



Emulsifying ability of exudate gums obtained from three plant species in Ghana

Owusu John ¹, Oldham J. H. ², Oduro I², Ellis W. O. ², Owusu-Boateng G. ³

¹*Koforidua Technical University, , Koforidua, Ghana, Faculty of Applied Science and Technology*

²*Kwame Nkrumah University of Science and Technology, Kumasi, Ghana, Department of Biochemistry,*

³*Kwame Nkrumah University of Science and Technology, Kumasi, Ghana, Department of Fisheries*

Abstract

Food emulsions are thermodynamically unstable mixtures which can be stabilized with the application of an emulsifier. In Ghana emulsifiers are imported, and this increases the final cost of food emulsions. In this study, gums obtained from three tree plant species in Ghana, i.e. *Albizia zygia* (Albizia), *Khaya senegalensis* (Khaya), and *Anacardium occidentale* (Cashew), were used to stabilize oil-in-water emulsion, and the stability of the emulsions were measured after centrifugation at 1300 x g for 5 min, and upon pH adjustment (from 2 to 3.5). Quantity of gum (mass), solubility of gum in the continuous phase, viscosity, oil volume fraction, and pH were investigated to determine how they affect emulsion stability. The results indicated with the exception of viscosity, emulsion stability is influenced by all the other factors studied. In addition there was no significant difference ($P < 0.05$) between the emulsion stabilities of food emulsions stabilized by gums of Cashew (0.77-0.86) and Acacia (0.78-0.87). The Pearson's co-efficient of correlation indicated that the emulsion stability values of the emulsions positively correlated with the solubility of the gums ($R^2 = 0.983$ at $P < 0.05$, and 0.997 at $P < 0.01$). Although there were no significant differences in the emulsion stability values of emulsions stabilized with Albizia and Khaya gums, both recorded significantly lower ($P < 0.05$) emulsion stability values (0.76-0.85 and 0.75-0.81 respectively) than the Acacia gum (control). The Cashew gum has the potential to be utilized as an emulsifier in the food industry.

Keywords: Emulsion, Emulsifier, Acacia gum, Oil-in-water Emulsion, Emulsion stability

1. Introduction

Food emulsions are dispersions of one liquid in another (McClements, 2016). Many foods such as milk, yoghurt, and beverages occur in the form of oil-in-water (O/W) emulsions, where small oil droplets are dispersed in water (Grigoriev and Miller, 2009). Generally emulsions are thermodynamically unstable (Technical Brief, 2011). The instability of emulsions is caused by factors such as gravitational separation, flocculation, coalescence, and Ostwald ripening (McClements, 2016). In unstable emulsions sedimentation occurs, and this reduces the consumer appeal of the product. This instability could reduce the shelf life of food emulsions. Conversely, stabilizing food emulsions can help increase their shelf life (Buffo et al., 2001). Therefore many methods have been designed to enhance the stability of food emulsions, but the common among these is the application of emulsifiers such as gums (Stauffer,

1999). The emulsifier is a surface-active substance, and has the ability to adsorb at the oil-water interface to aid in droplet formation and stabilization through the generation of repulsive forces (McClements, 2016). In order to assess the effectiveness of an emulsifier, the emulsion is subjected to disturbances such as heating, addition of electrolyte, and centrifugation (McClements, 2016). The use of gum emulsifiers is influenced by factors such as solubility of gum, viscosity of gum solution, surface tension and oil-volume fraction of emulsion, and protein content of gum (Imeson, 1992; Damodoran, 1996).

Application of gums in the food industry is influenced by their functional properties. They may be used as binding agents, bulking agents, foam stabilizers, protective colloids, syneresis inhibitors, clarifying agents, emulsifiers, etc (Damodoran, 1996). Studies on emulsifying functionality of gums have been reported and most of them have made use of

Acacia gum (Sabah El-Kheir et al., 2008; Samanta et al., 2010), xanthan gum (Krstonošić et al., 2015) gum tragacanth and gum karaya (Samanta et al., 2010). The price of Acacia gum is \$1,500 per ton, gum karaya is \$2,250 – \$6,000, and gum tragacanth is \$3,000 - \$4,000 (Nussinovitch, 2010). Due to the expensive nature of these gums and their irregular supply pattern, many authors have explored the possibility of using alternatives such as starch, soy protein isolate (Achouri et al., 2012), flaxseed protein concentrate, and soybean protein concentrate together with Acacia gum (Wang et al., 2011), to stabilize oil-in-water (O/W) emulsions.

