UNIVERSITI PUTRA MALAYSIA

CHARACTERIZATION AND FUNCTIONAL PROPERTIES OF PECTIN DERIVED FROM LEAVES, PULP AND SEEDS OF LADY'S FINGER (Abelmoschus esculentus Moench)

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By

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October 2014

Chairman : Professor Amin Ismail, PhD
Institute : Halal Product Research Institute

In Malaysia, lady's finger also known as okra (*Abelmoschus Esculentus* Moench) can be easily available all year round with low maintenance cost. In order to overcome issues regarding contamination of pork-related gelatin substance in food products, the development of plant based gelling agent was encouraged as an alternative to replace animal gelatin. Based on previous studies, okra plant was indicated as one of the more promising crops which possess unique properties of a gelling agent. Therefore, this study aims to extract, characterize the physicochemical and functional properties of pectin derived from okra leaves, pulp (skin without seeds) and seeds. Pectin was extracted using a sequential extraction with the applications of hot buffer (HB), hot buffer with chelating agents (CH), diluted alkali (DA) and concentrated alkali (CA) soluble solids. The fractions obtained were compared to commercial pectin in terms of functional group identification using Fourier Transform Infrared Spectroscopy (FTIR), nutritional composition, monosaccharide composition, pH, melting point, viscosity, gel strength and functional properties. Optimization of concentration was performed to determine the optimal concentration for gel formation and subjected to melting point, viscosity and gel strength analysis. The highest pectin yield was extracted from seeds with all fractions yield of 86%, followed by the leaves (75%) and pulp (71%). CH extraction gave the highest yield (>40%) compared to HB and DA from okra leaves, pulp and seeds. Nutritional composition showed total dietary fibre was the highest in okra leaves (65.06 ±1. 59) which was significantly different ($p < 0.05$) from okra pulp and seeds. HB fraction of leaves, pulp and seeds had highly purified pectin due to high anhydro uronic acid content and degree of esterification. Gel formation was achieved when okra pectin was blended together with konjac glucomannan (KG) and stored 16 - 18hr at 4°C ± 1.0 (5.0% of okra pectin: 1.6% of KG). The presence of major functional groups of pectin lies at 1,300-800 cm^{-1} in most of the HB, CH and DA fractions of okra leaves, pulp and seeds. Gel formation was identified by analysing gel strength and viscosity which showed HB had lower gel strength (< 15 Bloom grams) than CH fraction, meanwhile DA fraction exceeds 50 (g) which generally failed to form a gel. Galacturonic acid and rhamnose were identified in all fractions of okra leaves, pulp and seeds by using HPLC-RI. Water and oil holding capacities of HB fraction from okra pulp were higher compared to others, meanwhile DA fractions of okra leaves showed a

higher emulsifying ability and better foaming properties than the commercial pectin. Conclusively, characterization and functional properties of HB, CH and DA fractions derived from okra leaves, pulp and seeds showed potential use of the plant as gelling agent.

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PENCIRIAN DAN CIRI-CIRI FUNGSI PEKTIN YANG DIPEROLEHI DARIPADA DAUN, PULPA DAN BIJI BENDI (*Abelmoschus esculentus* Moench)

Oleh

NUR FARHANA ABD RAHMAN

Oktober 2014

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Di Malaysia, bendi dikenali sebagai okra (*Abelmoschus Esculentus* Moench) yang mudah didapati sepanjang tahun dengan kos penjagaan yang rendah. Untuk mengatasi isu berkaitan kontaminasi gelatin-babi dalam produk makanan, pembangunan sumber yang berasaskan tumbuhan adalah digalakkan sebagai alternatif untuk menggantikan gelatin haiwan. Berdasarkan kajian sebelum ini, pokok bendi adalah salah satu tanaman yang mempunyai satu ciri unik iaitu sebagai agen gel. Oleh itu, kajian ini bertujuan untuk mengekstrak, menentukan sifat fizikokimia dan fungsian pektin yang diperolehi daripada daun bendi, pulpa (kulit tanpa biji) dan biji. Pektin telah diekstrak dengan menggunakan pengekstrakan berurutan dengan aplikasi penimbal yang bergerak balas (panas) (HB), penimbal yang bergerak balas (panas) dengan agen pengelat (CH), alkali cair (DA) dan alkali pekat (CA) untuk pepejal terlarut. Bahagian yang diperolehi dibandingkan dengan pektin komersial dari segi identifikasi kumpulan berfungsi dengan menggunakan spektroskopi inframerah transformasi fourier (FTIR), komposisi nutrisi, komposisi monosakarida, pH, takat lebur, kelikatan, kekuatan gel dan sifat kefungsian. Pengoptimuman konsentrasi telah dijalankan untuk menentukan kepekatan optimum untuk membentuk gel, takat lebur, kelikatan dan analisis kekuatan gel. Hasil tertinggi pektin diekstrak daripada biji bendi dengan keseluruhan hasil sebanyak 86% diikuti oleh daun bendi (75%) dan pulpa (71%). Pengekstrakan CH memberikan hasil yang paling tinggi (>40%) berbanding dengan HB dan DA daripada daun bendi, pulpa dan biji. Komposisi nutrisi menunjukkan jumlah serat tertinggi dalam daun bendi (65.06 ± 1.59) di mana ia jauh berbeza ($p < 0.05$) dengan pulpa dan biji bendi. Bahagian HB yang telah diekstrak daripada daun, pulpa dan benih bendi menunjukkan pektin yang tulen kerana kandungan anhydro uronic asid dan darjah pengesteran proses yang tinggi. Pembentukan gel telah dicapai apabila pektin dicampurkan dengan konjac glucomannan (KG) dan disimpan selama 16-18 jam, pada 4 °C ± 1.0 (5.0% pektin bendi : 1.6% KG). Kehadiran kumpulan berfungsi utama pektin terletak di 1,300-800 cm^{-1} di kebanyakan HB , CH dan DA bahagian daun, pulpa dan biji bendi. Pembentukan gel telah dikenal pasti melalui analisis kekuatan dan kelikatan gel. Kekuatan gel HB adalah lebih rendah (< 15) (g) daripada bahagian CH, sementara bahagian DA melebihi 50 (g) dimana ia gagal untuk membentuk gel. Galacturonic asid dan rhamnose adalah komposisi gula yang telah dikenal pasti dalam semua bahagian daun, pulpa dan biji bendi dengan menggunakan HPLC - RI. Bahagian HB daripada

pulpa bendi telah menunjukkan keupayaan mengikat air dan minyak yang lebih tinggi berbanding dengan bahagian lain, sementara bahagian DA daripada daun bendi menunjukkan keupayaan mengemulsi yang lebih tinggi dan sifat berbusar yang lebih baik daripada pektin komersial. Kesimpulannya, pencirian dan sifat fungsian daripada bahagian HB, CH dan DA yang diekstrak daripada daun, pulpa dan biji bendi menunjukkan tumbuhan yang berpotensi untuk digunakan sebagai agen penjelan.

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Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

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LIST OF ABBREVIATIONS

AIS	Alcohol insoluble solids
AUA	Anhydro uronic acid
CA	Concentrated alkali
CH	Chelating agent
DA	Diluted alkali
DE	Degree of esterification
EA	Emulsion ability
EAI	Emulsion ability index
FA	Foaming ability
FS	Foaming Stability
FTIR	Fourier Transform Infra-red
HB	Hot buffer
HBSS	Hot buffer soluble solids
HPLC	High performance Liquid Chromatography
MeO	Methoxyl
KG	Konjac glucomannan
LMP	Low methoxyl pectin

CHAPTER 1

INTRODUCTION

1.1 Research background

Food is very important in our life as it is essential for growth, energy production, cell repair and maintenance of proper health. Any issues regarding food eventually will attract public interest and indirectly affect the requirement of the body. Therefore, it is necessary for humans to consume not only ordinary food but also functional food which promotes health. As Muslims, it is obligatory to consume halal food which concerns more about the source of food products and suggested to consume 'tayyib' food, which generally known as 'halal' and 'tayyib' food. Halal is an Arabic word known as permitted or permissible by the Shariah Law. When applied to the halal food and drinks, it means permissible for consumption by Muslims. Meanwhile, 'tayyib' refers to wholesomeness of food which concludes nutritious, healthy, quality and safe to consume. The opposite term of 'halal' is 'haram' which is known as illegal, prohibited, forbidden to consume by people if it involves food and beverages application. For instance, prohibition of pork-based consumption is strictly mentioned in Holy Quran, in Surah Al Ma'idah : verse 3 which stated "You are forbidden (to eat) that which dies of itself (flesh of unslaughtered animals), blood (which is flowing), and the flesh of swine (including all), also any flesh dedicated to any other than Allah, and those killed by strangling, and those beaten or gored to death, and those killed by a fall, and those mangled by beasts of prey, unless (you find it still alive), and slaughter it, and those sacrificed to idols; and (you are also forbidden) to seek division by arrows. That is a vicious practice."

