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CHARACTERIZATION OF PECTIN EXTRACTED FROM MUSKMELON (*Cucumis melo* L.)

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Abstract

Muskmelon (Cucumis melo L.) fruits are cultivated for their seeds, but the peels are potential sources of pectin for food and pharmaceutical applications. The objective of this study was to extract and characterize pectin from muskmelon peels subjected to two different drying techniques. The pectin was extracted using acid treatment and the structure, chemical composition and functional properties determined. Oven and solar dried muskmelon pectin extracts gave comparable yields (6.48% and 5.27%), high degree of methylation (60.53 and 64.97%) and anhydrouronic acid content of 46.99% and 56.60%, respectively. Intrinsic viscosity was 0.3 gdL^{-1} irrespective of drying technique used. The pectin extracts from the oven and solar dried muskmelon demonstrated good water absorption (208g/100g and 269g/100g), oil absorption (237g/100g and 152g/100g) and emulsion (50% and 46%) capacities, respectively. The different drying techniques used did not significantly influence physicochemical and functional properties. The findings show that muskmelon pectin are high methoxyl pectin with good functional properties which can be tailored for use in food and pharmaceutical formulations.

Keywords
muskmelon, pectin, extraction, degree of esterification

Introduction

Muskmelons belong to one of the largest plant families: the Cucurbitaceae family which comprises of a large group of plants with 130 genera and 800 species (Rolnik and Olas, 2020). The most well-known cucubits are water melon, pumpkins and cucumbers (Rolnik and Olas, 2020). Botanically, muskmelons are described as annual creeping or climbing plants with scabrous stems. The fruits of muskmelons particularly vary in shape, size and rind: a background for the various varietal classifications. In Ghana the fruit is highly underutilized since it is almost exclusively cultivated for its seeds (*wrewre*). The processing of the fruits results in large quantities of waste materials and by-products in the form of peels that can be re-used for the production of functional ingredients (Mallek-Ayadi et al., 2017). The quest to find alternative sources of industrially functional polymers, and also expand the utilization base of wastes from fruits and vegetables had led to various studies exploring the pectin potential of cucubits (Chen et al., 2015; Denman and Morris, 2015).
Pectin is a complex mixture of structural polysaccharides that make up one third of the cell wall material of most fruits and vegetables (Sriamornsak, 2003). They coexist with other cell wall polysaccharides such as lignin, cellulose and hemicellulose. Pectin is a soluble polysaccharide and therefore can easily be extracted from various sources. As with all natural polysaccharides, pectin from different plant sources have demonstrated variations in structural and chemical composition (Kpodo, 2019). The variations have been attributed not only to the differences in geographical location of the plant but also due to the plant variety, season, extraction conditions and physiological stage of maturity of the material (Kpodo et al., 2017; Kpodo, 2019). These variations introduce certain unique attributes to pectin which can be exploited for specific food, medicinal and non-food applications. Research studies have asserted on this basis that pectin from specific geographical sources have specific qualities that adequately qualifies them for certain industrial applications. Thus the objective of the study is to extract and characterize muskmelon pectin for specific industrial application.

Materials and Methods

Sample preparation

Matured Fresh *Cucumis melo* (muskmelon) samples were obtained from the Volta Region, Ghana. The samples (5 kg) were washed, deseeded and divided into two portions. The first part was oven dried at 50°C for 24 h and the latter was solar dried for 48 h at temperatures between 30–36°C using the tunnel solar drier. The dried samples were milled to a particle size of 450 μm using a hammer mill. The milled samples were kept in zip locked bags and stored in the freezer (Protech PRCF-500, China) at -18°C prior to pectin extraction.

