Seaweed based jam as a source of nutrition

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Abstract

The study focus on introducing seaweed extract as thickening agent replacing pectin which is normally used as binding agent of fruit jams and to improve nutritional quality. The study was conducted to select the best composition of jam containing fruit pulps such as wood apple, orange, *Ulva* powder, and mango; incorporated with sugar; citric acid and seaweed extracts (agar agar or carrageenan).The agar and carrageenan content was incorporated in varied levels keeping constant levels in other ingredients to select most acceptable product. The developed products were analyzed for nutritional properties and shelf life compared with commercially purchased jams. The analysis of jam samples revealed that the best jam mixture contained about 6% (w/w) of carrageenan. Developed ten jam mixtures (wood apple, mango, *Ulva*, orange) were compared with a commercial orange jam product. The viscosity of all the jam mixtures were ranged 203 ±14.9- 278±18.9 cP. Ten jam mixtures had water activity values ranging from 0.81±0.074 - 0.88±0.03. Crude protein contents of jam mixtures were ranged from 0.24± 0.01 - 9.62±0.15%, (wet weight basis) and a significant highest (9.62±2.78) value was found in *Ulva* jam. Iodine content of above ten jam types were found in the range of 0.03±0.01- 0.094±0.08, 56±5.9 - 150±13.2 and 125.0±32.0 – 135.0±21.8 µg/L in commercial, carrageenan and agar jam respectively. The potassium contents were reported as 278±53.9-526 ±67.5 mg/L while Ca content was ranged 6.7±1.4-101.3±21.9 mg/L. The total bacterial counts were at the consumable level and ranged from $1.0 \times 10^1 \pm 0.03$ to $6 \times 10^1 \pm 1.9$ CFU/g over a six month period at 30°C. The yeast and mould counts were ranged from $1.0 \times 10^1 \pm 0.2$ - $6 \times 10^3 \pm 1.2$ CFU/g during the six months shelf life studies. The seaweed based fruit jams provide an affordable and convenient source of nutrients.

Keywords: Fruit pulps, Agar agar, Carrageenan, Seaweeds, Jam, Nutrients

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Introduction:

Seaweed is known as a source of several phyto-nutrients such as minerals, protein, vitamins and dietary fiber and also bio active compounds such as antibiotics and antioxidants. Seaweed based foods have a strong possibility of controlling several risk of diseases such as cancer, diabetic, cholesterol and nutritional deficiency (Kritchevsky *et al.*, 1982). Previous studies have shown that iodine content in breast milk of lactating mothers has a strong correlation with frequency and quantity of seaweed consumption (Kritchevsky *et al.*, 1982). Red seaweed species are used for extraction of valuable polysaccharides such as agar and carrageenan which was used for preparation of confectionaries such as jam, jelly, etc. Seaweed polysaccharides can be considered as source of minerals, vitamins and amino acid. (Jayasinghe *et al.,* 2012). These polysaccharides are allowed for wide variety application due to their gelation ability at room temperature to interact with other factors in composite foods.

Jams are produced by the preservation of fruits which are canned or sealed to extension of shelf life. Jam is a popular food product because it's all year long availability and organoleptic properties. Normally agar agar and carrageenan have high gelling properties at room temperature (Shaha and Bhattachaya, 2010). Incorporation of agar or carrageenan to fruit pulps helps to improve nutritional properties of jam than incorporation of commercial pectin. In addition, *Ulva* jam has a potential to provide high source of functional compounds available in *Ulva* and can be produced at a low cost. The present study focuses on utilization of seaweed extract as a stabilizer in formulation of fruit and *Ulva* jam. Further compare shelf life and nutritional composition of laboratory prepared and commercial fruit jam.

Materials and methods

Wood apple, orange, mango and sugar were purchased from market. The fresh *Gracilaria verrucosa* and *Kappaphycus alvarezii* were collected from Northeastern coastal belt, and *Ulva lactuca* from Southwestern coastal belt of Sri Lanka. The samples were packed in insulated boxes and transported to laboratory. Further, seaweed species were washed, cleaned and epiphytes were removed.

The cleaned seaweeds were sun dried for 1-2 days. Then, dehydrated seaweed species were powdered and kept in air tight containers and stored at -18°C until taken out for preparation of jam. Seaweed powder of *G. verrucosa* and *K. alvarezii* (carrageenophyta) were used to extract agar agar (SOP/AP/001/2003) and Carrageenan (Stanely, 1987).

