} = \frac{\text{The initial titer, } I + \text{the final titer, } F }{I} \times 100 \]

**Antioxidant activity of OFG**

**Hydrogen peroxide scavenging assay of OFG**

The method proposed by Xiong et al., 2013 [29]; Yao et al., 2013 [30]; Kamboj and Rana, 2014 [31]; Nehete and Bhatia, 2011 [32] was used to measure the activity of OFG to scavenge H$_2$O$_2$. For this, a 40 mM solution of H$_2$O$_2$ was prepared in phosphate buffer solution using NaH$_2$PO$_4$-Na$_2$HPO$_4$ (pH=7.40, 0.2 mol/L). Concentration of H$_2$O$_2$ was determined spectrophotometrically at 230 nm. H$_2$O$_2$ solution (0.6 ml, 40 mM) was added to OFG samples of various concentrations (0.1-10.0 mg/ml) in distilled water. The absorbance of H$_2$O$_2$ at 230 nm was determined after 10 minutes against a blank solution containing phosphate buffer without H$_2$O$_2$. The antioxidant activity of various samples to scavenge H$_2$O$_2$ was calculated using the following equation:

\[ \% \text{SE} = 1 - \frac{\text{Abs}}{\text{Abs}_{\text{control}}} \]

Where, SE is scavenging effect, Abs$_{\text{sample} 230}$ and Abs$_{\text{blank} 230}$ is Absorbance at 230 nm of sample solution and blank solution, respectively.

**Reducing power determination of OFG**

The method reported by Nehete and Bhatia, 2017 [32]; Xiong et al., 2013 [29]; Yao et al., 2013 [30] was used to determine the reducing power of OFG. Different concentrations 0.1-10.0 mg/ml of OFG (2.0 ml) were mixed with 2.5 ml sodium phosphate buffer (pH=6.60, 0.2 M) and 2.5 ml potassium ferriyanide (1% w/v), respectively. The mixtures were incubated for 20 min at 50°C, cooled down in ice-cold water and then 2.5 ml trichloroacetic acid (10%, w/v) was added to the mixtures, followed by centrifugation at 3000 rpm for 10 minutes. 2.0 ml supernatant was mixed with 2.5 ml distilled water, 0.5 ml ferric chloride solution (0.1%, w/v) and the absorbance of this mixture was measured at 700 nm.

**RESULTS AND DISCUSSION**

**Phytochemical screening of OFG sample**

The existence of polysaccharides was confirmed by the formation of red color with Ruthenium red and violet ring at the intersection of two liquids on reaction with Molsch reagent. The absence of blue color on treatment with iodine solution inferred the sample to be free of starch [2,27].

**Characterization of OFG sample**

**Swelling index**

Swelling index of OFG sample is shown in Table 1. The swelling index of OFG sample was investigated in 0.1 N HCl, pH 1.2, 6.8, 7.4 and water. The swelling index of OFG sample was observed to pursue an increase with increase in pH of buffer from 1.2 to 7.4. The swelling index of OFG in different media followed the order water > pH 7.4 > pH 6.8 > pH 1.2 > pH 10.0 > HCl (0.1 N). This can be explained as that at low pH values (pH 1.2) the polymer network retained in its collapsed state due to the minimal/partial ionization of carboxyl group. This established the low swelling of the polymer [23,24]. However, as the pH increased to 7.4, the swelling of OFG increased. This could be credited to higher ionization of carboxyl group in polymer resulting in an increased intracellular...
Table 1: Swelling index, solubility, WST, powder flow properties, pH and LOD of OFG sample

| Parameter          | Results                          |
|--------------------|----------------------------------|
| WST                | 182±6.21 seconds                 |
| Moisture content   | 0.65±0.04 w/w                    |
| Angle of repose    | 34.21±0.61                       |
| Bulk density       | 0.42±0.03                        |
| Tapped density     | 0.48±0.04                        |
| Compressibility index | 12.5%±0.12              |
| Hausner ratio      | 1.14±0.09                        |
| Effective pore radius | 9.31×10⁻¹ mm                 |
| pH                 | 6.4±0.2                          |
| LOD (%w/w)         | 11.9                             |
| Swelling index     |                                  |
| Water              | 5.40±0.35                        |
| 0.1 N HCl          | 1.43±0.20                        |
| pH 1.2             | 2.50±0.25                        |
| pH 6.8             | 3.42±0.42                        |
| pH 7.4             | 4.01±0.31                        |
| pH 10.0            | 2.45±0.24                        |
| Solubility (%)     |                                  |
| pH 2.0             | 59.5±0.80                        |
| pH 3.0             | 62.15±0.02                       |
| pH 4.5             | 66.14±0.75                       |
| pH 5.0             | 74.29±0.87                       |
| pH 5.5             | 81.12±1.02                       |
| pH 6.8             | 89.23±1.89                       |
| pH 7.4             | 94.15±1.54                       |
| pH 10.0            | 73.92±1.48                       |
| Water              | Sparringly soluble                |
| Acetone            | Insoluble                        |
| Ethanol            | Insoluble                        |
| Chloroform         | Insoluble                        |