Commonly used food additives such as emulsifier, gelling agent, stabilizer and many more were added in order to obtain desired foodstuff texture. Gelling agent is one of the food additives substantially used in food to obtain desired texture and fulfil satisfaction of consumer. Nowadays, most of the commonly used commercial gelling agent in food industry consists of gelatin from porcine and bovine due to its unique properties. However its source presents problems for religions such as Islam and Judaism. These communities cannot accept any porcine related food products and if bovine gelatin is used, it must been processed in accordance to Islamic Law. Since then, there has been considerable interest in finding and using alternative substitutes.

Therefore, finding an alternative or similarities in functional properties such as gelation that can be acceptable by these religious groups is very recommendable and eventually overcoming halal food issues rising recently. Research focuses on the exploitation of particular plant namely ladies finger (okra) which can be classified as plant based source.

Okra (*Abelmoschus esculentus* (L.) Moench) known as ladies finger had a branched, semi-woody, annual or biennial, and the height of the plant in the range of 1- 3 m. In India, okra is called as 'bhindi' meanwhile in Malaysia it is commonly known as 'bendi' or 'kacang bendi'. The leaves of okra are alternate, long-stemmed, widely spaced up the stem and deeply divided with toothed margins (Morton, 1990**)**. Okra is widely known as the plant which has viscous mucilaginous and contributes to the production of a plasma expander, suspending and emulsifying agents (Emeje et al.,

2011). In addition, parts of the immature fruit of okra can be used in folk medicine as a diuretic agent and treatment for dental disease (Ndjouenkeu et al., 1996). It was also used as fat substitute in chocolate bar cookies (Romanchik-Cerpovikz et al., 2002), egg white substitute (Costantino and Romanchick-Cerpoviez, 2004) and chocolate frozen dairy dessert (Romanchik-Cerpovikz et al., 2006). Lengsfeld et al. (2004) reported that okra has high carbohydrate content which can be used as a food additive that eventually can act against gastric irritative and inflammative disease. Generally, okra plants possess highly viscous and slimy mucilage, which is composed of mixtures of polysaccharides and other materials such as protein (Woofle et al., 1977). Sequential extraction of okra cell wall material revealed that okra contained different types of polysaccharides, including pectins, xyloglucans, xylans, and celluloses (Sengkhamparn et al., 2009).

Pectin is the methylated ester of polygalacturonic acid that contained 1,4-linked α-D-galacturonic acid residues that could be obtained from many types of plant sources such as hetero polysaccharides derived from cell walls of higher terrestrial plants, peels of citrus fruits, guava and apples (Sengkhamparn et al., 2009). It is capable of forming gels with the presence of sugar and acid solutions under suitable conditions. It is usually added in jams and jellies as a gelling agent (Mishra et al., 2001). Moreover, pectin is also widely used as a thickener, texturizer and stabilizer in food industry. The suitability of pectin for different purposes depends on its chemical and characteristics of the extracted pectin. Pectin extracted from a variety of sources can be different in molecular weight, degree of esterification and methoxyl content, thus possessing different functional properties. Therefore, it is an inevitable aspect that pectin should be investigated more thoroughly (Madhav and Pushpalata, 2002; Aina et al., 2012; Ismail et al., 2012).

1.2 Problem statements

Nowadays, the halal status of gelatine as a food additive is doubted. Generally, gelatin is from animal source; porcine and bovine based are the most commonly used. Animals such as porcine and those bovine which do not fulfil the requirement of slaughtering process according to Shariah law are not allowed to be consumed especially by Muslim and Jewish society. However, gelling agent is one of the food additives that are substantially used in food products to obtain desired texture and fulfil satisfaction of consumer. Majority of commercial gelling agents applied in food industry is gelatin. Gelatin is a valuable protein derived from animal by-products, obtained through partial hydrolysis of collagen originated from cartilages, bones, tendons and skins of animals, where one of the functions is to increase the viscosity and acts as thickeners in food product.

Most of commercial gelatin mainly derived from porcine and bovine source. Recently porcine gelatin gained increased interest due to issues of bovine spongiform encephalopathy (BSE) products sourced from cow (Baziwane and He, 2003; Gudmundsson, 2002). BSE is widely known as mad cow disease (Morrison et al., 1999) .However, its sources present problems for Muslims and Jewish society. These communities cannot consume any porcine related food products and for beef gelatin, it has to be processed in accordance with religious requirements.

In such situation, finding an alternative or similarities to the functional properties of gelation that can be acceptable to these religious groups is highly recommended since there is no study comparing the gelation properties of okra polysaccharides derived from leaves, pulp and seeds with commercial pectin as control. In addition, their unique properties such as "mucilage" that are present naturally, eventually initiate an idea to explore this property in more details. In Asian countries, okra leaves are rarely consumed directly, unlike in most African countries where the leaves are consumed as vegetables as often as the okra fruits are consumed. In Malaysia, the leaves are wasted once the okra fruits are sufficiently grown. Instead of discarding the leaves, they can be effectively disposed by producing useful by products from them.

Moreover, okra plants can be obtained any time, everywhere and can be easily grown at a low maintenance cost. According to FAO database, the five highest okra producing countries in 2012 were India with 6 million (tons) followed by Nigeria (1.1 million tons), Sudan(263000 tons), Iraq (160000 tons) and Cote d'Ivoire (134260 tons) over the total production of okra 8 359 944 tons (FAOSTAT,2012). Okra is widely grown in the tropics, sub-tropics and warmer areas of the temperate zones (Camciuc et al.,1998). Higher yields are obtained with hot weather (temperatures above 26ºC), especially in regions with warm nights (>20ºC). Production of okra in Malaysia was 26,530 tons in the year 2012, and therefore ranks 14th the most okra yield production in the world (FAOSTAT, 2012). These are also some other reasons why this plant was chosen in this research. In the end, research focuses on the exploitation of particular plant namely, ladies finger (okra), which can be classified as plant based source. Properties of okra leaves, pulp and seeds can be compared directly with gelatin, and determined whether it is suitable or not as an alternative substance for gelatin in terms of physico - chemical, gel formation and functional properties in this research.

1.3 Significance of the study

The parameter of this research will determine whether okra plant pectin is comparable to the animal based gelatin. The importance of the characterization on physicochemical and functional properties of okra plant pectin can be categorized as an alternative to commercial pectin or gelatin. This study is important especially to those who are vegetarian by which they could not consumed animal based of food product. Instead of using gelatin which is sourced from animal, pectin is applicable as it is sourced from plants. Moreover, okra plant is available abundantly anywhere regardless of season, a very suitable plant to be used as it can be easily obtained anytime with low maintenance cost for farming. Thus, it could possibly ease the research as the availability of the sources is easily obtained.

Basically, okra fruits were harvested when they were immature and high in mucilage to prepare the dishes with a desired consistency. As for mature okra seeds, can be used as animal feed specifically for poultry feed. Besides, roasted okra seeds also are used as a good coffee substitute in Turkey (Calisir et al. 2005). In addition, okra seeds have been claimed to be a small source of oils that contain an unsaturated fatty acid known as linoleic acid (Andras et al., 2005; Anwar et al., 2010). However, particularly, okra leaves are rarely used for consumption in Malaysia. At the end, after okra fruits are harvested, they are discarded and become waste.

Therefore, to utilize both okra leaves and fruits, this research was performed to identify the preliminary potential of their residues. Besides, limited literature can be obtained regarding gelling agent properties from okra leaves and fruits which directly compared with mammals gelatin. Therefore, in this study, it can be used for preliminary references as one of the alternative gelatin to replace mammals gelatin based. This study promises a financially lucrative process if pectin can be produced from an alternative okra source. Pointedly, it could help reduce agricultural waste production particularly for okra leaves.

1.4 Objectives

1.4.1 General objective

To evaluate the pysico-chemical and functional properties of pectin derived from okra leaves, pulp and seeds.

1.4.2 Specific objectives

1. To determines different types of pectin by sequential extraction.
2. To evaluate the effects of different extraction conditions on the yield, chemical composition and functional groups of okra leaves, pulp and seeds.
3. To determine nutritional composition, sugar composition and functional properties of pectin from okra leaves, pulp and seeds.

REFERENCES

Adelakun, O. E., Adeyemi, I. A., and Venter, M. Van De. (2011). Mineral composition and the functional attributes of Nigerian okra seed (*Abelmoschus esculentus Moench*) flour. *Food Research International*,*47*(2), 348-352.

Adelakun, O. E., Oyelade, O. J., Adeyemi, I. A., and Venter, M. Van De. (2009a). Chemical composition and the antioxidative properties of Nigerian Okra Seed (*Abelmoschus esculentus Moench*) Flour. *Food and Chemical Toxicology*, *47*(6), 1123–1126.

