Some Physical and sensory parameters of marshmallows with different fluid mucilage

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Abstract:

The objective of this study was to replace gelatin in marshmallows with different concentrations of fluid mucilage, combined with different concentrations of powdered hydrocolloids. Ten different formulations were prepared: Control (100% gelatin); 75% gelatin + 25% starch; 75% gelatin + 25% agar-agar; 75% gelatin + 25%

Guar gum; 50% gelatin + 50% starch; 50% gelatin + 50% agar-agar; 50% gelatin + 50%Guar gum; 25% gelatin + 75% starch; 25% gelatin + 75% agar-agar; 25% gelatin + 75% Guar gum; Consistency, texture, tenderness of gel and water activity were determined. There were significant ($p<0.05$) differences between the different samples for all measurements. The best formulation for gelatin replacement was found to be the 75% starch + 25% gelatin combination, as it only differed significantly ($p<0.05$) from the control (100% gelatin) sample in regard to shear, as measured by the Warner Bratzler Shear. It was significantly ($p<0.05$) less tender and resembled the shear of commercially available marshmallows in Egypt. All samples had a light, greyish yellow color.

Keywords: Mucilage; agar-agar; gelatin; marshmallows; starch

Introduction

Marshmallows are one of the earliest confections known to man and were originally made from the root sap of the marshmallow (*Althaea officinalis)* plant. The first marshmallows were made by boiling pieces of the marshmallow root pulp with sugar until it thickened, whereafter the mixture was strained and left to cool. In 2000 B.C., Egyptians combined the marshmallow root with honey, and made a candy which was reserved for gods and royalty **(Groves, 1995 and Olver, 2000).**

Modern marshmallow confections were first made in France around 1850 when marshmallows were cast and molded individually. When mass production became possible, by 1900, marshmallows were made by implementing the starch mogul system. By 1955, Alex Doumakof Doumak, Inc. patented a new manufacturing method, called the extrusion process, which changed the history of marshmallow production and is still used today **(Groves, 1991).**

Marshmallows are made by using sweeteners and emulsifying agents. Proportionally, there is more corn syrup than sugar, because it increases the ability of the sugar to dissolve and retards crystallization. Corn starch, modified food starch, water, hydrocolloids, gelatin, and/or whipped egg whites are used in various formulations, resulting in a specific texture.

Hydrocolloids act as emulsifiers in marshmallows and provide the aeration that makes marshmallows puffy; however, they also act as gelling agents. Most marshmallows also

contain natural and/or artificial flavoring **(Groves, 1995 and Olver, 2000).** Mucilage is, therefore, commonly referred to as a gum or hydrocolloid. Hydrocolloids are water-soluble dietary fiber that can be used as healthy additives for profitable food products.

None of the mucilage found in cladodes is hydrolyzed or absorbed by the human digestive system, but they can make up alimentary fiber **(Sepulveda *et al.*, 2007 and Osuna-Martinez *et al.*, 2014).**Mucilage has a strong emulsifying capability in that it reduces surface interfacial tensions, stabilizes oil-in-water emulsions and does not contribute to the viscosity of the system. Its stabilizing properties are similar to those of xanthan and guar gums. It can also form part of gelled dessert and powdered drinks, to be reconstituted with water or milk (**Bensadon *et al.*, 2010).**

Another possible function for mucilage could be as a fat mimic, as it has the required tendency to increase the viscosity of the water phase. With increased concentration, it will exhibit gelling capabilities. Mucilage can, therefore, be used to emulsify systems, but as it is not a true emulsifier, processing costs would be reduced, while providing the final product with a natural and healthy ingredient as a replacement for fat **(Bensadon *et al.,* 2010 &Milani and Maleki, 2012).**

Today, new facts at the molecular level of chemistry, as well as on functional properties, allow improved knowledge on the selection of a suitable hydrocolloid for a specific product. The aim of this study was to replace gelatin in marshmallows with different concentrations of

liquid mucilage, in combination with different concentrations of gelatin. Various physical parameters, such as consistency, percentage sag, shear, color and water activity (aw), were determined.