LOD: Loss on drying, OFG: Okra fruit gum, WST: Water sorption time

Table 1: pH and LOD of OFG sample

| Parameter          | Results                          |
|--------------------|----------------------------------|
| pH                 |                                  |
| pH 10.0            | 89.23±1.89                       |
| pH 7.4             | 94.15±1.54                       |
| pH 5.5             | 81.12±1.02                       |
| pH 5.0             | 74.29±0.87                       |
| pH 4.5             | 66.14±0.75                       |
| pH 3.0             | 62.15±0.02                       |
| pH 2.0             | 59.5±0.80                        |
| pH 1.2             | 2.50±0.25                        |
| pH 6.8             | 3.42±0.42                        |
| pH 7.4             | 4.01±0.31                        |
| pH 10.0            | 2.45±0.24                        |

It is well known that low swelling in acidic pH restricts the release of drugs from dosage forms, and high swelling in alkaline pH would be useful for sustaining the drug release as the dosage form travels down the gastrointestinal tract [25]. Thus, the swelling behavior of OFG can be established to be useful for regulating the drug release from dosage forms.

Solubility

Solubility of OFG powder was observed to follow a similar trend as that of swelling index (Table 1). An increase in solubility with increase in pH of buffer from 2.0 to 7.4 was observed. The low solubility of the polymer at low pH values can be due to the minimal/partial ionization of carboxyl group and the polymer network retained in its collapsed state [2]. However, as the pH increased to 7.4, solubility of OFG increased as at higher pH, higher ionization of carboxyl group in polymer result in an increased intraionic repulsion. Solubility decreased with further increase in pH which may be due to dissolution of ionic linkages within the polymer structure ensuing breaking of its intact network [2].

OFG was pragmatic to be scarcely soluble in water and insoluble in acetone, chloroform, and ethanol. At high temperature, an augment in solubility was observed. OFG produced cluttered gum in acetone. This suggested acetone to be good precipitating agent to fabricate dried okra. OFG powder swelled and shaped sticky dispersion in water. The slightly soluble behavior of OFG is useful in controlled release formulation as the viscous distribution stand for a strong matrix polymeric system that can control the discharge of exceedingly soluble drug in the stomach.

Results

The dried OFG had 0.65% w/w of moisture content. Poor moistening capability of OFG is indicated by high WST of 182 seconds. Poor moistening capability and low moisture content make it suitable to use in the presence of moisture sensitive ingredients and during storage.

Packaging and flow properties

The bulk and tapped densities give an insight into the packing arrangement of the particle and the compaction profile of a material [25,34]. The compressibility index and angle of repose of OFG were found to be 12.5% and 34.21° (Table 1), respectively. Compressibility values lying between 11 and 15 indicate good flow character [34]. Further, angle of repose values between 31° and 35° is good; 36° and 40° indicate fair flow character with no need of adding flow promoter. The results indicated good flow properties as compressibility’s index, Hausner ratio, and angle of repose (Table 1) are in the range of good flow characteristics according to USP30 NF25. Therefore, good flow behavior of OFG particles is suggested by the results obtained, and no need of addition of flow promoters during formulation processing is suggested.

Porosity of powder is indicated by effective pore radius. Berger et al., (2012) [35] reported Rₐₑ of Cassia fistula gum (CFG) (2.72×10⁻¹ mm), carboxymethylated CFG (3.04×10⁻¹ mm) and carbamoylated CFG (3.42×10⁻¹ mm). These were observed to exhibit good wicking properties, which increased with increase in Rₐₑ suggesting their super disintegration potential. Hence, Rₐₑ of 9.31×10⁻¹ mm (Table 1) suggests high porosity and good compressibility in comparison to Rₐₑ of CFG (2.72×10⁻¹ mm), carboxymethylated CFG (3.04×10⁻¹ mm), and carbamoylated CFG[3.42×10⁻¹ mm] which were observed to exhibit good wicking properties, which increased with increase in Rₐₑ suggesting their super disintegration potential.

LOD

The LOD of OFG sample on drying was found to be 11.8% (w/w). This value suggests thermostable nature of OFG sample which was also confirmed from the differential scanning calorimetry (DSC) studies as no signs of degradation were observed till 195°C.

Ash content

The total ash and soluble ash content were found to be 1.0% and 0.24% w/w, respectively. The lower ash value indicates low levels of contamination in the finally obtained OFG.

pH

Okra gum was found to have neutral pH (Table 1). At neutral pH range OFG is known to have maximum viscosity and thus helps in the retarding effect for the development of sustained release tablets. Neutral pH also causes minimum irritation to the gastrointestinal tract and is suitable use in formulation employing acidic, basic and neutral drugs [36].