Adelakun, O. E., Oyelade, O. J., Adeyemi, I. A., Venter, M. Van De, and Koekemoer, T. C. (2009b). Influence of pre-treatment on yield chemical and antioxidant properties of a Nigerian okra seed (Abelmoschus esculentus moench) flour. *Food and Chemical Toxicology*, *47*(3), 657–661.

Agustiniano - Osornio, J. C., González-Soto, R. A., Flores-Huicochea, E., Manrique-Quevedo, N., Sánchez-Herna´ndez, L., and Bello-Pérez, L. A. (2005). Resistant starch production from mango starch using a single screw extruder. *Journal of the Science of Food and Agriculture*, *85*, 2105–2110.

Ahmad, M., and Benjakul S. (2011).Characteristics of gelatin from the skin of unicorn leatherjacket (*Aluterus monoceros*) as influenced by acid pre-treatment and extraction time. *Food Hydrocolloids*, *25*, 381-388

Aina, V. O., Barau, M. M., Mamman, O. A., Zakari, A., and Haruna, H. (2012). Extraction and Characterization of Pectin from Peels of Lemon (*Citrus limon*), Grape Fruit (*Citrus paradisi*) and Sweet Orange (*Citrus sinensis*). *British Journal of Pharmacology and Toxicology*, *3*(6), 259–262.

Alka, K., and Bhattacharya, S. (2008). Gelling behavior of rice flour dispersions at different concentrations of solids and time of heating. *Journal of texture studies*, *39*, 231–251

Al-Sheraji, S. H., Ismail, A., Manap, M. Y., Mustafa, S., Yusof, R. M., and Hassan, F. A. (2012). Purification, characterization and antioxidant activity of polysaccharides extracted from the fibrous pulp of *Mangifera pajang* fruits. *LWT - Food Science and Technology*, *48*(2), 291–296.

Alvarez-Manceñido F, Landin M, Lacik I, Martínez- Pacheco R. (2008). Konjac glucomannan and konjac glucomannan/xanthan gum mixtures as excipients for controlled drug delivery systems. Diffusion of small drugs. *International Journal of Pharmaceutics, 349,*11-18.

Ameena, K., Dilip, C., Saraswathi, R., Krishnan, P. N., Sankar, C. and Simi, S. P. (2010). Isolation of the mucilages from *Hibiscus rosasinensis* linn. and Okra (*Abelmoschus esculentus* linn.) and studies of the binding effects of the mucilages. *Asian Pacific Journal of Tropical Medicine*,*3*(7), 539–43.

Andras, C. D., Simandi, B., Orsi, F., Lambrou, C., Tatla, D. M., and Panayiotou, C. (2005). Supercritical carbon dioxide extraction of okra (*Hibiscus esculentus* L.) seeds. *Journal of Science and Food Agriculture, 85*,1415–1419

Anthon, G. E., and Barret, D. M. (2008). Combined enzymatic and colorimetric method for determining the uronic acid methylester content of pectin: application to tomato products. *Food Chemistry, 110*, 239-247.

Anwar, F., Rashid, U., Ashraf, M., and Nadeem, M. (2010). Okra (*Hibiscus esculentus*) seed oil for biodiesel production. *Applied Energy, 87*(3), 779–785.

Association of Official Analytical Chemists (AOAC). (2000). Official methods of analysis (17th ed.). Washington DC, USA: Association of Official Analytical Chemists.

Arapitsas, P. (2008). Identification and quantification of polyphenolic compounds from okra seeds and skins. *Food Chemistry, 110*, 1041–1045.

Armisen, R., Galatas, F., and Hispanagar, S. A. (2000). *Agar.In:Handbook of Hydrocolloids*, Phillips, G. O., and Williams, P. A., Eds., Woodhead Publishing Co., Cambridge, U.K. pp. 21–39.

Aspinall, G. O., and Bail Lie, J. (1963). Gum tragacanth – Part I. Fractionation of the gum and the structure of tragacanthic acid. *Journal of Chemical Society, 318*, 1702–1714.

Avachat, A. M., Dash, R. R., and Shrotriya, S. N. (2011). Recent Investigations of Plant Based Natural Gums, Mucilages and Resins in Novel Drug Delivery Systems. *Indian Journal of Pharmaceutical Education and Research*, *45*(1), 86–99.

Baht, U. S., and Tharathan, R. N. (1987). Functional properties of okra (*Hibiscus esculentus*) mucilage. *Starch/starke, 39*, 165–167

Balian, G., and Bowes, J. H. (1977). *The structure and properties of collagen*. In A. G. Ward, and A. Courts (Eds.), The science and technology of gelatin (pp. 1–31). London: Academic Press.

Banerjee, S., and Bhattacharya, S. (2012). Food gels: gelling process and new applications. *Critical Reviews in Food Science and Nutrition, 52*(4), 334–46.

Barrera, A. M., Ramı´rez, J. A., Gonza´lez-Cabrialezs, J. J., and Va´zquez, M. (2002). Effect of pectins on the gelling properties of surimi from silver carp. *Food Hydrocolloids, 16*, 441–447

Baziwane, D., and He, Q. (2003). Gelatin: the paramount food additive. *Food Reviews International, 19*, 423-435.

Benjakul, S., Oungbho, K., Visessanguan, W., Thiansilakul, Y., and Roytrakul, S. (2009). Characteristics of gelatin from the skins of *bigeye snapper, Priacanthus tayenus* and *Priacanthus macracanthus*. *Food Chemistry, 116*, 445-451.

Burey P, Bhandari BR, Howes T, and Gidley M (2008) Hydrocolloid gel particles: formation, characterization and application. *Critical Review in Food Science and Nutrition, 48*, 361–377.

Butt, M. S., and Batool, R. (2010). Nutritional and Functional Properties of Some Promising Legumes Protein Isolates. *Pakistan Journal of Nutrition*, *9*(4), 373–379.

Calisir S., Ozcan M. and Hacıseferogullari H., Y. M. (2005). A study on some physico-chemical properties of Turkey okra (*Hibiscus esculenta* L .) seeds. *Journal of Food Engineering*, *68*, 73–78.

Camciuc, M., Deplagne, M., Vilarem, G., and Gaset, A. (1998). Okra-Abelmoschus esculentusL. (Moench.) a crop with economic potential for set aside acreage in France. Industrial Crops and Products, 7, 257-264

Campo, V. L., Kawano, D. F., Braz, D., and Carvalho, I. (2009). Carrageenans: Biological properties, chemical modifications and structural analysis – A review. *Carbohydrate Polymers*, *77*(2), 167–180.

Chanamai, R., and McClements, D. J. (2001). Depletion flocculation of beverage emulsions by gum arabic and modified starch. *Journal of Food Science, 66*,457-463.

Chang, K. C., Dhurandhar, N., You, X., and Miyamoto, A. (1994). Cultivar/location and processing methods affect yield and quality of sunflower pectin. *Journal of Food Science*, *59*, 602

Clark, A. H. (1992). *Gels and Gelling. In: Physical Chemistry of Foods*, Schwartzberg, H. G., and Hartel, R.W., Eds., Marcel Dekker, New York. pp. 263–283.

Cofrades, S., and Herrero, A. M. (2012). Konjac gel fat analogue for use in meat products: Comparison with pork fats. *Food hydrocolloids*, *26*(1), 63–72.

Costantino, A. J., and Romanchick-Cerpoviez, J. E. (2004). Physical and sensory measures indicate moderate fat replacement in frozen dairy dessert is feasible using okra gum as a milk-fat ingredient substitute. *Journal of American Dietetic Association*, *104*, 44.

Cui, S. W., Ikeda, S., and Eskin, M. N. A. (2007). *Seed Polysaccharide Gums. In:Functional Food Carbohydrates*. Biliaderis, C. G., and Izydorczyk, M., Eds., CRC Press, Boca Raton, FL, pp. 128–139.

Damodaran, S. (1997). *Protein-stabilized foams and emulsions. In: Food proteins and their applications*. New York, New York : Marcel Dekker, pp. 57–110.

Delgado-Pando, G., Cofrades, S., Rodríguez-Salas, L. and F. J. C. (2011). A healthier oil combination and konjac gel as functional ingredients in low-fat pork liver pâté. *Meat Science journal*, *88*(2), 241–248.

De Rosa, I. M., Kenny, J. M., Maniruzzaman, M., Monirruzaman, M., Monti, M., Puglia, D., Santulli, C., and Sarasini, F. (2011). Effect of chemical treatments on the mechanical and thermal behavior of okra *(Abelmoschuse sculentus*) fibres. *Composites Science and Technology, 71*, 246-254.

De Rosa, I. M., Kenny, J. M., Puglia, D., Santulli, C., and Sarasini, F. (2010). Morphological, thermal and mechanical characterization of okra (*Abelmoschus esculentus*) fibres as potential reinforcement in polymer composites. *Composites Science and Technology*, *70*, 116–122

Deters, A. M., Lengsfeld, C., and Hensel, A. (2005). Oligo- and polysaccharides exhibit a structure-dependent bioactivity on human keratinocytes in vitro. *Journal of Ethnopharmacology*, *102*(3), 391–399

Dickinson, E., Goller, M. I., and Wedlock, D. J. (1995). Osmotic pressure, creaming, and rheology of emulsions containing nonionic polysaccharide. *Journal of Colloid and Interface Science*, *172*,192-202

Di Lorenzo, C, (1988). Pectin delays gastric emptying and increase satiety in obes subjects, *Gastroenterology, 95*, 1211-1213.