Pectin extraction

Alcohol insoluble residue (A.I.R.) was prepared according to method as described by Denman and Morris (2015). The milled dried samples were treated with 95% ethanol (1:2 w/v), followed by acetone (1:2 w/v) for 48 h. The samples were then decanted and the insoluble fraction left to dry at 35°C for 48 h. The dried A.I.R. was kept in zip locked bags and stored in a dry keeper. The pectin extraction was done as described by Denman and Morris (2015) with slight modification. The alcohol insoluble residue was weighed and dissolved in HCl (1.5 g : 45 ml; pH 1). The mixture was then heated on a

hotplate at 80°C with magnetic stirring continuously for 4 h. The solution was then cooled and the pH was adjusted to 4.5 with 2M NaOH solution. The solution was then centrifuge at 2500 rpm for 15 min. Equal volume of ethanol (95% v/v) was added to the supernatant to precipitate the pectin out of solution. The liquid was decanted and the remaining centrifuged at 2500 rpm for 15 min. The residue was further washed with 95% ethanol and freeze dried (at -47°C to -55°C, 0.002 to 2.7 Torr) for 72 h using the vacuum freeze dryer (model: YK-118-50, Taiwan) for further analysis.

Physicochemical analysis

Pectin yield and purity

The percentage yield was calculated based on the amount of the milled muskmelon sample used for the extraction process. The percentage yield (w/w) was expressed as:

$$\%\ \text{Ext. yield} = \frac{\text{Wt. of freeze dried polysaccharide} \times 100}{\text{Wt. of dried muskmelon powder}} \quad (1)$$

where % = percentage; Ext. = extraction; Wt. = Weight.
Total carbohydrate was estimated using the phenol-sulphuric acid assay (Dubois et al., 1956). The Bradford protein assay was used in the determination of the protein content of the muskmelon pectin (Bradford, 1976).

Determination of equivalent weight

Pectin sample (0.5 g) was weighed into a 250 ml conical flask and moistened with 5 mL ethanol. Then 1.0 g sodium chloride was added to the mixture followed by 100 mL distilled water. Finally, six drops of phenol red was added and the resulting solution titrated against 0.1N NaOH until the colour of the solution changed to pink at the end point. The colour change persisted for 30 s indicating the endpoint. Equivalent weight was calculated using the following equation:

$$\text{Eq. Wt} = \frac{\text{Wt of sample(g)} \times 1000}{\text{Vol of alkali(ml)} \times \text{Normality of alkali}} \quad (2)$$

where Eq. = Equivalent; Wt. = Weight; Vol. = Volume.

Determination of methoxyl content

For methoxyl content, 25 ml of 0.25M NaOH was added to the neutral solution from equivalent weight determination containing 0.5g of pectic substance. The solution was shaken and allowed to stand for 30 min at room temperature in a stoppered flask. HCl (25 ml, 0.25M) was added and titrated with 0.1M NaOH to the same end point as before. The methoxyl content was then calculated using the formula;

$$\text{M. con} = \frac{\text{Vol of alkali(mL)} \times \text{N. of alkali} \times 31 \times 100}{\text{wt of sample(g)} \times 1000} \quad (3)$$

where M. = Methoxyl; con. = content; Vol. = Volume; N = Normality; wt. = Weight.

Total anhydrouronic acid content (TAUA)

The TAUA was calculated from the values of the equivalent weight and the methoxyl content by the expression given below (Girma and Worku, 2016):

$$AUA(\%) = \frac{176 \times 0.1Z \times 100}{w \times 1000} + \frac{176 \times 0.1y \times 100}{w \times 1000} \quad (4)$$

where molecular unit of AUA (1 unit) = 176g, z = ml (titre) of NaOH from equivalent weight determination, y = ml (titre) of NaOH from methoxyl content determination, W = weight of sample (g).

Degree of esterification

The degree of esterification was calculated from methoxyl and anhydrouronic acid content using the following expression (Virk and Sogi, 2004):

$$\text{D. of E} = \frac{176 \times \text{methoxyl content}(\%) \times 100}{31 \times \text{Anhydrouronic acid}(\%)} \quad (5)$$

where D = Degree; E = Esterification.