Electrical properties

Zeta potential studies and particle size measurement of OFG

Particle size analysis stand for mean diameter of total population of the particles and PI is measure of particle size distribution. The PI of OFG was found to be 0.395 indicating narrow particle size distribution (256.3 nm with PI of 0.395) suggesting their super disintegration potential. These were observed to exhibit good wicking properties, which increased with increase in Rₐₑ suggesting their super disintegration potential.

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Electrical properties

Zeta potential studies and particle size measurement of OFG

Particle size analysis stand for mean diameter of total population of the particles and PI is measure of particle size distribution. The PI of OFG ranges from 0.00 (monodisperse) to 0.545 (very broad particle size distribution). The average mean diameter of OFG was found to be 256.3 nm with PI of 0.395 indicating narrow particle size distribution and small mean particle size. Aqueous dispersions of OFG exhibited zeta potential of ~9.85 mV indicate its anionic character. The negative zeta potential of OFG proposes its applicability in imposing gum–polymer or gum–ion interactions for regulating drug release character.

SEM images of OFG sample

Scanning electron microscopic images of OFG powder (Fig. 2) revealed irregular, rough surfaced, and amorphous structure of OFG powder.
Chemical properties of OFG sample

Degree of esterification

Titrimetric method was used to determine degree of esterification of OFG. 7.8 was found to be the degree of COOH of esterification in OFG.

Antioxidant activity of OFG

Hydrogen peroxide scavenging assay of OFG

As hydrogen peroxide may give rise to hydroxyl radical in the cells, it can sometimes be toxic to cells. H2O2 can cross cell membranes rapidly and once inside the cell, it can potentially react with Fe3+ or Cu2+ to form hydroxyl radicals, and this may be the origin of many of its toxic effects in neuronal cells. It is, therefore, advantageous for cells to control the amount of H2O2 that is allowed to accumulate [29,31]. The scavenging activity of OFG (0.1-10.0.0 mg/ml) on H2O2 is shown in Fig. 3. The inhibitory concentration 50% (IC50) of OFG was 1.6 mg/ml while IC50 for ascorbic acid was 0.2 mg/ml. The hydroxyl radical scavenging activity of guar gum was only 30% at 5 mg/ml. However, this activity of sulfated derivative of guar gum and xanthan oligosaccharides; xanthan oligosaccharides (XGOS-A) or XGOS-B was reported to be 50% at 7.79, 2.5 and 9.4 mg/ml [29,37]. This suggested higher hydroxyl radical scavenging activity of OFG. Ascorbic acid and pyruvate acid were used as a control and their IC50 were 0.26 and 0.37 mg/ml, respectively.

Reducing power of OFG

Reducing power assay has been used to evaluate the ability of antioxidants to donate electrons. Antioxidant compounds cause the reduction of ferric (Fe3+) form to the ferrous (Fe2+) form because of their reductive capabilities. Prussian blue-colored complex is formed by adding FeCl3 to the ferrous (Fe2+) form. Therefore, reducing power can be determined by measuring the formation of Prussian blue at 700 nm. In this experiment, yellow color of the test solution changes to green or blue color depending on the reducing power of antioxidant samples. Similarly, higher absorbance indicates higher ferric reducing power and hence high antioxidant activity [29,38]. Fig. 4 summarizes the results of reducing power of OFG. The absorbance of OFG solutions increases with the increase in OFG concentrations. The maximum absorbance (0.5424) was obtained at 10 mg/ml OFG solution concentration. The absorbance of corn flour gum at the same concentration was 0.5199 [31] which proves that okra gum has better reducing power than corn flour gum.

CONCLUSION

Ultrasound assisted extraction technology was used for extraction of OFG to enhance the extraction yield. Optimization of optimal extraction conditions was done by single factor design and Box-Behnken design (BBD). The optimum extraction conditions given BBD were as follows: Ratio of water to raw material 44.98 mL/g; ultrasonic power, 60 W; and extraction time, 40 minutes. The experimental yield obtained under these conditions was 31.52%±0.22% (n=3), which was identical to the predicted value as well. OFG was associated with low ash value and high WST. The particles were rough and displayed a narrow range of particle size distribution. A reasonable negative charge of -9.85 mV and high value of degree of esterification (7.8) recommended its possible use in dosage forms for regulating release of drug through gum-polymer or gum-ion interaction. Attenuated total reflection-Fourier transform infrared and 1H NMR analysis were performed to determine the main the functional groups of OFG. Amorphous nature of OFG is explained by XRD spectra and DSC studies recommended higher thermal stability of OFG. Micromeritic properties, effective pore radius and swelling index of OFG confirm its porous nature which suggested use of OFG as diluents in various pharmaceutical preparations. The antioxidant activity of OFG was higher compared to corn flour gum. Thus, OFG could be researched as natural antioxidant food ingredients and also for application in medicine and health care products.

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