MATERIALS AND METHODS

Extraction of liquid mucilage

. Preparation of marshmallows

The formulation for the marshmallows that were used as the control sample is given in Table (1). The gelatin was soaked in cold water. The sugar, salt, syrup and the remaining water were heated and stirred to dissolve the sugar. After the mixture reached a temperature of 118 °C, the gelatin was added. The stiffly beaten egg whites were added to the hot mixture, whilst continuously mixing it until thick and creamy. The mixture was then poured into a greased pan, cooled overnight and cut into 25-mm squares. The squares were rolled in a mixture of corn flour and icing sugar, and stored in an airtight container **(Foods and Cookery, 1991)**

Table 1. Formulation of control marshmallow (Foods and Cookery, 1991).

Ingredient Percentage	**(%)**
Gelatin	2.30
Water cold, to hydrate gelatin	11.52
Sugar	46.09
Water	28.81
Egg whites	9.22
Syrup	1.93
Salt	0.13

Replacement of gelatin with liquid mucilage

Ten different formulations were prepared according to Table (2). The three hydrocolloids that were chosen to be used in combination with the fluid mucilage, to replace gelatin in the formulation, were gum guar, agar, and starch. Guar was chosen because of the synergistic effect that it displayed when used in combination with starch (**Pangborn, *et al.* 1978).**

According to **Bensadon *et al.* (2010)**, the stabilizing properties of mucilage are similar to those of stach and guar gums. Agar was also chosen, because it is commercially used in Egypt in chocolate candies to stabilize the marshmallow layer, such as *Cadburys Chocolate log* (Made in Egypt.).

The control sample contained 100% gelatin. The highest concentration at which the mucilage was used in the formulations was 75%. The lowest concentration at which the other hydrocolloids were added, was 25%. Nine different formulations were prepared: 75% gelatin + 25% starch (sample 1); 75% gelatin + 25% agar-agar (sample 2); 75% gelatin + 25%

Guar gum (sample 3); 50% gelatin + 50% starch (sample 4); 50% gelatin + 50% agar-agar (sample 5); 50% gelatin + 50%Guar gum (sample 6); 25% gelatin + 75% starch (sample 7); 25% gelatin + 75% agar-agar (sample 8); 25% gelatin + 75% Guar gum (sample 9).

Samples were cut into cubes of 1x1x1cm and rolled in a mixture of icing sugar and corn flour Samples were evaluated simultaneously, under white lights and served on white polystyrene trays. Bottled water was used as a palate cleanser and between samples. The liking of taste, aftertaste, texture and overall acceptability were evaluated on a structured line scale, ranging from 1 (dislike extremely) to 9 (like extremely). The nine-point hedonic scale has been used routinely in food science research for the past 60 years and is a scale of liking. It should be emphasized that the numbers on the scale are alternative names for the categories. **(Foods and Cookery, 1991).**

Consumer panel

Twenty consumers, 10 male and 10female panelists, aged 18 to 23,

were sourced from students of the Menoufia University, Menoufia Governator, Egypt. All had to be regular consumers of marshmallows, in dicating that they consume it at least once every two weeks.

Physical texture analysis of marshmallow samples

Consistency

A glass plate, placed on paper with concentric circles drawn on it, at intervals of 0.5 cm was used. An open-ended tube, 2 cm x 2 cm in diameter, filled with 5 mL of the liquid sample, was placed in the center of the circles. After the tube was lifted, the liquid sample was allowed to flow for 2 min. The distance, traveled by the liquid, was then measured at each 90o section of the circle and the average calculated; the line spread value (LSV) was the mean of the four values obtained **(Kim, 2007)** and expressed in cm.

Texture

The penetrometer was used to determine the comparative tenderness and penetration

properties of semi-solid substances **(Mohos, 2010).** The cone penetration test (ASTM D217) was used and the depth was measured in mm. The larger the reading, the more tender the product. The more tender the sample, the deeper the penetrometer will sink into the sample and, thus, the higher the penetration number will be. The flat attachment tests resistance against pressure; thus, the higher the value the more compression is achieved, indicating a more tender softer product. The results were expressed in mm.