In addition, *Ulva* powder jam was developed adding *Ulva* powder according to Krishnamurthy *et al*., (1981). *Ulva* powder was added to a boiling sugar syrup and left to boil for 30 minutes. Boiled mixture is filled into sterilized glass jars of 250 g and tightly capped. Three fruit jams were prepared using wood apple, orange and mango. Each jam was prepared with 40% fruits pulp, 68.5% total soluble solid, 0.5% citric acid and 0.025% sodium benzoate with five different percentages, 2, 3, 4, 5, 6 of agar or carrageen (SLSI, 1985). The prepared fruit jams were packaged in a 250 g sterilized jam bottles and stored at ambient temperature (27 °C) for further analysis.

Sensory attributes were tested for different carrageenan and agar fruit jams percentages to determine most acceptable levels. Furthermore, comparison of shelf life, proximate composition and mineral content of most acceptable fruit jams and *Ulva* jam contents were made with similar commercially available products.

Sensory evaluation:
Sensory attributes were tested for color, taste, aroma, sweetness spreadability and overall acceptability using 9-point hedonic scale. The seven different laboratory prepared jams and similar commercial fruit jams were tested. The taster was served with jam, bread knives, and water and requested to grade them on 9-point hedonic scale (Peryam and Pilgrim, 1957). Several trials were conducted to improve overall acceptability of the product up to the standard of the commercially available products.

Shelf life studies:
The shelf life studies were conducted storing the product at ambient temperature for six months period. Overall acceptability, total bacterial count (SLSI, 1991) and total fungal counts (SLSI, 1991) were determined at monthly intervals for a six months period.

Chemical parameters:

Most acceptable different types of laboratory processed fruits, *Ulva* and commercially available jams were analyzed for macro and micro elements (K, Ca, Mn, Mg, Na, and I content) and proximate composition (AOAC, 1995). Viscosity (Brook field viscosity meter) and water activity (Spring novasina-TH-500- water activity meter) were also tested.

Statistical Analysis: Non-parametric tests were used to analyse the sensory attributes. Significant difference between the results were calculated by analyzing the variance using software package SPSS 22 (2015).

Result and Discussion

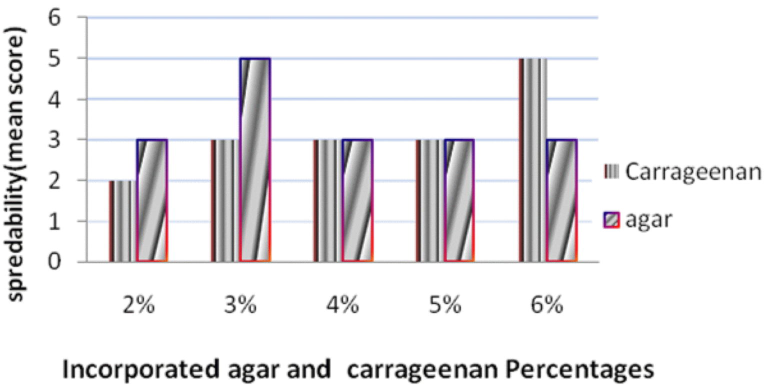

Fig. 1. Evaluation of variation of agar agar and carrageen and content on spreadability of fruit Jam

Fig.1. shows variation of mean scores for spreadability of jam, incorporated with varied agar agar and carrageenan percentages. Among the five different percentages (2, 3, 4, 5 and 6%), the highest spreadability (hedonic point -5) was observed in 6% carrageenan incorporated jam and in 3% agar incorporated jam. The lowest spreadability was scored for 2% agar incorporated jam while rest of carrageenan and agar incorporated Jams obtained score of point 3.

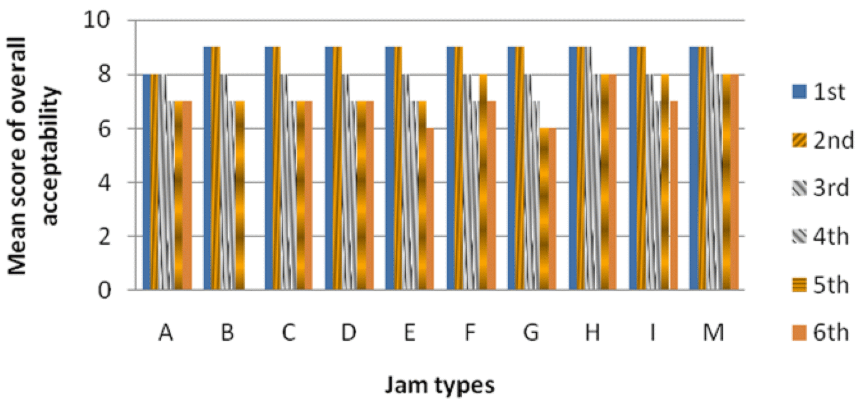

Fig. 2. Mean sensory attributes of spreadability, colour, aroma, texture, sweetness and overall acceptability of different seaweed based jams.