Fourier-Transform Infrared (FTIR) Spectroscopy

FTIR spectra were obtained between 500 and 4000cm^{-1} for all muskmelon pectin samples in Attenuated Total Reflection (ATR) mode at a resolution of 4cm^{-1} using 128 scans (Nicolet 380, Thermo Scientific, UK). Spectral smoothing was applied using instrument software (OMNIC 3.1). The degree of methyl esterification was calculated from the FTIR spectra corrected peak areas at 1639.4 (COO-asymmetric stretching) and at 1747cm^{-1} (C=O esterified), using the following expression (Manrique and Lajolo, 2002):

$$MED(\%) = 124.7R + 2.2013 \quad (6)$$

where, $R = A_{1740}/(A_{1740} + A_{1630})$; A = Absorbance, MED = degree of methyl esterification.

Functional properties

The water and oil absorption capacities of the freeze dried muskmelon pectin extract was determined according to method as described by (Noorlaila et al., 2015) whereas the emulsion and foaming capacities were also determined by method as described by (Archana et al., 2013).

Intrinsic viscosity measurement

The muskmelon pectin extracts were dispersed at 0.4 – 2% gdL^{-1} in 0.1M NaCl at pH 7.0 in Sorensen's phosphate buffer with 0.02 gdL^{-1} NaN^{-3} as a preservative. This was done in sealed glass vials with continuous magnetic stirring to ensure complete solubilization. The intrinsic viscosity $[\eta]$ of the muskmelon pectin solutions was determined at 25°C with a Ubbelohde capillary viscometer (PSL Rheotek OB. C 80705). The calculations were made using Huggins and Kraemer equations (Agbenorhevi et al., 2011).

Data analysis

Data obtained was analysed using Statistical Package for Social Sciences (version 22). Data was reported as averages of duplicate determinations and independent sample t-test was used to check for the significance level at 95% confidence interval.

Results and Discussion

Yield and purity of muskmelon pectin extract

The yield of alcohol insoluble residue generated prior to the extraction process was 92.4% and 86% for oven and solar dried muskmelon powder, respectively. This represent a marked 7.6 to 14% loss in the weight of sample. This decrease in weight could be associated with the removal of cytosolic component (mitochondria, plastids and other cell organelles). The insoluble residue fraction, is known to contain polysaccharides or acid hydrolyzable material such as lignin, cellulose, pectin and hemicellulose.

Table 1. Yield and chemical characterization of muskmelon pectin extract

Parameter	Oven dried	Solar dried
% Yield (A.I.R.)	92.4±0.00	86.0±0.00
% Yield	6.476±1.24^a	5.27±0.22^a
Carbohydrate content (%)	62.12±0.69^a	69.92±0.00^a
Protein content (%)	4.05±0.59^a	6.04±1.11^a
Equivalent weight	1265.92±65.64^a	990.97±41.6^a
Methoxyl (%)	5.14±0.26^a	7.51±0.76^a
Total anhydrouronic acid (%)	46.99±2.24^a	56.60±5.07^a
Degree of esterification (%)	60.53±4.75^a	64.97±0.14^a
Degree of methyl esterification (FTIR)	63.46±4.65^a	70.72±1.4^a

- Values are averages of duplicate determinations. Means followed by the same letters in a row are not significantly different ($p > 0.05$).
- A.I.R: Alcohol Insoluble Residue.

The 14% loss recorded for the oven dried sample could perhaps signal a relatively effective cell wall breakdown when the drying technique is employed due to the high unfluctuating temperatures, leading to a much higher release of the cystolic components.

The percent yield of pectin obtained after the extraction process were 5.3 and 6.5% of the AIR for solar and oven dried muskmelon samples, respectively (Table 1). Comparatively, the values recorded can be said to be low since commercial extracted sources could yield as high as 25-35% (citrus peels), 10-15% (apple pomace) and 10-20% (sugar beet) (Sundarraj et al., 2017). The values however are in agreement with Denman and Morris (2015) who recorded pectin yield between 2.2% and 7.9% for varying temperature, time and pH combinations for honeydew muskmelon. The combinations (time, pH and temperature) which corresponds directly to that used in this extraction gave a yield of 7.9±1.8% which is very close to the yield obtained in this extraction. Other authors per their extraction protocols and models have also reported relatively lower yields for muskmelon pectin extraction. Muthukumaran et al. (2017) reported a yield in a range of 2.1 to 3.8% whereas (Edima et al., 2014) reported values in the range of 0.23 to 4.53% for their extraction process. Generally, muskmelons can be considered as a relatively low yielding source of pectin. However, the unique qualities of pectin extracts obtained from this source could be a major factor facilitating its extraction.