Djabourov, M., Lechaire, J., and Gaill, F. (1993). Structure and rheology of gelatin and collagen gels. *Biorheology*, *30*, 191–205.

Doublier, J. L., and Cuvelier, G. (2006). *Gums and Hydrocolloids: Functional Aspects.In:Carbohydrates in Food*, Charlotte Eliason, A., Ed., Taylor and Francis Group, LLC, New York pp. 232–272.

Doymaz, İ. (2005). Drying characteristics and kinetics of okra. *Journal of Food Engineering*, *69*(3), 275–279.

Dubois, M., Gilles, K. A., Hamilton, J. K., Rebers, D. A., Smith, F. (1956). Colorimetric method for determination of sugars and related substances. *Analytical Chemistry*, *28*, 350–356

Dzung, N. T. (2012). Optimization the freeze drying process of Penaeus Monodon to determine the technological mode. International Journal of Chemical Engineering and Applications, 3 (3), 187-194

Eastoe, J. E., and Leach, A. A. (1977). *Chemical constitution of gelatin*. *In The science and technology of gelatin*, A. G. Ward, andA. Courts (Eds.), (pp. 73–107). New York: Academic Press.

Effiong, G. S., Ogban, P. I., Ibia, T. O., and Adam, A. A. (2009). Evaluation of nutrient-supplying potentials of fluted pumpkin (*Telfairia occidentalis, Hook* , F .) And Okra (*Abelmoschus esculentus*) (L .) Moench. *Academic Journal of Plant Sciences*, *2*(3), 209–214.

El-Mahdy A. R. and El-Sebaiy L. A. (1984). Preliminary studies on the mucilages Extracted from okra fruits, Taro Tubers, Jew's Mellow leaves and Fenugreek seeds. *Food Chemistry, 14*, 237-249

Emeje, M., Isimi, C., Byrn, S., and Fortunak, J. (2011). Extraction and physicochemical characterization of a new polysaccharide obtained from the fresh fruits of *Abelmoschus Esculentus*. *Iranian Journal of Pharmaceutical Research*, *10*(2), 237-246.

Ergel, J. and Bachinger, H. P. (2005). Structure, stability and folding of the collagen triple helix. In: Brinckmann, Notbohm, J. and Muller, P. K. H. (Eds.): *Collagen: primer in structure, processing and assembly*, New York, Springer, 23–24.

Evageliou, V., Ptitchkina, N. M., and Morris, E. R.(2005). Solution viscosity and structural modification of pumpkin biopectin. *Food Hydrocolloid*, *19*, 1032–1036.

FAOSTAT. (2012). Economic and social Department. The Statistics Division. Major Food and Agricultural Commodities and Producers. Retrieved from http://faostat.fao.org/site/339/default.aspx

Food Chemical Codex. (1996). *IV monographs*. Washington DC: National Academy Press. pp. 283

Fu, J. T. and Rao, M.A. 2001. Rheology and structure development during gelation of low-methoxyl pectin gel: the effect of sucrose. *Food Hydrocolloid, 15,* 93-100**.**

Funami, T., Hiroe, M., Noda, S., Asai, I., Ikeda, S., and Nishinari, K. (2007). Influence of molecular structure imaged with atomic force microscopy on the rheological behavior of carrageenan aqueous systems in the presence or absence of cations. *Food Hydrocolloids, 21*,617-629.

Funami, T., Kataoka, Y., Omoto, T., Goto, Y., Asai, I., and Nishinari, K. (2005). Effects of non-ionic polysaccharides on the gelatinization and retrogradation behavior of wheat starch. *Food Hydrocolloids, 19*, 1–13.

Funami, T., Noda, S., Nakauma, M., Ishihara, S., Takahashi, R., Al-Assaf, S., et al. (2009). Molecular structures of gellan gum imaged with atomic force microscopy

(AFM) in relation to the rheological behavior in aqueous systems in the presence of sodium chloride. *Food Hydrocolloids, 23,* 548-554.

Georgiadis, N., Ritzoulis, C., Sioura, G., Kornezou, P., Vasiliadou, C., and Tsioptsias, C. (2011). Contribution of okra extracts to the stability and rheology of oil-in-water emulsions. *Food hydrocolloids*, *25*(5), 991–999.

Giménez, B., Turnay, J., Lizarbe, M. A., Montero, P., and Gómez-Guillén, M. C. (2005). Use of lactic acid for extraction of fish skin gelatin. *Food Hydrocolloids, 19,* 941-950

GITCO (1999). Twenty-five Prospective Food Processing Projects. Gujarat Industrial and Technical Consultancy Organization Ltd., (GGITCO) House, Ahmadabad, *2*,52.

Gelatine Manufactures of Europe (GME). (2008). All about gelatin. Gelatine Manufactures of Europe, Europe. http://www.gelatine.org/en.html.

Gelatin Manufacture Institute of America (GMIA). (2012). Gelatin handbook. http: //www.gelatin-gmia.com/images/GMIA_Gelatin_Manual_2012. Accessed on 24 October 2012

Gomez-Guillén, C., Borderias, A. J., and Montero, P. (1997). Thermal gelation properties of two different composition sardine (Sardina pilchardus) muscles with addition of non-muscle and hydrocolloids. *Food Chemistry, 58,*81-87.

Gómez-Guillén, M. C., and Montero, P. (2001). Extraction of gelatin from megrim (*Lepidorhombus boscii*) skins with several organic acids. *Journal of Food Science, 66*(2), 213-216

Gudmundsson, M.. (2002). Rheological properties of fish gelatins. *Journal of Food Science, 67*, 2172–2176

Gunning, A. P., and Morris, V. J. (1990). Light scattering studies of tetramethyl ammonium gellan. *International Journal of Biological Macromolecules, 12*,338-341.

Gunning, A. P., Kirby, A. R., Ridout, M. J., Brownsey, G. J., and Morris, V. J. (1996). Investigation of gellan networks and gels by atomic force microscopy. *Macromolecules, 29,* 6791-6796.

Haddar, A., Bougatef, A. L. I., Balti, R., Souissi, N., Koched, W., and Nasri, M. (2011). Physicochemical and functional properties of gelatin from tuna (*Thunnus thynnus*) head bones. *Journal of Food and Nutrition Research*, *50*(3), 150–159.

Hao, S., Li, L., Yang, X., Cen, J., Shi, H., and Bo, Q. (2009). The characteristics of gelatin extracted from sturgeon (*Acipenser baeri*) skin using various pretreatments. *Food Chemistry, 115*, 124-128.

Harrington, J. C., and Morris, E. R. (2009). An unusual manifestation of phase separation in mixtures of disordered gelatin with konjac glucomannan. *Food Hydrocolloids*, *23*, 460–467.

Hashim D.M., Che Man Y.B., Norakasha R., Shuhaimi M., Salmah Y., Syahariza Z.A., (2010). Potential use of Fourier transform infrared spectroscopy for differentiation of bovine and porcine gelatins. *Food Chemistry*, *118*, 856–860.

Hassan, F. A., Ismail, A., Hamid, A. A., Azlan, A., and Al-sheraji, S. H. (2011). Characterisation of fibre-rich powder and antioxidant capacity of *Mangifera pajang* K. fruit peels. *Food Chemistry*, *126*(1), 283–288.

Hermansson, A. M., Ericsson, E., and Jordansson, E. (1991). Effects of potassium, sodium and calcium on the microstructure and rheological behaviour of kappa-carrageenan gels. *Carbohydrate Polymers*, *16*, 297–320.

Herranz, B., Tovar, C. A., Solo-de-Zaldívar, B., and Borderias, A. J. (2012). Effect of alkalis on konjac glucomannan gels for use as potential gelling agents in restructured seafood products. *Food Hydrocolloids*, *27*, 145-153.

Hidaka, S., and Liu, S. Y. (2002). Effects of gelatins on calcium phosphate precipitation: A possible application for distinguishing bovine bone gelatin from porcine skin gelatin. *Journal of Food Composition and Analysis*, *16*, 477–483.

Hilz, H., Bakx, E. J., Schols, H. A., and Voragen, A. G. J. (2005). Cell wall polysaccharides in black currants and bilberries—characterisation in berries, juice, and press cake. *Carbohydrate Polymer*, *59*, 477-488.

Hokputsa, S., Harding, S. E., Inngjerdingen, K., Jumel, K., Michaelsen, T. E., and Heinze, T. (2004). Bioactive polysaccharides from the stems of the Thai medicinal plant *Acanthus ebracteatus*: their chemical and physical features. *Carbohydrate Research*, *339*, 753-762.