Table 1. Abbreviations

Jam	with 3%	with 6%	Commercial
Ulva – A	-	-	-
Wood	B-WAJ	E-WCJ	H–CWJ
Mango	C-MAJ	F-MCJ	I- CMJ
Orange	D-OAJ	G-OCJ	M–COJ

Fig. 2. shows mean sensory score of different jam types. The scores were analyzed in terms of spreadability, colour, aroma, texture and sweetness. The results obtained from the analysis revealed that sample H and M have best acceptable colourwith the mean value of 8. However, there was no significant difference ($p > 0.05$) between mean values. Sample H and M showed the highest value 9 for aroma and colour.

In texture analysis of samples, M has yield value 9. There weren't significant difference between sample M and others. In terms of the spreadability, all the samples indicated value of 5, thus there weren't significant difference between spreadability among the different jams. In terms of sweetness, sample F to M have the mean value of 8. The results of sensory evaluation shows that samples from commercial market have most acceptable aroma, color and sweetness than the laboratory made jams.

Table 2. shows viscosity and water activity of different jams. The agar agar, carrageenan incorporated jams were observed with improved viscosity ranging from 203.6±14.9-

278±18.9 cP. values respectively for *Ulva* (A), wood apple with agar (B), mango with agar (C), orange with agar (D), wood apple with carrageenan (E), mango with carrageenan jam (F), orange carrageenan jam (G), commercial wood jam (H), commercial Mango jam (I) commercial Orange jam (M). The viscosity of *Ulva* jam and other fruit jams are lower than that of commercially available jam samples. The agar incorporated wood apple (B) and mango jam (C) have similar values. The carrageenan incorporated mango (F) and orange jam (G) have shown improved viscosity 266.3±11.46 and 268±14.7 respectively. Viscosity of the carrageenan jam were significantly ($p < 0.05$) higher than agar incorporated jam. The viscosity improved the rheological behavior of fruit jam. The rheological behaviors are affected by temperature, shear rate and composition of fruit jam (Javanmard and Endan, 2010). In the present study incorporation of agar or carrageenan as food thickening agent during jam preparations were effective in improving its texture and nutritional composition.

The water activity (Table. 2) did not show any significant difference ($p > 0.05$) among values in all jam content which ranged from 0.81 -0.88. The highest water activity content observed in *Ulva* jam, while agar incorporated mango jam (C) had lowest water activity followed by agar incorporated wood apple jam (B) and carrageenan incorporated orange jam (G). The water activity content of seaweed incorporated fruit jams were comparable with commercially available jams which have observed one year shelf life. Generally water activity content of foods can be measured as an indicator of its shelf life (Fellows, 2000).

Table 2. Mean water activity and viscosity of seaweed based jams. (Mean± SE)

Jam Sample codes	A	B	C	D	E	F	G	H	I	M
Viscosity (Cp)	226.3 ±21.6	212.4 ±12.8	210.5± 20.7	203.6± 14.9	206±1 5.9	266.3± 11.46	268±1 4.7	270±3 0.8	260± 13.9	278± 18.9
Water activity (a_w)	0.88± 0.03	0.83± 0.02	0.81±0 .74	0.857± 0.31	0.83±0 .05	0.86±0 .01	0.83±0 .01	0.83±0 .04	0.83± 0.53	0.84 ±0.0 31

According to Fig. 3. agar incorporated wood apple jam (B) was found to be with lowest protein content among fruit jams, while *Ulva* jam (A) have the highest content. Carrageenan incorporated wood apple jam (E) was found with second highest protein value 8.3±0.78%. Commercial wood apple jam (H) reported significantly lowest ($p>0.05$) content of protein 0.245±0.01%. According to the nutritional labeling, common ingredients are fruits, sugar, pectin and citric acid. None of the ingredients used are an abundant source of protein, resulting in low protein content of jams in the jam processing industry. But (seaweed extracts) agar carrageenan and *Ulva* powder jam had improved the protein content into significantly highest level ($p<0.05$) than the industrial jam.