Tenderness of gel

The percentage sag test was used to determine the gel tenderness and was expressed as percentage of the height, before unmolding. For this test, the depth of the marshmallow sample was measured in its container, by using a probe. After the sample was unmolded onto a flat surface the depth was measured again. Percentage sag was then calculated as the change in height of the sample measured in the container or mold, compared to that of the freestanding gel placed on a flat surface. The greater the percentage sag value, the more tender the gel **(McWilliams, 1989).**

Water activity (aw)

The water activity of the marshmallow samples in (aw) containers (height of 5 mm and diameter of 39 mm) was measured with a Thermoconstanter TH 200 water activity meter, at room temperature (20 oC). The means of the replications for the marshmallow samples were recorded (**Mathenjwa *et al.,* 2012).**

Statistical Analysis

All results were captured in multiple spreadsheets in Microsoft Excel 2007. A one-way analysisof variance (ANOVA) procedure **(NCSS, 2007)** was used to determine the effect of mucilage/ hydrocolloid formulations on the physical parameters of the marshmallow samples. Differences were considered statistically significant at $p<0.05$ level or lower.

RESULTS AND DISCUSSION

For gender group, there was a significant ($p=0.0124$) difference between the liking for after taste, meaning that the male group of consumers ranked the liking of the after taste higher than the female group (Table 2).

Liking of aftertaste was included to determine whether the consumers would detect the grassy aroma of the mucilage (**Rothman *et al*., 2012**).

Although only 50 % of the panelists
in the present study fell into the male group, it is still a valid
result, confirming **Hoffman and co-workers' (2016)** findings that male find sugar more pleasant at higher concentrations, such as in confectionaries,
compared with female **(Petry,2004).**

Table (2). Effect of gender group on the liking of sensory properties of marshmallows types.

Sensory property	Female	Male	P value
Taste	**7.43 ± 1.15**	**7.80 ± 2.64**	**0.0889**
Sweet aftertaste	**7.26a ± 1.08**	**7.78b ± 2.63**	**0.0124**
Texture	**7.11 ± 1.32**	**7.55 ± 2.78**	**0.0576**
Overall acceptability	**7.39 ± 0.09**	**7.76 ± 2.59**	**0.0752**

Means with different superscripts in the same row differed significantly, according to two sample *t*test.

In Table 3 the effect of the mucilage inclusion on the liking of taste, aftertaste, texture and overall acceptability is shown. The best samples were 1 and 4 which was nonsignificant as compared with control sample followed by 2 and 7 which was staticaaly significant . the lowest samples were 8 and 9 which contained 75% agar and 75% guar gum with 25% gelatin . The starch was thus successful in masking the grassy flavor of the mucilage **(Rothman *et al*., 2012),** as there was an increase of almost three categories in ranking, on the hedonic scale, from the 25% starch to 50% starch mucilage sample

Table 2. Effect of marshmallow type on the sensory properties of the samples.

Sample	Taste	Aftertaste	Texture	Overall Acceptability
Control	**8.26a ± 1.30**	**8.30a ± 2.53**	**8.73a ± 2.18**	**8.31a ± 2.15**
Sample 1	**8.34a ± 2.89**	**8.18a ± 1.75**	**8.28a ± 1.28**	**8.48a ± 1.76**
Sample 2	**7.32b ± 2.41**	**7.38b ± 1.69**	**7.30b ± 1.15**	**7.48b ± 1.12**
Sample 3	**6.47c ± 0.84**	**6.60c ± 1.59**	**5.46c ± 2.20**	**6.32c ± 1.33**
Sample 4	**8.11a± 0.58**	**8.11a ± 1.61**	**8.58a ± 1.22**	**8.20a ± 1.10**
Sample 5	**4.21d ± 1.02**	**5.57d ± 1.10**	**5.52d ± 1.24**	**5.58d± 1.23**
Sample 6	**5.51d ± 1.32**	**5.47d ± 1.30**	**5.62d ± 1.04**	**5.32d ± 1.11**
Sample 7	**7.51b ± 1.12**	**7.37b ± 1.34**	**7.92b ± 1.94**	**7.45b± 1.36**
Sample 8	**3.41e ± 1.12**	**3.33e ± 1.32**	**3.02e ± 0.74**	**3.12e ± 0.98**
Sample 9	**3.51e ± 1.42**	**3.47e ± 1.20**	**3.92e ± 0.04**	**3.48e ± 1.18**

Means with different superscripts in the same column differed significantly, according to two sample *t*test.