For efficient characterization and utilization, pectin extraction is usually followed with a purity test. Pectin is a known polysaccharide (a carbohydrate molecule) and hence high values are anticipated for carbohydrate content. The carbohydrate content obtained were 62% and 69% for the oven dried and solar dried samples, respectively (Table 1). These values are considered high enough to indicate the extraction of a polysaccharide .Other authors have recorded values above 50% (Košťálová et al., 2013). The total carbohydrate content sums up the galacturonic acid content (backbone unit) and the total neutral sugar units present on the pectin molecule.

The protein contents of the extracts were 4% and 6% for oven and solar dried samples, respectively with no significant differences ($p > 0.05$; Table 1). This implies the type of drying process has no significant impact on the protein content of the extracts. Plant cell walls are composed primarily of polysaccharides and proteins; in addition to pectin coexisting with other polysaccharides (cellulose, lignin, and hemicelluloses), pectins also coexist with some proteins in their biological state (Harholt et al., 2010). Extracting processes could thus extract some quantities of pectins. Usually low quantities of proteins are anticipated for extracted pectins and quantities below 10% has been recorded by several authors from varied sources (Cui and Chang, 2014; Sato et al., 2011). Emulsification properties of pectin has been attributed to the presence of protein moieties (Chen et al., 2015). These moieties exist in covalent linkages with the polysaccharide background. This protein - polysaccharide complex in some instances has been considered as an arabinogalactan protein (AGP) (McKenna et al., 2006) hence a component of the pectin chain and not an "impurity". The obtained values perhaps could be signal to enhanced emulsification potential of this muskmelon pectin extract.

Equivalent weight and total anhydrouronic acid

Equivalent weight gives a measure of the total non-esterified free galacturonic acid content in the molecular chains of the pectin extract. The equivalent weight obtained for the extracts were 1265.92±65.64 and 990±41.6 g/ml for oven dried and solar dried samples, respectively with no significant differences. The values obtained were similar to that of banana and mango peel pectin which were 925 and 895g/ml respectively (Girma and Worku, 2016). In comparison to pectin extract from pumpkin peels (1250g/ml) however the equivalent weight of muskmelon pectin extract was found to be very similar. However, the values were higher compared to that recorded for jackfruit peel and core (475.74 and 460.63 respectively) (Ahmmed et al., 2017) and that recorded for guava peels which ranged from 345.4 to 685.30 (Bhat and Singh, 2014). The relatively high values recorded can be attributed to the polymerization of the pectin into longer chains which

in turn decreases the free acid content. This chemical change is typical for low pH extractions as lower equivalent weight has been strongly attributed to higher partial degradation of pectin chains (Altaf et al., 2015). The equivalent weight is used in the calculation of Anhydrouronic acid (AUA) content and Degree of esterification (DE).

The anhydrouronic acid content is a critical parameter and indicates the purity and the suitability of the extracted pectin for use. For commercially available pectins, FAO indicates an anhydrouronic acid content of not less than >65%. The values recorded were 43% and 63% for solar and oven dried samples respectively. For commercial purposes these extracts are therefore classified impure and should be further purified. The values however are comparable to that obtained for banana peel pectin (53.60%) and apple peel pectin 62.82% (Girma and Worku, 2016; Virk and Sogi, 2004). The low AUA recorded can however be attributed to the relatively high protein content recorded for both samples.