In terms of fat content (Fig. 3.) of the different type of jams majority of the analyzed jams generally have lower amount of fat content. The *Ulva* jam (A) has highest 4.15± 1.2% fat content while the agar incorporated wood apple (B) and mango jam (C) has less fat contents (3.57±0.23 to 3.42± 0.52%). The fat content of the carrageenan incorporated jams were lower than that of agar incorporated jams. It was reported that Industrial jams have lowest fat content compared to the seaweed based jam types.

As given in Fig. 3., all the jams have highest carbohydrate content more than 65%. The *Ulva* jam (A) indicated lowest value followed by agar incorporated mango (C) and orange jam (D). It was reported that carbohydrate content ranged from 65±8.0 to 67.56± 2.96%. The highest value was found in commercial mango jam (I) while lowest in *Ulva* jam (A). Carbohydrate content in carrageenan incorporated jams were found in the range of 65±8.0-67.43±4.6%.The statistical difference weren't significant among treatments with respect to carbohydrate content. Jams can be associated with the large presence of sugar (>50 g/kg) as observed from the nutrient labeling on its packaging.

The ash content of jams ranged from 0.33±0.031 to 10.56±2.31% which is higher compared to that of all commercial market jams range from 0.45 ±0.03- 0.07±0.031%. *Ulva* jam (A) has significantly highest ash content. Differences were found to be statistically significant. Generally, market jam indicated low ash content and seaweed based jam have high ash content indicating their high mineral content.

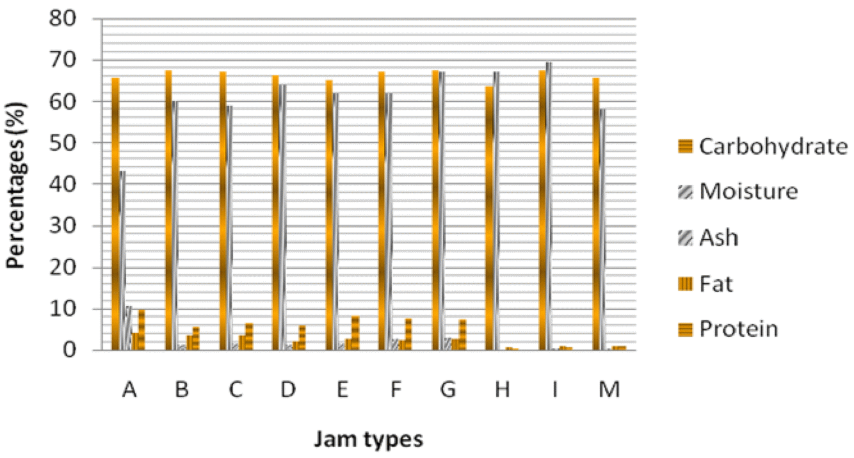

Fig. 3. Mean Proximate composition of seaweed based jams with respect to the protein content

Table 3. Mean value of mineral composition (in mg/L) of different treatments of jams.

Sample Code	Potassium	Calcium	Magnesium	Manganese	Sodiuma	Iodine
A	436.3±27.6	101.3±21.9	77.7±8.7	0.05±0.001	241±24.9	240.0±20.5
B	442.8±22.9	53.4±4.9	118.1±32.1	0.05±0.0054	165±25.0	135.0±21.8
C	509.1±56.9	57.9±5.6	73.01±31.8	0.03±0.0076	245±26.7	125.0±32.0
D	371.2±45.0	27.6±4.3	280. 9±56.0	0.02±0.023	348±28.9	134.0±51.6
E	285.2±12.9	55.9±8.9	210±34.9	0.05±0.04	278±23.0	102±21.8
F	509±42.9	57.3±8.7	131.3±42.1	0.03±0.008	371±25.4	150 ±13.2
G	526±67.5	76.4±4.8	105±9.0	0.05±0.006	110±28	56±5.9
H	278±53.9	10.89±1.9	68±0.67	0.03±0.021	87±7.9	0.08±0.02
I	371±47.9	9.57±2.3	72.1±6.0	0.02±0.089	120±24.9	0.03±0.01
M	325 ±52.9	6.7±1.4	72.21±0.7	0.054±0.043	65±12.6	0.094±0.08

Composition of minerals in analyzed jam samples is given in Table 3. The commercial orange jam (M) had the lowest Na content. On the other hand carrageenan incorporated mango jam (F) has significantly highest Na content. *Ulva* jam (A) and agar incorporated mango jam (C) had similar Na contents (241±24.9, 245±26.7 mg/L). The differences in the Na content between the fruits jams can be associated with the presence of sodium citrate during jam making. In addition, the higher Na levels in the seaweed jam and agar due to incorporated jam could be absorption of Na by seaweed from seawater.