Huang, L., Takahashi, R., Kobayashi, S., Kawase, T., and Nishinari, K. (2002). Gelation behaviour of native and acetylated konjac glucomannan. Biomacromolecules, 3, 1296-1303

Huang, X., Kakuda,Y., and Cui,W. (2001). Hydrocolloids in emulsions: particle size distribution and interfacial activity. *Food Hydrocolloid*, *15*, 533–542.

Hwang, J., Roshdy, T. H., Kontominas, M. and Kokini, J. L. (1992). Comparison of dialysis and metal precipitation effects on apple pectin. *Journal of Food Science*, *57*, 1180-1184

Iagher, F., Reicher, F. and Ganter, J. L. M. S. (2002). Structural and rheological properties of polysaccharides from mango (*Mangifera indica L.*) pulp. *International Journal of Biological Macromolecules*, *31*, 9–17.

Iqbal, S., Younas, U., Chan, K. W., and Sarfraz, R. A. (2012). Proximate Composition and Antioxidant Potential of Leaves from Three Varieties of Mulberry (*Morus* sp .): A Comparative Study. *International Journal of Molecular sciences*, *13* (6), 6651–6664.

Iqbal, S., and Bhanger, M. (2006). Effect of season and production location on antioxidant activity of *Moringa oleifera* leaves grown in Pakistan. *Journal of Food Composition and Analysis, 19*, 544–551

Irwandi, J., Faridayanti, S., Mohamed, E. S. M., Hamzah, M. S., Torla, H. H., and Che Man, Y. B. (2009). Extraction and characterisation of gelatin from different marine fish species in Malaysia. *International Food Research Journal, 16*, 381-389.

Ismail, M. N. S., Ramli, N., Hani, M. N. and Meon, Z. (2012). Extraction and characterization of pectin from dragon fruit (*Hylocereus polyrhizus*) using various extraction conditions. *Sains Malaysiana, 41*(1), 41- 45

Isong, E. U., and Idiong, U. I. (1997). Comparative studies on the nutritional and toxic composition of three varieties of *Lesianthera africana*. *Plant Foods for Human Nutrition, 51*, 79-84.

Jamilah, B., Tan, K. W., Umi Hartina, M. R., and Azizah, A. (2011). Gelatins from three cultured freshwater fish skins obtained by liming process. *Food Hydrocolloids, 25*(5), 1256–1260.

Jani, G. K., Shah, D. P., Prajapati, V. D., and Jain, V. C. (2009). Gums and mucilages : versatile excipients for pharmaceutical formulations. *Asian Journal of Pharmaceutical Sciences*, *4*(5), 308–322.

Jena, R., and Bhattacharya, S. (2003). Viscoelastic characterization of rice gel. *Journal of Texture Studies, 34*, 349–360.

Kalapathy, U., and Proctor, A. (2001). Effect of acid extraction and alcohol precipitation conditions on the yield and purity of soy hull pectin. *Food Chemistry, 73*, 393-396.

Kalentunc, G., Nussinovitch, A., and Peleg, M. (1990). Alginate texturization of highly acid fruit pulps and juices. *Journal of Food Science, 55*, 1759–1761.

Kaper, T., Talik, B., Ettema, T. J., Bos, H., van der Maarel, M. J. E. C., and Dijkhuizen, L. (2005). *Amylomaltase* of *Pyrobaculum aerophilum* IM2 produces thermoreversible starch gels. *Applied and Environmental Microbiology, 71*, 5098-5106.

Karakoltsidis P. A. and Constantinides S.M. (1975). Okra Seeds: A New Protein Source. *Journal of Agriculture and Food Chemistry*, *19*(47), 13–16.

Karim, A. A., and Bhat, R. (2009). Fish gelatin: properties, challenges, and prospects as an alternative to mammalian gelatins. *Food Hydrocolloids, 23*, 563-576

Karim, A. A., and Bhat, R. (2008). Gelatin alternatives for the food industry: recent developments, challenges and prospects. *Trends in Food Science and Technology*, *19*(12), 644–656.

Karim, A. A., Chang, Y. P., Norziah, M. H., Ariffin, F., Nadiha, M. Z., and Seow, C. C. (2005). Exothermic events on heating of semi-dilute konjac glucomannan-water systems. *Carbohydrate Polymers, 61*, 368-373.

Kaur, M. and N. Singh, 2007. Characterization of protein isolates from different Indian chickpea (*Cicer arietinum* L.) cultivars. *Food Chemistry, 102*, 366-374.

Khanna, S., and Tester, R. F. (2006). Influence of purified konjac glucomannan on the gelatinisation and retrogradation properties of maize and potato starches. *Food Hydrocolloids, 20*, 567–576.

Kinsella, J. E. (1976). Functional properties of proteins in foods: A survey. CRC .*Critical Review Food Science and Nutrition, 7*, 219 -280.

Kontogiorgos, V., Margelou, I., Georgiadis, N., and Ritzoulis, C. (2012). Rheological characterization of okra pectins. *Food hydrocolloids*, *29*(2), 356–362.

Koubala, B. B., Mbome, L. I., Kansci, G., Tchouanguep Mbiapo, F., Crepeau, M. J., Thibault, J. F., and Ralet, M.C. (2008). Physicochemical properties of pectins from ambarella peels (*Spondias cytherea*) obtained using different extraction conditions. *Food Chemistry*, *106*(3), 1202–1207.

Kulkarni, S. G., and Vijayanand, P. (2010). Effect of extraction conditions on the quality characteristics of pectin from passion fruit peel (*Passiflora edulis f. flavicarpa L.*). *LWT - Food Science and Technology, 43*, 1026-1031.

Kumar, A., and Chauhan, G.S. (2010). Extraction and characterization of pectin from apple pomace and its evaluation as *lipase* (*steapsin*) inhibitor. *Carbohydrate Polymers*, *82*, 454–459.

Kuntz, I. D. (1971). Hydration of macromolecules III. Hydration of polypeptides. *Journal of the American Chemical Society, 93*, 514-515.

Larrauri, J. A., Rupérez, P., Borroto, B., and Saura-Calixto, F. (1996). Mango peels as a new tropical fiber: Preparation and characterization. *LWT-Food Science and Technology*, *29*, 729–733.

Lawal, O. S. (2004). Functionality of African locust bean (*Parkia biglobossa*) protein isolate: effects of pH, ionic strength and various protein concentrations. *Food Chemistry*, *86*, 345–355.

Le Cerf, D., Irinei, F., and Muller, G. (1990). Solution properties of gum exudates from *Sterculia urens* (Karaya gum).*Carbohydrate Polymer,13*, 375–386

Lee, C. M., Wu, M. M., and Okada, M. (1992). *Ingredient and formulation technology for surimi-based products*. In T. C. Lanier, and C. M. Lee (Eds.), Surimi technology (pp. 273-302). New York: Marcel Dekker

Lefebvre, J., and Doublier, J. L. (2005). Rheological behaviour of polysaccharides aqueous systems. In S. Dumitriu (Ed.), Polysaccharides structural diversity and functional versatility New York: Marcel Dekker.pp. 357-394.

Lengsfeld, C., Titgemeyer, F., Faller, G., and Hensel, A. (2004). Glycosylated compounds from okra inhibit adhesion of *Helicobacter pylori* to human gastric mucosa. *Journal of Agricultural and Food Chemistry*, *52*(6), 1495–1503.

Lin, M. J. Y., Humbert, E. S., and Sosulski, F. W. (1974). Certain functional properties of sunflower meal products. *Journal of Food Science, 39*, 368–370.

Lockeett, C. T., Calvert, C. C. and Grivetti, L. E. (2000). Energy and micronutrient composition of dietary and medicinal wild plants consumed during drought. Study of rural Fulani, Northeastern Nigeria. *International Journal Food Science Nutrition*, (*51),* 195- 208.

Madhav, A., and Pushpalatha, P. B. (2002). Characterization of pectin extracted from different fruit wastes. *Journal of Tropical Agriculture, 40*, 53-55.

Malaysian Standard. (2010). Malaysian Standard - 1230:1991-Fresh Lady's Finger (Okra) -Specification (1st revision)

Maxwell, E. G., Belshaw, N. J., Waldron, K. W., and Morris, V. J. (2012). Pectin e An emerging new bioactive food polysaccharide. *Trends in Food Science and Technology*, *24*(2), 64–73.

McClements D.J. (1999). *Food emulsions: Principle, Practices and Techniques*. Boca Raton in CRC Press.

Mesbahi, G., Jamalian, J., and Farahnaky, A. (2005). A comparative study on functional properties of beet and citrus pectins in food systems. *Food Hydrocolloids, 19*, 731-738.