In Ghana, the current use of Albizia and Khaya trees are mainly for timber production, Cashew is grown widely and is mainly for its nuts. The gums produced by these tree species have not been exploited and utilized probably due to lack of data on their utilization. It is against this background that this research was done to determine the factors which influence the application of gums in oil-in-water emulsions and to assess the stability of emulsions stabilized by gums obtained from three tree species in Ghana, in order to determine their suitability in the utilization in the food industry.

2. Methodology

2.1 Source of gums

The Cashew gum (*Anacardium occidentale*) was collected from a Cashew farm at Ejura in the Ashanti Region. Albizia (*Albizia zygia*) and Khaya (*Khaya senegalensis*) were obtained from a forest in Juaso, and the Acacia gum (*Acacia species*) which served as the control was obtained from the Forest Research Institute of Ghana (FORIG). The gums were collected in the dry season.

2.2 Processing of gums

The gums were sorted to remove debris, dirt and pieces of wood from them. They were then dried in the sun for 2 weeks. They were ground into powder, and then used for the emulsion stability experiment.

2.3 Viscosity of gums

Three percent (w/v) of each gum exudate was prepared and the Brookfield Viscometer (Model DV-II+ Version 3.0) used to determine the viscosity at 100 rpm as described in a previous study (Owusu et al., 2005).

2.4 pH of the gums

Two grams of the gums was dispersed in 100mL of distilled water at room temperature. A standardized pH meter (HI9024 Microcomputer) was used to determine the pH of the gum exudates (Sadler and Murphy, 2010).

2.5 Solubility of gums

A centrifuge tube was dried and weighed, 1g of exudate gum was placed in it and 40 mL distilled water added. The resulting solution was stirred constantly and centrifuged at 2200 rpm for 15 min (Damodoran, 1996). A glass crucible was weighed and the supernatant solution transferred into it, and then evaporated to dryness. The solubility was then determined in triplicates using the formulae:

$$\% \text{Solubility} = \frac{\text{Weight of soluble gum exudate} \times 100\%}{\text{Weight of sample (dry basis)}}$$

2.6 Emulsion stability

The stability of oil-in-water (O/W) emulsion stabilized with the various gums was assessed using a centrifuge (McClements, 2016) and pH adjustment (Samanta et al., 2010).

2.7 Centrifuge method

Vegetable cooking oil (Frytol) and water were used to prepare O/W emulsion. The emulsion was prepared using the method of Stauffer (1980). Briefly, O/W emulsions of ratios 3/15 and 4/25 were prepared using a blender (Kenwood Chef Excel, JKP 280 Series). O/W emulsion of ratios 3/15 (oil volume fraction, 16.7%) and 4/25 (oil volume fraction, 13.8%) were each blended with 0.2, 0.3, and 0.4g of *A. species*, *A. occidentale*, *K. senegalensis*, and *A. zygia* gum powders. The solution was then placed in a graduated centrifuge tube. The solution was centrifuged at 1300 x g for 5 min. The volume of the separated cream phase was read from the graduated centrifuge tube and expressed as a ratio of the total volume. Emulsion stability was calculated using the formula proposed by Damodoran (1996):

$$\text{Emulsion stability} = \frac{\text{Volume of cream layer}}{\text{Total volume of emulsion}}$$

All determinations were made in triplicates.

2.8 pH adjustment method

The pH of O/W emulsions stabilized with 0.4g of each of the exudate gum studied was adjusted to two pH levels, i.e. 2.0 and 3.5 using dilute hydrochloric acid (HCl). The volume of the cream layer was determined and the stability of the emulsions was calculated using a previously proposed formula (Damodoran, 1996).

2.9 Experimental design and data analysis

The factors which were investigated to determine how they affect emulsion stability were the quantity of gum (mass), solubility of gum in the continuous phase, oil volume fraction, and pH. The data

obtained were analyzed using Analysis of Variance (ANOVA), and differences in means were deemed to be significant at $P < 0.05$.

3. Results and Discussion

3.1 Effect of type of gum on emulsion stability

In this study, two emulsions of different oil-to-water ratio were used. The emulsion stability (ES) values of the emulsions prepared with 3mL oil and 15mL water (with oil volume fraction 16.7%) and stabilized with the gum exudates studied are shown in Table 1. At each gum quantity, the ES

Table 1

Effect of type and quantity of gum exudates on ES (3mL oil: 15mL water, oil volume fraction 16.7%)