75% gelatin + 25% starch (sample 1); 75% gelatin + 25% agar-agar (sample 2); 75% gelatin + 25%

Guar gum (sample 3); 50% gelatin + 50% starch (sample 4); 50% gelatin + 50% agar-agar (sample 5); 50% gelatin + 50%Guar gum (sample 6); 25% gelatin + 75% starch (sample 7); 25% gelatin + 75% agar-agar (sample 8); 25% gelatin + 75% Guar gum (sample 9).

The replacement of gelatin with mucilage, in combination with guar, agar agar and starch had a significant ($p<0.05$) effect on all the evaluated physical parameters of the marshmallows (Table 3).

Consistency

For the line spread test, the sample1 had the lowest value, signifying that the consistency of this formulation was the highest of the all the samples. This sample differed significantly ($p<0.05$) from all the other samples (Table 3). The consistency of the control sample did not differ from that of 2 and 4, however, it was significantly ($p<0.05$) lower than 3,5,6,8 & 9 and significantly ($p<0.05$) more fluid than sample 1, and 7 . Sample 8 had the highest value for the line spread test, indicating that it was the most consistency and was significantly ($p<0.05$) more consistency than all the other samples (Table 3). Since the control sample contained 100% gelatin and resulted in a successful product, a line spread test value of around 1.97 cm could result in a successful product. The combinations 2and 4 did not differ from the consistency of the control sample (Table 3). In both of these samples, starch was used in combination with mucilage, which could be responsible for the satisfying results. Starch and gum are used in confectionaries, because of its solubility and the strength it confers upon the product **(Nussinovitch, 1997).** It was also found that, as soon as the percentage additive mucilage increased, so did consistency.

Table (3): Consistency properties of different formulations of hydrocolloids, in the making of marshmallows.

samples	Cont.	S1	S2	S3	S4	S5	S6	S7	S8	S9
Consistency (cm)	1.97±0.12c	1.42±0.26f	1.96±0.65c	2.14±0.14b	1.98±0.95c	2.05±0.61b	2.27±0.42a	1.83±0.31d	2.33±0.27a	2.32±0.17a

Means with different superscripts in the same row differ significantly ($p < 0.05$).

Texture

The sample with the highest measurement for the flat attachment was the control sample.According to McWilliams (1989), the larger the reading, the tenderer is the product, as the attachment will sink deeper into a tender sample, resulting in a higher penetration value. The samples with the lowest reading were 3, 6 and 4 indicating that these samples were less tender (Table 4). Sample 1 differed from 8 and 9 but was significantly (p<0.05) softer than 7, 5 and 2. Although 7was also significantly (p<0.05)

harder than G, it was the mucilage combination closest to the tenderness achieved by the control sample, containing 100% gelatin. Agar is known as a 'gelling type' hydrocolloid, likegelatin (**Saha and Bhattacharya, 2010),** but it has stronger setting properties (five times greater), so agar form gels at lower concentrations **(Condrasky, 2014)**. starch, on the other hand, is used for thickening **(Saha and Bhattacharya, 2010**) and adds elasticity **(Condrasky, 2014).** The more crumbly texture caused by agar **(Condrasky, 2014)** may have been softened by the starch, resulting in a tenderer texture.

Table (4): Texture properties of different formulations of hydrocolloids, in the making of marshmallows.

Samples	Cont.	S1	S2	S3	S4	S5	S6	S7	S8	S9
Texture (mm)	0.23±0.33f	0.77±0.22d	1.10±0.21c	0.53±0.20e	0.54±0.07e	1.33±0.15b	0.53±0.03e	1.90±0.05a	0.90±0.09c	0.90±0.19c

Means with different superscripts in the same row differ significantly ($p < 0.05$).

Tenderness of gel

The sample that scored the lowest percentage sag was the control sample (G), indicating a strong gel texture, as the greater the percentage sag value, the more tender the gel **is (McWilliams, 1989);** this sample differed significantly ($p<0.05$) from all the other samples (Table 5). The 4 and 9 samples had the highest percentage sag, meaning that they were the tenderest of all the samples. The sample closest to the control sample (G), again, was 7, which was also the best sample in the penetrometer tests. There is no significant different among 1,2 and 5.

Table (5): Tenderness of gel properties of different formulations of hydrocolloids, in the making of marshmallows.