Michel, F., Thibault, J.-F., Mercier, C., Heitz, F., and Pouillaude, F. (1985). Extraction and characterization of pectins from sugar beet. *Journal of Food Science, 50*, 1499-1500

Min, B., Lim, J., Ko, S., Lee, K. G., Lee, S. H., and Lee, S. (2011). Environmentally friendly preparation of pectins from agricultural byproducts and their structural/rheo- logical characterization. *Bioresource Technology*, *102*, 3855-3860.

Mishra, S., Mann, B. and Joshi, V. K. (2001). Functional, improvements of whey protein concentrate on interaction with pectin. *Food Hydrocolloids, 14*, 227-335

Miyamoto, A., and Chang, K. C. (1992). Extraction and physicochemical characterization of pectin from sunflower head residues. *Journal of Food Science, 57*(6), 1439–1443

Mohd Ismail. N. S., Ramli N., Hani M. N. and Meon Z.,(2012). Extraction and characterization of pectin from dragon fruit (*Hylocereus polyrhizus*) using various extraction conditions. *Sains Malaysiana, 41*(1): 41–45

Monpien, W. (2005). Master Thesis, Department of Food Science and Technology, Kasetsart University, Thailand., 142 pp

Montero, P., and Gomez-Guillen, M. C. (2000). Extracting conditions for megrim *(Lepidorhombus boscii*) skin collagen affect functional properties of the resulting gelatin. *Journal of Food Science, 65*, 434–438.

Morris, E. R, Powell, D. A., Gidley, M. J. and Rees, D. A. (1982). Conformations and interactions of pectins *I. Polymorphism* between gel and solid states of calcium polygalacturonates. *Journal of Molecular Biology, 155*, 507-516.

Morris, V. J. (1998). Gelation of polysaccharides. In: Hill SE, Ledward DE, Mitchell JR (eds) Functional properties of food macro-molecules. Aspen Publ, Gaithersburg, pp. 143–226.

Morris, V. J., Kirby, A. R., and Gunning, A. P. (1999). A fibrous model for gellan gels from atomic force microscopy studies. *Progress in Colloid and Polymer Science, 114*, 102-108.

Morrison, N. A., Clark, R. C., Chen, Y. L., Talashek, T., and Sworn, G.(1999). *Gelatin alternatives for the food industry*. In K. Nishinari,F. Kremer, and G. Lagaly (Eds.), Physical chemistry and industrial application of gellan gum, pp. 127-13.

Morton, J. F. (1990). Mucilaginous Plants and their uses in medicine. *Journal of Ethnopharmacology, 29*, 245–266.

Mubarak, A. E., (2005). Nutritional composition and anti-nutritional factors of mung bean seeds (*Phaseolus aureus*) as affected by some home traditional processes. *Food Chemistry, 89*, 489-495

Muyonga, J. H., Cole, C. G. B., and Duodu, K. G. (2004). Extraction and physico-chemical characterisation of Nile perch (*Lates niloticus*) skin and bone gelatin. *Food Hydrocolloids, 18*, 581-592

Nazaruddin, R., Noor Baiti, A. A., Foo, S. C., Tan, Y. N. and Ayob, M. K. (2013). Comparative chemical characteristics of hydrochloric acid- and ammonium

oxalate-extracted pectin from roselle (*Hibiscus sabdariffa* L .) calyces. *International Food Research journal*, *20*(1), 281–284.

Naji, S., Razavi, S.M.A., Karazhiyan, H.(2012). Effectof thermal treatments on functional properties of cress seed (*Lepidium sativum*) and xanthan gums: A comparative study. *Food Hydrocolloid*, *28*, 75–78

Ndjouenkeu, R., Goycoolea F. M., M. E. R. and A. J. O. (1996). Rheology of okra (*Hibiscus esculentus* L.) and dika nut (Irvingia gabonensis) polysaccharides. *Carbohydrate Polymers*, *8617*(96), 263–269.

Nishinari, K., and Zhang, H. (2004). Recent advances in the understanding of heat set gelling polysaccharides. *Trends in Food Science and Technology, 15,* 305-312

Nik Aisyah, N. M., Nurul, H., Azhar, M. E. and Fazilah, A. (2014). Poultry as an Alternative Source of Gelatin. *Health and the Environment Journal*, *5*(1), 37–49.

Nnamani, C. V., Oselebe, H. O. and Agbatutu, A. (2009). Assessment of nutritional values of three underutilized indigenous leafy vegetables of Ebonyi State , Nigeria. *African Journal of Biotechnology*, 8(*9*), 2321–2324.

Noda, S., Funami, T., Nakauma, M., Asai, I., Takahashi, R., Al-Assaf, S. (2008). Molecular structures of gellan gum imaged with atomic force microscopy in relation to the rheological behavior in aqueous systems. *Food Hydrocolloids, 22*, 1148-1159

Norazelina S. M. I, Nazaruddin R., N. M. H. and Z. M. (2012). Extraction and Characterization of Pectin from Dragon Fruit (*Hylocereus polyrhizus*) using Various Extraction Conditions. *Sains Malaysiana*, *41*(1), 41–45.

Norziah, M. H., and Ching, C. Y. (2000). Nutritional composition of edible seaweed *Gracilaria changgi*. *Food Chemistry*, *68*, 69–76.

Norziah, M. H., Al-Hassan, A., Khairulnizam, A. B., Mordi, M. N., and Norita, M. (2009). Characterization of fish gelatin from surimi processing wastes : Thermal analysis and effect of *transglutaminase* on gel properties. *Food hydrocolloids*, *23*(6), 1610–1616

Nzikou, J. M., Mvoula-Tsieri, M. Matouba, E., Ouamba, J.M. Kapseu, C., Parmentier, M. D. S. (2006). A study on gumbo seed grown in Congo Brazzaville for its food and industrial applications. *African journal of Biotechnology*, *5*(December), 2469–2475.

Oakenfull, D. (1987). Gelling agents. *Critical Review in Food Science and Nutrition, 26,* 1–25

Osagie, A.U., and Eka, O.U. (1996). Nutritional quality of plant foods. Ambik, Press pp: 120-133

Oshodi, A.A., Olaofe, O. and Hall, G.M. (1993). Amino acid, fatty acids and mineral composition of pigeon pea (*cajanus cajan*). *International Journal of Food Science and Nutrition, 43*,187-191

Owens, H. S., McCready, R. M., Shepard, A. D., Schultz, T. H., Pippen, E. L., Swenson, H. A., Miers, J. C., Erlandsen, R. F. and Maclay, W. D. (1952). *Methods used at western regional research laboratory for extraction of pectic materials.* pp. 9.Washington DC: USDA Bureau of Agricultural and Industrial Chemistry

Oyelade, O. J., Ade-Omowaye, B. I. O., and Adeomi, V. F. (2003). Influence of variety on protein, fat contents and some physical charasteristics of okra seeds. *Journal of Food Engineering*, *57*, 111–114.

Park, J. W. (2000). Surimi and surimi seafood. New York: Marcel Dekker, Inc

Parker, A., Gunning, P. A., Ng, K., and Robins, M. M. (1995). How does xanthan stabilise salad dressing? *Food Hydrocolloids*, *9*,333-342.

Pavia, D. L., Lampman, G. M., and Kriz G. S. (2001). *Introduction to spectroscopy*. (3rd ed.). USA: *Thomson Learning*. pp. 26

Pearce, K. N., and Kinsella, J. E. (1978). Emulsifying properties of proteins: evaluation of a turbidimetric technique. Journal of Agricultural and Food Chemistry, 26, 716–723

Peleg, M. (2006). On fundamental issues in texture evaluation and texturization—A view. *Food Hydrocolloids*, *20*(4), 405–414.

Peris-Tortajada, M. (2004). Carbohydrates and starch. In Leo M. L. N., *Handbook of food analysis.Physical characterization and nutrient analysis*(pp392). USA : Marcel Dekker, Inc.

Prosky, L., Asp, N.G., Schweizer, T. F., DeVries, J. W. and Furda, I. (1988). Determination of isoluble, soluble and total dietary fiber in foods and food products: Collaboration study. *Journal Association of Official Analytical Chemists*, 71 (5), 1017-1023.

Ramirez, J. A., Uresti, R. M., Velazquez, G., and Vázquez, M. (2011). Food hydrocolloids as additives to improve the mechanical and functional properties of fish products: A review. *Food Hydrocolloids*, *25*(8), 1842–1852.

Ramli, N. and A. (2011). Effect of ammonium oxalate and acetic acid at several extraction time and pH on some physicochemical properties of pectin from cocoa husks (*Theobroma cacao*). *African Journal of Food Science*, *5*(15), 790–798.

Ramula, P. and Rao, P.U. (2003). Dietary fibre content of fruits and leafy vegetables. *Nutraceutical International Corporation News, 24*, 1-6.

Ranganna, S. (1986). *Handbook of analysis and quality control for fruit and vegetable products. Vegetable Products* (2nd ed.). New Delhi: Tata McGraw Hill Publishing Co. Ltd. pp. 1112.

Rao, M. A. (2006). Pectins: Structure, Functionality and Uses, 353–411.