Mass of gum (g)	0.2	0.3	0.4
Acacia	0.78 ± 0.00 ^{ax}	0.80 ± 0.20 ^{aβ}	0.82 ± 0.10 ^{aμ}
Cashew	0.77 ± 0.20 ^{abz}	0.79 ± 0.00 ^{abβ}	0.81 ± 0.10 ^{abμ}
Albizia	0.76 ± 0.10 ^{bzx}	0.78 ± 0.00 ^{bβ}	0.80 ± 0.00 ^{bμ}
Khaya	0.75 ± 0.10 ^{bcz}	0.77 ± 0.00 ^{bcβ}	0.79 ± 0.10 ^{bcμ}

Means with different alphabets are significant at $P < 0.05$ in a column. Means with different Greek letters in a row indicate significant difference at $P < 0.05$.

value of Acacia (Control) and the Cashew gums were not different ($P < 0.05$), but those of Albizia and Khaya gums were different. The ES values for the emulsion prepared with 4mL water and 25mL oil (oil volume constitute 13.8%) also showed similar results (Table 2). The higher solubility values of Acacia and

Cashew gums (Table 3) may account for their high ES values. Solubility of an emulsifier in an emulsion is known to influence its emulsion stability (Damodoran, 1996). There was a high positive correlation ($R^2 = 0.983$ at $P < 0.05$, and $R^2 = 0.997$ at $P < 0.01$) between solubility and emulsion stability for emulsions of oil-water ratio 3:15 (oil)

Table 2

Effect of type and quantity of gum exudates on ES (4mL oil: 25mL water, oil volume fraction 13.8%)

Mass of gum (g)	0.2	0.3	0.4
Acacia	0.86 ± 0.20 ^{ax}	0.87 ± 0.10 ^{ax}	0.87 ± 0.20 ^{ax}
Cashew	0.83 ± 0.10 ^{bzx}	0.85 ± 0.00 ^{bβ}	0.86 ± 0.20 ^{abβ}
Albizia	0.80 ± 0.20 ^{cx}	0.83 ± 0.20 ^{cβ}	0.85 ± 0.10 ^{bμ}
Khaya	0.78 ± 0.00 ^{dx}	0.80 ± 0.10 ^{dβ}	0.81 ± 0.20 ^{cβ}

Means with different alphabets are significant at $P < 0.05$ in a column. Means with different Greek letters in a row indicate significant difference at $P < 0.05$.

volume constitutes 16.7%) and 4:25 (oil volume constitutes 13.8%) respectively (Tables 4 and 5). The results indicate that Cashew gum could be used as a

better substitute for Acacia gum in oil-in-water emulsions (such as milk, yoghurt, and orange juice) than Khaya and Albizia gums.

3.2 Effect of gum quantity on emulsion stability

In the present study, as the quantity of gum exudate in the emulsions increased the ES values

Table 3

Physicochemical properties of gum exudates

Gum exudate	pH	% Solubility	Viscosity (mPas) at 3% concentration)
Acacia	5.00±0.20 ^a	81.87±3.00 ^a	93.0±4.0 ^a
Cashew	4.10±0.30 ^c	72.57±3.00 ^a	210.0±4.0 ^c
Albizia	4.50±0.10 ^b	62.71±2.00 ^b	11195.0±3.0 ^b
Khaya	3.80±0.10 ^d	43.85±3.00 ^b	5204±3.0 ^d

Means in each column are significant at P<0.05

also showed increasing trend (Tables 1 and 2). Emulsifier concentration is known to influence emulsion stability (McClements, 2016). This might be due to the fact that greater amount of gum can provide enough coating for the dispersed phase to

prevent coalescence. Similar results were reported for O/W emulsions stabilized with various types of gums (Sun et al., 2007; Sabah El-Kheir et al., 2008; Wang et al., 2011; Mahfoudhi et al., 2012; Almeida et al. 2015).

Table 4

Correlation between solubility of gum exudates and ES (3mL oil: 15mL water, oil volume fraction 16.7%)

		Solubility	Emulsion stability
Solubility	Pearson Correlation	1	.983*
	Sig. (2-tailed)		.017
	N	4	4
Emulsion stability	Pearson Correlation	.983*	1
	Sig. (2-tailed)	.017	
	N	4	4

Correlation is significant at 0.05 level (2-tailed)

Table 5

Correlation between solubility of gum exudates ES (4mL oil: 25mL water, oil volume fraction 13.8%)

		Solubility	Emulsion stability
Solubility	Pearson Correlation	1	.997**
	Sig. (2-tailed)		.003
	N	4	4
Emulsion stability	Pearson Correlation	.997**	1
	Sig. (2-tailed)	.003	
	N	4	4

Correlation is significant at 0.01 level (2-tailed)

3.3 Effect of viscosity on emulsion stability

Viscosity of the continuous phase of an O/W emulsion may influence its ES value. The results on the correlation between viscosity and ES are shown in Tables 6 and 7. When emulsions of different volume fractions were stabilized with the various gums of different viscosities it was found out that viscosity had negative correlation with emulsion stability (R=-0.647 and -0.392) which was not significant (P>0.05). This means that the stability of the emulsions was not influenced by viscosity of the gums. The results are in consonance with those

reported by Desplanques et al. (2012), but contrary to those of other authors (Paraskevopoulou et al., 2005; Wang et al., 2011; Gavlighi et. al., 2013). The difference may stem from the differences in the gums utilized in the studies.