Methoxyl content and degree of methyl esterification (MED)

Pectin has become an important ingredient in many foods because of its unique and outstanding gelling properties. This unique property is largely affected by the methoxyl content and the degree of methoxylation. Methoxyl content is defined as the amount of methoxy groups that esterifies acid groups along the pectin chain whereas MED refers to the ratio of methoxylated galacturonic acid unit to the total galacturonic acid unit of the pectin chain. The methoxyl content obtained for the samples were 5.14 and 7.51% for oven and solar dried extract respectively. The value is comparable to methoxyl content of commercial pectin (5.3%) as reported by Virk and Sogi (2004) and dried apple pomace (5.8 to 6.7%) (Sato et al., 2011). The type of drying method used however had no significant ($p > 0.05$) effect on the methoxyl content.

The degree of esterification further serves as a bases for classification of pectins as it determines the gel strength and setting time of the pectin used. Pectins with degree of esterification greater than 50% are generally classified as high methoxyl pectins whereas those with degree of esterification less than 50% are known as low methoxyl pectins. For this study the degree of esterification was determined using titration Virk and Sogi (2004) and extrapolation from FTIR spectra (Manrique and Lajolo, 2002). Values recorded from the titration were 60% and 64% for oven and solar dried samples, respectively with no significant differences ($p > 0.05$; Table 1). Values extrapolated from the FTIR spectra corresponded to 63% and 70% for oven and solar dried samples respectively. With reference to these values the muskmelon pectin extract can therefore be classified as high methoxyl pectin. In application, it is anticipated that the extract will form high sugar gels with rapid setting times. Muthukumaran et al. (2017) also classified pectin extract from muskmelon (*Cucumis melo var. reticulatus*) peels as high methoxyl pectin; reference from a degree of esterification value of 61.38%. Similar findings has also been reported by Denman and Morris (2015) who reported values in a range of 40 to 70% for pectin extract from *Cucumis melo Inodorus*.

FTIR spectra

FTIR spectra (3500 to 500 cm^{-1}) were used to compare the oven and solar dried muskmelon pectin extract (Figure 1) and this confirmed the presence of similar functional groups. Pectin as a polysaccharide is saturated with hydroxyl groups (OH). The O−H absorption is represented as the broad band within the range of 3500 to 3000 cm^{-1} for oven and solar dried samples. The development of this band has been attributed to O−H stretching vibrations which arises from inter- and intra-molecular hydrogen bonding of the D-GalA backbone (Altaf et al., 2015). Similar O−H stretching absorption peak has been reported within the range of 3600 to 3200 cm^{-1} for grewia polysaccharides (Kpodo, 2019) and in the region of 3600 to 3000 cm^{-1} for lacebark polysaccharides (Sim et al., 2018).

Bands in the region of 2920 to 2800 cm^{-1} correspond to C−H stretch of methyl groups (CH, CH2 and CH3 stretching vibrations) typical of carbohydrate molecules (Kpodo et al., 2017). The band is represented in the oven dried spectrum as sharp and strong whereas it is represented in the solar dried sample as sharp but weak. These peaks can generally be related to the methyl and methylene groups present on the muskmelon pectin chain. Furthermore, the backbone of pectin is known

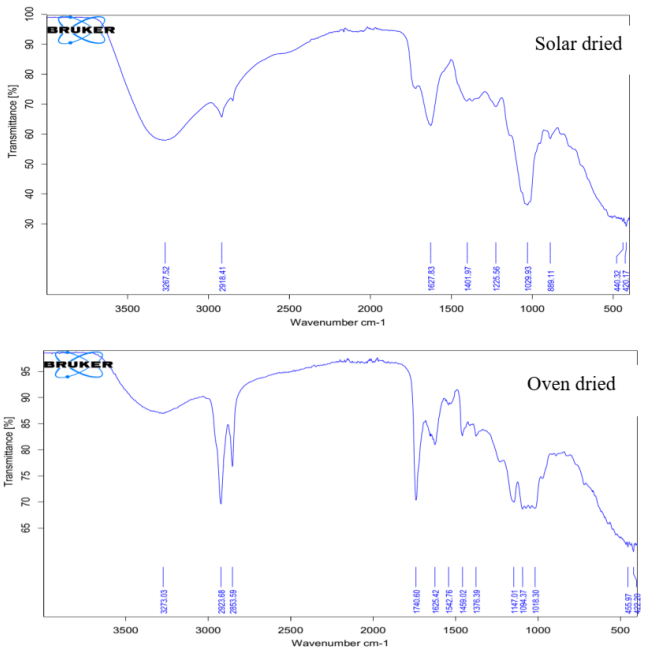

Figure 1. FTIR spectra of solar and oven dried muskmelon pectin extract

to be of uronic acid derivative, which implies the presence of carbonyl and carboxylic acid functional groups on any typical pectin molecule. The two bands around the regions of 1625