Ratcliffe, I., Williams, P. A., Viebke, C., and Meadows, J. (2005). Physicochemical characterisation of konjac glucomannan. *Biomacromolecules, 6*, 1977-1986

Rees, D. A., Morris, E. R., Thom, D., and Madden, J. K., (1982).Shape and interactions of carbohydrate chain, in The Polysaccharides, Aspinall, G. V., Ed., Academic Press, New York, 196

Riaz, M. N. and Chaudry, M. M. (2004). Halal Food Production. CRC Press, 267 pp.

Richardson, P. H., Willmer, J., and Foster, T. J. (1998). Dilute solution properties of guar and locust bean gum in sucrose solutions. *Food Hydrocolloids*, *12*, 339–348

Rodríguez-Ambriz, S. L., Islas-Hernández, J. J., Agama-Acevedo, E., and Tovar, J. (2008). Characterization of a fibre-rich powder prepared by liquefaction of unripe banana flour. *Food Chemistry, 107*, 1515–1521

Rolin, C. (1993*). Pectin. In Industrial gum*s, eds. R.L. Whistler and J.N. BeMiller. 3rd edn. (New York: Academic Press)

Romanchik-Cerpovicz, J. E., Tilmon, R. W., Baldree, K. A. (2002). Moisture retention and consumer acceptability of chocolate bar cookies prepared with okra gum as a fat ingredient substitute. *Journal of American Dietetic Association, 102*(9): 1301-1303.

Romanchik-Cerpovicz, J. E., Costantino, A. C., and Laura, H. G. (2006). Sensory evaluation ratings and melting characteristics show that okra gum is an acceptable milk-fat ingredient substitute in chocolate frozen dairy dessert. *Journal of American Dietetic Association, 106*, 594–597

Roopa, B. S., and Bhattacharya, S. (2008). Alginate gels: I. Characterization of textural attributes. *Journal of Food Engineering, 85,* 123–131

Rubatzky VE, Yamaguchi M (1997): World vegetables: principles, production, and nutritive values. Chapman and Hall, New York, USA

Sa´nchez, C. C., and Patino, J. M. R. (2005). Interfacial, foaming and emulsifying characteristics of sodium caseinate as influenced by protein concentration in solution. *Food Hydrocolloids, 19*, 407–416

Sathe, S. K., Deshpande, S. S., and Salunkhe, D. K. (1982). Functional properties of winged bean (*Psophocarpus tetragonolobus* L. DC) proteins. *Journal of Food Science, 47*, 503-509.

Savello, P. A., Hill, J. M., Admin-, E., and Rico, P. (1980). Nutritional composition of okra seed meal. *Journal of Agriculture and Food Chemistry*, *28*, 1163–1166.

Schorsch, C., Garnier, C., and Doublier, J. L. (1997). Viscoelastic properties of xanthan/galactomannan mixtures: Comparison of guar gum with locust bean gum. *Carbohydrate Polymer*, *34*, 165–175.

Schrieber, R., and Gareis, H. (2007). *Manufacture of gelatin: theory and practice. In Gelatin handbook, theory and industrial practice* . Weinheim: Wiley-VCH, pp. 42-88.

Seggiani, M., Puccini, M., Pierini, M., Giovando, S., and Forneris, C. (2009). Effect of different extraction and precipitation methods on yield and quality of pectin. *International Journal of Food Science and Technology*, *44*, 574-580.

Sengkhamparn, N., Sagis, L. M. C., Vries, R. De, Schols, H. A., Sajjaanantakul, T., and Voragen, A. G. J. (2010). Physicochemical properties of pectins from okra (Abelmoschus esculentus (L.) Moench). *Food hydrocolloids*, *24*(1), 35–41.

Sengkhamparn, N., Verhoef, R., Schols, H. A., Sajjaanantakul, T., and Voragen, A. G. J. (2009). Characterisation of cell wall polysaccharides from okra (*Abelmoschus esculentus* (L.) Moench). *Carbohydrate Research*, *344*(14), 1824–1832.

Seymour, G. B., and Knox, J.P. (2002). Pectins and their manipulation. Boca Raton, FL: CRC Press LLC

Shahidi, F., Xiao-Qing, H., and Synowiecki, J. (1995). Production and characteristics of protein hydrolysates from capelin (*Mallotus villosus*). *Food Chemistry*, *53*, 285–293.

Sharma N., Kulkarni G.T., and Sharma A. (2013). Development of *Abelmoschus esculentus* (Okra) -based mucoadhesive gel for nasal delivery of rizatriptan. *Tropical Journal of Pharmaceutical Research*, *12*(April), 149–153.

Sharma, B. R., Naresh, L., Dhuldhoya, N. C., Merchant, S. U., and Merchant, U. C. (2006). An Overview on Pectins. *Times Food Processing Journal*, *51*,(44).

Sikorski, Z. E. (2001). *Functional properties of proteins in food systems*. *In: Chemical and functional properties of food proteins*. Sikorski, Z. E. (Eds.). Lancaster, Pennsylvania : Technomic Publishing, pp. 113–136.

Singthong, J., Chui, S. W., Ningsanond, S., and Goff, H. D. (2004). Structural characterization, degree of esterification and some gelling properties of Krueo Ma Noy (*Cissampelos pareira*) pectin. *Carbohydrate polymers*, *58*, 391- 400.

Srivastava, P., and Malviya, R. (2011). Sources of pectin, extraction and its applications in pharmaceutical industry − An overview. *Indian Journal of Natural products and Resources*, *2*(March), 10–18

Srivastava, S., Kapoor, R., Thathola, A., and Srivastava, R. P. (2006). Nutritional quality of leaves of some genotypes of mulberry (*Morus alba*). *International journal of Food Sciences and nutrition*, *57*(September).

Stanley, N. F. (2006). *Agar In:Food Polysaccharides and their Application.* Stephen. A. M., Philips, G. O., and Williams, P. A., Eds., CRC Press, Boca Raton, FL. pp. 186–204.

Sutherland, I. W. (2007). *Biotechnology of Microbial Polysaccharides in Food, In: Food Biotechnology*. 2nd Ed. Shetty, K., Paliyath, G., Pometto, A., and Levin, E., Eds. CRC Press, Boca Raton, FL pp. 193–220

Sych, J., Lacroix, C., Adambounou, L. T., and Castaigne, F. (1990). Cryoprotective effects of some materials on cod-surimi proteins during frozen storage. *Journal of Food Science*, *55*, 1222-1227

Tabarestani, H. S., Maghsoudlou, Y., Motamedzadegan, A, and Mahoonak, A R. S. (2010). Optimization of physico-chemical properties of gelatin extracted from fish skin of rainbow trout (*Onchorhynchus mykiss*). *Bioresource technology*, *101*(15), 6207–6214.

Takigami, S. (2000). *Konjac mannan.In:Handbook of Hydrocolloids*, Ch. 25.Phillips, G. O., and Williams, P. A. Eds., Woodhead Publishing Limited and CRC Press LLC, Cambridge, UK

Tavares, C., Monteiro, S. R., Moreno, N., and Lopes de Silva, J. A. (2005). Does the branching degree of galactomannans influence their effect on whey protein gelation. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, 213-219.

Tee, E. S., Mohd Ismail, N., Mohd Nasir, A., and Khatijah, I. (1988). *Nutrient composition of Malaysian foods.* Kuala Lumpur: ASEAN Sub-Committee on Protein, Food Habits Research and Development.

Thakur, B. R., Singh, R. K., Handa, A. K., and Rao M. A. (1997). Chemistry and uses of pectin - A review. *Critical Reviews in Food Science and Nutrition*, *37*(1), 47-73.

Thakur, B. R., Singh, R. K., Handa, A. K., and Rao, M. A. (2009). Critical Reviews in Food Science and Nutrition Chemistry and uses of pectin — A review Chemistry and Uses of Pectin — A Review. *Critical reviews in food science and nutrition*, *37(1)*, 47–73.

Thiansilakul, Y., Benjakul, S., and Shahidi, F. (2007). Compositions, functional properties and antioxidative activity of protein hydrolysates prepared from round scad (*Decapterus maruadsi*). *Food Chemistry*, *103*(4), 1385–1394.

Tian, B. S., Dong, C. M., Luo, D. F., and Yao, S. N. (1999). Preparation of konjac glucomannan esters of long fatty acid and studies on the emulsifying properties. *Acta Polymerica Sinica*, *3*, 326–331

Tobin, J. T., Fitzsimons, S. M., Chaurin, V., Kelly, A. L., and Fenelon, M. A. (2012). Thermodynamic incompatibility between denatured whey protein and konjac glucomannan. *Food Hydrocolloids*, *27*, 201-207

Tomoda, M., Shimada, K., Saito, Y. and Sugi, M. (1980). Plant mucilages. XXVI. Isolation and structural features of a mucilage, "okra mucilage F", from the immature fruits of *Abelmoschus esculentus. Chemical and Pharmaceutical Buletin*, *28*, 2933-2940.