Table 6

Correlation between viscosity and ES (3mL oil: 15mL water, oil volume fraction 16.7%)

		Viscosity	Emulsion stability
Viscosity	Pearson Correlation	1	-.647
	Sig. (2-tailed)		.353
	N	4	4
Emulsion stability	Pearson Correlation	-.647	1
	Sig. (2-tailed)	.353	
	N	4	4

Correlation is significant at 0.05 level (2-tailed)

3.4 Effect of oil volume fraction on emulsion stability

The oil volume fraction of the emulsions influenced their ES values (Tables 1 and 2). The ES values for the emulsions of greater oil volume fraction, 3mL oil: 15mL water (oil volume constitutes 16.7%) were generally lower than those of lower oil volume fraction, 4mL oil: 25mL water (oil volume constitutes 13.8%). The results corroborates those of a previous study where an increase in oil volume fraction of an emulsion led to a decrease in emulsion stability (Dluzewska et al., 2006). In another study,

lower level of oil volume fraction was reported to favour emulsion stability than higher oil content (Sargolzaei et al., 2011). Imeson (1992) has indicated that an emulsion of greater oil volume fraction requires more gum to stabilize it than that of lower oil volume fraction.

3.5 Effect of pH changes on emulsion stability

The effect of pH of the emulsion on ES was also investigated (Tables 8 and 9). The results indicated that for each gum-stabilized emulsion, a reduction in pH led to a reduction in ES values

Table 7

Correlation between viscosity and ES (4mL oil: 25mL water, oil volume fraction 13.8%)

		Viscosity	Emulsion stability
Viscosity	Pearson Correlation	1	-.392
	Sig. (2-tailed)		.608
	N	4	4
Emulsion stability	Pearson Correlation	-.392	1
	Sig. (2-tailed)	.608	
	N	4	4

Correlation is significant at 0.05 level (2-tailed)

($P < 0.05$) for emulsions prepared with different oil volume fractions. The reduced pH might have led to the removal of some of the protective film which surrounds the dispersed oil phase, leading to some amount of flocculation and coalescence. Generally, Cashew gum-stabilized emulsions were more stable in acidic medium than emulsions stabilized with

Khaya and Albizia gums, indicating that Cashew gum could potentially be utilized in acidic beverages such as fruit juices (Nussinovitch, 2010). A previous study found out that emulsions were more stable in the pH range 5-8 when almond tree (*Prunus dulcis*) emulsifier was applied (Mahfoudhi et al., 2012).

Table 8

Effect of pH on ES (3mL oil: 15mL water, oil volume fraction 16.7%)

pH	2.0	3.5
Acacia	0.86±0.20 ^{az}	0.88±0.20 ^{bx}
Cashew	0.83±0.00 ^{aβ}	0.87±0.20 ^{bx}
Albizia	0.80±0.20 ^{aμ}	0.86±0.20 ^{bμx}
Khaya	0.79±0.10 ^{aμ}	0.85±0.00 ^{bμ}

Means with different alphabets in the same row are significant at P<0.05. Means with different Greek letters in a column indicate significant difference at P<0.05.

Table 9

Effect of pH on ES (4mL oil: 25mL water, oil volume fraction 13.8%)

pH	2.0	3.5
Acacia	0.86±0.00 ^{az}	0.88±0.00 ^{bx}
Cashew	0.83±0.20 ^{aβ}	0.86±0.00 ^{bβμ}
Albizia	0.73±0.00 ^{aμ}	0.87±0.20 ^{bαβ}
Khaya	0.72±0.00 ^{aμ}	0.85±0.10 ^{bμ}

Means with different alphabets in the same row are significant at P<0.05. Means with different Greek letters in a column indicate significant difference at P<0.05.

4. Conclusions

The results of the study have shown that ES of the emulsions were influenced by type of gum, quantity of gum, solubility of gum in the continuous phase, oil volume fraction, and pH. In addition Cashew gum has similar emulsion stability values as Acacia gum, therefore it can be used as a substitute for Acacia gum to stabilize oil-in-water emulsions.

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