and 1542 denotes vibrations that corresponds to the carboxylic acid structure (O=C−O) present on chain. Generally, C=O functional group is assigned to peaks within wavenumbers of about 1780-1650. This characteristic peak is a major difference between the two spectra as a sharp strong peak is seen around 1740 cm^{-1} for the oven dried extract but it is absent for the solar dried extract. According to Manrique and Lajolo (2002), this characteristic peak at 1740 cm^{-1} can be assigned to C=O stretching vibration of methyl esterified carboxylic group and protonated carboxylic group.

Generally, carbohydrates show absorbance signals between 1200 and 950 cm^{-1} and is known as the fingerprint region, specific for each polysaccharide.

Water absorption capacity (WAC) and oil absorption capacity (OAC) of muskmelon pectin extract

The WAC for the samples were found to be 208g/100g and 269g/100g for oven dried and solar dried samples respectively with no significant differences ($p > 0.05$) (Figure 2). In hydrocolloid study, water absorption capacity can be defined as the amount of water that a hydrocolloid can absorb to suitably adapt it for a specific functionality. The high WAC values recorded can be attributed to the widespread again imply that the muskmelon pectin extract could be efficiently employed in water based food systems for efficient functionality.

Most often such extracts are employed as humectants, stabilizers and/or thickeners because of their ability to act as water immobilizers. It must however be indicated that the values recorded are relatively lower when compared with WAC values of okra pectin extract which ranges between 800-963g/100g for okra pectin (Kpodo et al., 2017).

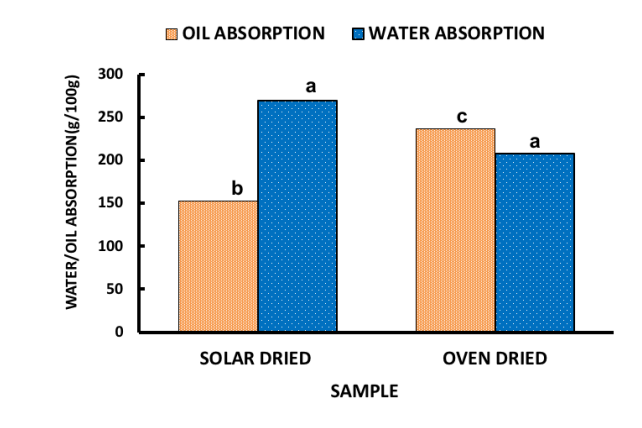

Figure 2. Water and oil absorption capacities of muskmelon pectin extract.

$^{a-c}$Bars with same pattern but different letters are significantly different ($p < 0.05$)

For OAC, values recorded for the extract were relatively lower when compared to the WAC values. Generally, the values recorded were 237 and 152g/100g for the oven dried and solar dried samples respectively (Figure 2). These values are high especially for polysaccharide samples and could be attributed to the presence of protein groups on the polysaccharide chain (Table 1). Even though the presence of hydroxyl groups on the polysaccharide chain introduces high level of hydrophilicity, the presence of protein groups (especially those with non-polar side chains) could also introduce some hydrophobic groups which could engage in hydrophobic interactions with hydrocarbon groups of the lipids and contribute to the relatively high OAC (Chandra et al., 2015). This attribute, perhaps could highlight the emulsifying potential of the extract.