Townsend, A. and Nakai, S. (1983). Relationships between hydrophobicity and foaming characteristics of food proteins. *Journal of Food Science*, *48*, 588–594.

Turquois, T., Rinaudo, M., Taravel, F. R., and Heyraud, A. (1999). Extraction of highly gelling pectic substances from sugar beet pulp and potato pulp: Influence of extrinsic parameters on their gelling properties. *Food Hydrocolloids*, *13*(3), 255–262

Ubando, J., Navarro, A., and Valdivia, M. A. (2005). Mexican lime peel: Comparative study on contents of dietary fiber and associated antioxidant activity. Food Chemistry, 89, 57–61

Udosen, E.O., Udok, U.E. and Unuigue, O.S. (1998). The comparison of the nutrient composition of *Lasianthera africana* and *Heinsia crinata*. *Journal of Food Biocemistry*, *23*, 571-576

Ueng, Y. E., and Chu, Y. J. (1996). Effect of dietary fibers on cold resistance of surimi. *Food Science (Taiwan)*, *23*, 266-275

Vierhuis, E., Schols, H. A., Beldman, G., Voragen, A. G. J. (2000). Isolation and characterisation of cell wall material from olive fruit (*Olea europaea cv koroneiki*) at different ripening stages. *Carbohydrate Polymers*, *43*, 11–21.

Vriesmann, L. C., and Petkowicz, C. L. O. (2013). Food Hydrocolloids highly acetylated pectin from cacao pod husks (*Theobroma cacao* L .) forms gel. *Food hydrocolloids*, *33*(1), 58–65.

Wang, C. C., Chang, S. C., and Chen, B. H. (2009). Chromatographic determination of polysaccharides in *Lycium barbarum* Linnaeus. *Food Chemistry*, *116*, 595-603.

Weiping, W., and Branwell, A. (2000). *Tragacanth and Karaya.In:Handbook of Hydrocolloids*,. Philips, G. O. and Williams, P. A., Eds., Woodhead Publishing Limited, New York. pp. 231–245

Williams, P. A., and Phillips, G. O. (2000). *Gum Arabic.In: Handbook of Hydrocolloids*, Philips, G. O. and Williams, P. A., Eds., Woodhead . Publishing Limited, New York, pp. 155–168

Woofle, M. L., Cahplin, M. F., and Ochere, G. (1977). Studies on the mucilages extracted from okra fruits (*Hibiscus esculentus* L.) and baobab leaves (*Adansonia digitata* L.). *Journal of the Science of Food and Agriculture, 28*, 519-529.

Wu, C.Y., and Shen, D.Y. (2001*). Konjac-glucomannan capsule for chronic stomach disease.* Faming Zhuanli Shenqing Gongkai Shuomingshu. CN1280829A, 24 Jan 2001, 5pp (Chinese) (People's Republic of China).

Yamazaki, E., Kurita, O., and Matsumura, Y. (2008). Hydrocolloid from leaves of Corchorus olitorius and its synergistic effect on κ-carrageenan gel strength. *Food Hydrocolloids*, *22*(5), 819–825.

Yang, B., Wang, J., Zhao, M., Liu, Y., Wang, W., and Jiang, Y. (2006). Identification of polysaccharides from pericarp tissues of litchi (*Litchi chinensis* Sonn.) fruit in relation to their antioxidant activities. *Carbohydrate Research, 341*, 634-638.

Yang, L., Yang, X.M., Petcavich, R.J., and Mao, L.J. (2001). Coating materials for preserving fresh produce. *United States Patent, 6,* 203,833.

Yaseen, E. I., Herald, T. J., Aramouni, F. M., and Alavi, S. (2005). Rheological properties of selected gum solutions. *Food Research International, 38,* 111– 119

Yujaroen P, Supjaroenkul U, Rungrodnimitchai S (2008). Extraction of pectin from sugar palm meat. *Thammasat International Journal of Science and Technology, 13,* 44 - 47.

Zayas, J. F. (1997). *Solubility of proteins. In: Functionality of proteins in food*. Berlin : Springer- Harwood Academic Publishers, pp. 6 – 22.

Zhang, H., Yoshimura, M., Nishinari, K., Williams, M. A. K., Foster, T. J., and Norton, I. T. (2001). Gelation behaviour of konjac glucomannan with different molecular weights. *Biopolymers, 59*(1), 38-50.

Zhang, Y.Q., Xie, B. J., and Gan, X. (2005). Advance in the applications of konjac glucomannan and its derivatives. *Carbohydrate Polymers, 60*, 27–31.

Zhou, P., and Regenstein, J. M. (2005). Effects of alkaline and acid pretreatments on *alaska pollock* skin gelatin extraction. *Journal of Food Science, 70*, 392– 396.

APPENDICES

Appendix 1. Foaming ability (FA) and stability (FS) of CP, HB, CH and DA fractions of okra leaves, pulp and seeds at different concentration

Sample	Fractions	Concentration (%)	FA %	FS %	
				30 min	60 min
Leaves	HB	0.5	34.33 ± 4.04	4.67± 0.71	nd
		1	56.78 ± 2.79	10.55 ± 0.95	5.93 ± 0.90
		2	51.67 ± 2.89	11.50 ± 2.12	5.67 ± 1.15
		3	43.33 ± 2.89	5.50± 0.71	5.33 ± 0.58
	CH	0.5	nd	nd	nd
		1	nd	nd	nd
		2	8.30 ± 0.81	3.11 ± 0.02	3.11 ± 0.02
		3	5.33 ± 0.32	4.85 ± 0.35	2.09 ± 0.12
	DA	0.5	63.29 ± 1.91	61.90 ± 4.13	61.90 ± 4.13
		1	48.33 ± 2.89	45.00 ± 5.00	43.33 ± 2.89
		2	41.05 ± 1.49	39.47 ± 3.72	39.47 ± 3.72
		3	48.67 ± 3.21	48.33 ± 2.89	48.00 ± 3.46
Pulp	HB	0.5	nd	nd	nd
		1	nd	nd	nd
		2	4.92 ± 0.14	4.50 ± 0.71	nd
		3	7.52 ± 0.78	4.54 ± 0.65	1.70 ± 0.56
	CH	0.5	nd	nd	nd
		1	nd	nd	nd
		2	6.63 ± 0.72	6.52 ± 1.09	5.84 ± 1.13
		3	6.20 ± 1.33	5.69 ± 0.61	1.55 ± 0.70
	DA	0.5	nd	nd	nd
		1	6.32 ± 1.49	nd	nd
		2	10.26 ± 0.37	1.70 ± 0.61	nd
		3	16.23 ± 0.62	nd	nd

Appendix 2. Foaming stability (FS) of CP, HB, CH and DA fractions of okra leaves, pulp and seeds at different concentration

Sample	Fractions	Concentration (%)	FA %	FS %	
				30 min	60 min
Seeds	HB	0.5	nd	nd	nd
		1	5.50 ± 0.71	1.25 ± 0.35	nd
		2	14.00 ± 1.41	6.00 ± 1.41	2.50 ± 0.70
		3	11.29 ± 1.01	4.40 ± 0.57	2.94 ± 0.08
	CH	0.5	nd	nd	nd
		1	nd	nd	nd
		2	4.46 ± 0.47	3.08 ± 0.95	nd
		3	5.13 ± 0.19	2.02 ± 0.97	1.02 ± 0.03
	DA	0.5	14.50 ± 0.71	4.00 ± 1.41	4.00 ± 1.41
		1	4.37 ± 0.75	3.89 ± 1.43	3.17 ± 2.45
		2	13.43 ± 0.61	8.89 ± 3.87	7.25 ± 2.02
		3	15.94 ± 0.79	14.02 ± 3.51	5.87 ± 4.06
Pectin		0.5	33.16 ± 2.23	28.95 ± 3.72	26.84 ± 0.74
		1	6.73 ± 0.58	6.28 ± 1.43	4.71 ± 0.78
		2	nd	nd	nd
		3	nd	nd	nd

Values are given as mean ± standard deviation from triplicate determinations.
nd: not determined; HB : hot buffer; CH: chelating agent, DA: Diluted alkali

LIST OF PUBLICATIONS

Publication in Journal

Abd Rahman, N. F..,Shamsudin, R., Ismail, A., & Karim Shah, N. N. A. (2016). Effects of post-drying methods on pomelo fruit peels. Food Science and Biotechnology, 25(S1), 85–90. doi:10.1007/s10068-016-0102-y

Publication in International Proceeding

Nur Farhana A. R., Sadeq H. A.S., Amin I. and Shuhaimi M. (2014).Okra (*Abelmoschus esculentus* L. Moench) pectin: Extraction yield and chemical composition. Malaysia International Halal Research and Education Conference (MIHREC 2014). Mariott Putrajaya Hotel, Putrajaya, Wilayah Persekutuan Putrajaya, Malaysia, 2nd - 4th Disember 2014