Samples	Con T.	S1	S2	S3	S4	S5	S6	S7	S8	S9
Tenderness of gel (%)	0.96 ±1.11e	9.18± 1.10c	9.70± 3.18c	19.84± 1.76b	27.90± 6.51a	9.74± 1.50c	8.85± 1.65c	5.41± 0.86d	16.38 ±3.18b	29.78± 3.63a

Means with different superscripts in the same row differ significantly ($p < 0.05$).

Water activity

All the samples fell within the range of intermediate moisture foods (IMF). These are foods with aw of 0.65 - 0.85, which is largely responsible for its protection from microbial spoilage **(Garbutt, 1997).** The sample with the lowest aw value was 7 this sample differed significantly ($p<0.05$) from all the other samples (Table 6). The sample with the highest aw of 0.80, namely sample 5, differed significantly ($p<0.05$) from all the samples, but still fell within the range of IMF. The sample 7 combination had a significantly ($p<0.05$) lower aw than the control (G) sample, rendering it even more acceptable as a substitute for gelatin in the marshmallow formulation. This water dispersing property is common to all hydrocolloids; however, the extent of thickening varies with the type and nature of the hydrocolloid **(Saha and Bhattacharya, 2010). Nammakuna *et al.* (2009)** found that addition of hydrocolloids to rice crackers increased its moisture content, which correlated to significantly higher aw in treated samples, as compared to the controls. It can be concluded that the best textural attributes were associated with sample 7 consisting of 25% gelatin + 75% starch. This sample showed good results in all the above mentioned physical evaluations and it was the closest sample to the control. It is then clear that in combination with starch, mucilage can be used as a substitute for gelatin in the production of marshmallows.

Table (6): Water activity properties of different formulations of hydrocolloids, in the making of marshmallows.

Samples	Cont.	S1	S2	S3	S4	S5	S6	S7	S8	S9
Aw	0.78 ±0.01b	0.78 ±0.01b	0.79 ±0.01a	0.76±0.01c	0.78± 0.01b	0.80± 0.01a	0.76± 0.01c	0.75±0.01d	0.77± 0.01b	0.78±0.01b

Means with different superscripts in the same row differ significantly ($p < 0.05$).

CONCLUSIONS

Marshmallows were selected as the potential vehicle for the incorporation of mucilage in different formulations, using a variety of hydrocolloids. The sample 7,containing 75% starch and 25% gelatin, obtained the best results for all the physical parameters tested and could be a potential formula requiring further research.Marshmallows containing mucilage in combination with starch , agar and gum might also be a good alternative for similar products, where only one hydrocolloid, for example, agar is used as a gelling agent, resulting in a tough texture. Furthermore, gelatin-less marshmallows might also open up amarket which was restricted by the use of gelatin, namely for Halaal consumers.

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بعض القياسات الطبيعية والحسيه للمارشملو مع تركيزات مختلفة من المواد الهلامية

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الملخص العربي

كان الهدف من إجراء هذه الدراسة هو استبدال الجيلاتين في المارشملو بتركيزات مختلفة من مواد هلاميه استخدمت مع تركيزات مختلفة من الجيلاتين وكانت التركيزات كالاتي :عينه كونترول ١٠٠%جيلاتين ،٧٥%جيلاتين +٢٥%نشا ،٧٥%جيلاتين +٢٥% اجار ،٧٥%جيلاتين +٢٥%صمغ عربي ،٥٠%جيلاتين +٥٠%نشا ،٥٠%جيلاتين +٥٠%اجار ،٥٠%جيلاتين +٥٠%صمغ عربي ، ٢٥%جيلاتين +٧٥%نشا ، ٢٥%جيلاتين +٧٥% اجار ،٢٥%جيلاتين +٧٥%صمغ عربي ، وقد تم تقدير التماسك ، القوام والطراوة والنشاط المائي فى جميع العينات . وقد وجد اختلافات معنوية ($p<0.05$) لجميع القياسات . وكانت افضل التركيزات التي تم الحصول عليها هي ٧٥% جيلاتين +٢٥% نشا حيث كانت بالرغم الاختلافات المعنوية بالنسبة للكنترول الا انها كانت الاقرب بالنسبة للمارشملو التجاري المتاح فى مصر .

الكلمات المفتاحيه :ماده هلاميه . اجار .مارشملو .نشا