Emulsion Capacity, Foaming Capacity and Stability of Muskmelon Pectin Extract

The emulsion potential of pectin from different sources has been reiterated over the years by several studies (Archana et al., 2013; Bueno et al., 2009; Ngouémazong et al., 2015; Yancheva et al., 2016; Yang et al., 2018). The emulsion capacities recorded for the samples were 50% and 46% for the oven dried and solar dried samples respectively with no significant differences at $p<0.05$. The values obtained for muskmelon pectin extract were comparable to that of okra pectin extract obtained by Archana et al. (2013); Kpodo et al. (2017) but were lower to that obtained by Noorlaila et al. (2015) (79.87 – 85.83%) for their okra pectin extract. The values were again higher than that of Yancheva et al. (2016) who obtained values in the range of 5.8% to 19.6% for pectin from celery and pectin for waste rose petals. The emulsifying potential of pectin is premised on its ability to increase viscosity of the continuous phase and its surface activity at the oil-water interface. This facilitates the formation and stabilization of fine oil droplets in the emulsion. The presence of acetyl and feruloyl esters in addition to proteins on the pectin structure have been implicated in the emulsifying behaviour because of their hydophobic nature (Ngouémazong et al., 2015).

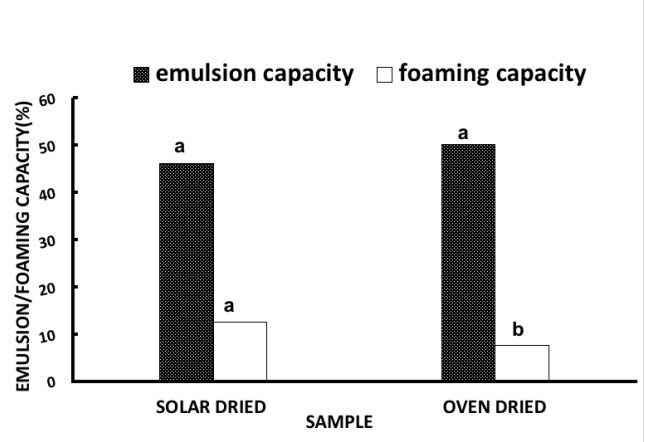

Figure 3. Foaming and emulsion capacity of muskmelon pectin extract.

$^{a-c}$Bars with same pattern but different letters are significantly different ($p < 0.05$)

Foaming capacity relates to the ability of a polysaccharide or protein to form a dispersion of a gaseous phase in an aqueous

Table 2. Intrinsic viscosity (dl/g) properties of muskmelon pectin

Sample	Huggins model			Kraemer's model			
	$[\eta](dLg^{-1})$	K_H	R^2	$[\eta](dLg^{-1})$	K_k	R^2	$K_H + K_k$
Oven dried	0.337 ± 0.00^a	0.469 ± 0.04^a	0.867	0.322 ± 0.02^a	0.660 ± 0.02^a	0.924	1.133
Solar dried	0.310 ± 0.02^a	0.568 ± 0.012^a	0.875	0.297 ± 0.01^a	0.748 ± 0.08^a	0.925	1.316

$[\eta]$, intrinsic viscosity; K_H, Huggins constant; K_k, Kraemer constant. Means followed by the same letters in a column are not significantly different ($P > 0.05$).

phase. The foam volumes recorded were 12.5 cm^3 and 7.5 cm^3 for solar and oven dried samples respectively with significant differences ($p < 0.05$)(Figure 3). The difference, perhaps is indicative of differences in molecular weight and protein content of the extracts. The volumes recorded were however consistent with that obtained by Yancheva et al. (2016). The authors examined foaming capacities of pectin extracted from different waste sources and found volumes in the range of 1.5 to 20 cm^3. In comparison with foaming ability of eggs (Van der Plancken et al., 2007), that obtained can be said to be low, however the values obtained further reiterate the findings of surface activity pectins; their ability to be adsorbed at the interface and form network strong enough to contain some volumes of gas.

Intrinsic viscosity

Generally, viscosity measurements of polymer solutions indicate the existences of molecular interactions between the solvent and the polymer understudy. The extent of interaction can also be predicted stemming from this basis. Intrinsic Viscosity provides a measure of the hydrodynamic volume occupied by an individual molecule i.e. the volume occupied by an individual polymer molecule. The intrinsic viscosity in this study was determined by different models: The Huggins and Kramer's model. The Kramer's model was more appropriate for the determination because of the high values of the coefficient of determination (R^2; Table 2).

The intrinsic viscosity resulting from both models was found to be in a range of 0.30–0.34 gdL^{-1} (Table 2). The intrinsic viscosity of pumpkin bio pectin and okra pectin had been found to be 0.9 and 0.41–2.71 gdL^{-1} respectively (Evageliou et al., 2005; Kontogiorgos et al., 2012). Comparatively the values obtained for this study can be said to be low, suggesting that muskmelon pectin occupies a much smaller volume when in solution. The dependence of intrinsic viscosity on source and type of raw material and extraction condition has been emphasized by several studies (Evageliou et al., 2005; Hesarinejad et al., 2015; Irani et al., 2016) and raw materials produces rheologically different polysaccharides extract. Values reported for similar polyelectrolyte pectin includes 2 to $4.5dLg^{-1}$; commercial pectin (Morris et al., 2010) and 0.3 to $3.95dLg^{-1}$ for sugar beet pectin (Morris et al., 2010).

There were no significant differences ($p > 0.05$) between the solar dried extract and the oven dried muskmelon pectin extract. This suggest that the type of drying (oven or solar) has no effect on the intrinsic viscosity. Different extraction processes has had significant impact on intrinsic viscosity, perhaps the intrinsic viscosities have been impacted because of specific unit operations in the different extraction protocols and altering these operations can produce polysaccharides of specific intrinsic viscosities.

The Huggins constant (K_H) relates to the polymer solvent interactions but also provides a guide on the chain conformation of the polymer molecule as well as indicate extent of polymer-polymer interactions in dilute solutions (Evageliou et al., 2005; Girma and Worku, 2016; Irani et al., 2016; Kontogiorgos et al., 2012). K_H is dependent on the molecular architecture and the extent of coil polymer expansion (Hesarinejad et al., 2015). Generally, the values ranges between 0.3 and 1. Flexible macromolecules with extended shapes in good solvents have KH values that varies between 0.3 to 0.4 whereas values between 0.5 to 0.8 are representative of macromolecules in theta solvents (i.e. solvents in which polymer chains act as ideal chains) (Evageliou et al., 2005; Girma and Worku, 2016; Irani et al., 2016; Kontogiorgos et al., 2012). Values greater than 1 reflects macromolecules in poor solvents with high polymer-polymer interaction (i.e macromolecule aggregation) (Hesarinejad et al., 2015). K_H values calculated for muskmelon pectin in deionised water was found to be approximately 0.5 which suggests high chain flexibility of the pectin polymer. The value also postulates deionised water as theta solvent for muskmelon pectin and suggests very low level of macromolecule aggregation. Similar results was obtained for okra pectin extract (Kontogiorgos et al., 2012; Kpodo et al., 2017), perhaps similarities exist between the molecular architecture of the two polymers. Theoretically the expression: $K_H + K_k = 0.5$ is said to be valid for Huggins and Kraemer constants for random coil conformation. The validity of this expression is however not conditioned by the nature of the polymer or solvent system but a mere mathematical consequence (Pamies et al., 2008). $K_H + K_k$ values obtained was found to vary between 1.13 and 1.32 for oven and solar dried samples, respectively (Table 2). It is postulated that larger or smaller values could be as a results of the molecular aggregation (Hesarinejad et al., 2015).

Conclusion

High methoxyl pectin with high galacturonic acid content (>60%) were extracted from muskmelon fruits dried using different techniques (solar and oven drying). The pectin extracts exhibited good foaming and emulsifying properties which implies they could be used as stabilizers in emulsions

and foams. The results showed that the chemical and rheological properties (intrinsic viscosity) are not responsive to the different drying process (solar and oven drying) used in the extraction process however some functional properties such as foaming capacity and oil absorption capacity were significantly responsive.

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