The agar incorporated orange jam (D) has highest Mg content and commercial products H to M were in the range of 68±0.67 – 72.21±0.7 mg/L. The level of Mg content in *Ulva* jam (A) and commercial jams weren't significantly different ($p<0.05$). The closer values were found in agar incorporated wood apple jam (B) and mango jam incorporated with carrageenan (F) (118.1±32.1-131.3 ±42.1 mg/L). The lower Mg levels in present data could be attributed to the dilution elements of fruit pulps with sugar during jam processing (Plessi *et al.,* 2007)

The agar and carrageenan incorporated wood apple, mango, and orange jam tend to have lower Ca content when compared to the *Ulva* jam. Commercially available orange jam (M) had recorded lower Ca content (6.7± 1.4 mg/L) while *Ulva* jam was reported highest Ca level (101.3± 21.9 mg/L). The Ca content in commercially purchased orange (M), mango (I) and wood apple jam (H) is comparable to the ones reported for strawberry and grapes jam (6-16 mg/L) (Giampieri *et al*., 2012). It is possible that variation in minerals absorption by sea and land plants respectively from seawater and land soils contributed to the differences (Luna and Barrett, 2000).

All the fruit jams have very low Mn content, while *Ulva* jam (A) has highest Mn content (0.05±0.001 mg/L). There weren't statistical significant difference among Mn values ($p<0.05$) in ten types of jams. However commercial mango jam (I) indicated lowest value. The differences in the Mn content of fruits and seaweed jams could be traced to the possible destruction of Mn due to the heat treatments during processing (Plessi *et al.,* 2007).

In terms of K content of orange jam incorporated with carrageenan (G) tend to have highest levels (526±67.5 mg/L). However, the second highest value is recorded in agar incorporated mango jam (C - 509.1 ± 56.9 mg/L) and carrageenan incorporated mango jam (F- 509.3±42.9 mg/L). No significant difference observed among them. K content of agar incorporated orange jam (D) was similar to that of the commercial mango jam (I) 371.2±45.0 and 371.00±47.9 mg/L respectively, lowest K content than others. The agar and carrageenan incorporated orange (G), mango (F), wood apple (E) and *Ulva* jam are abundant with K due to high K in fruits and seaweeds.

Iodine was detected significantly higher amount in *Ulva* jam (A) followed by mango jam incorporated with carrageenan (F) respectively 240.0±20.5, 150±13.2 mg/L. Similar values were reported in agar incorporated wood apple (B), orange jam (D) and mango jam (C), 135.02±21.8, 134±51.6 and 125±32 mg/L respectively. The carrageenan incorporated jams were found in the range from 56±5.9-150±13.2 mg/L. In the study *Ulva* and carrageenan jam were rich source of iodine compared to the others. The commercial market jams indicated very low levels of iodine content comparable to other jams. The reason for differences in iodine content was absorption and concentration capacity of iodine in different seaweed varieties. These jams can be extensively used as health food.

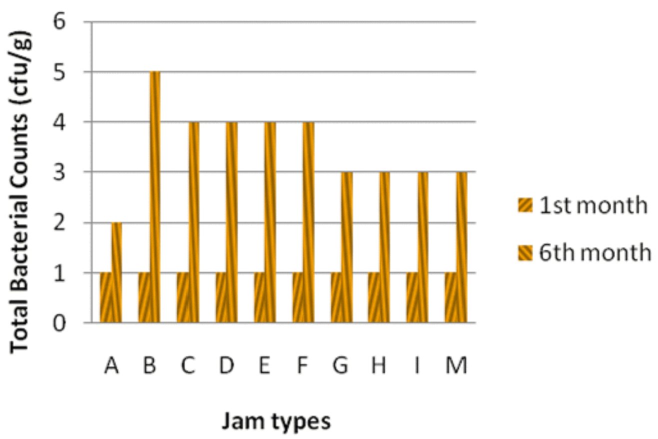

Fig. 4. Changes of total bacterial counts (CFU/g) in different jams during storage

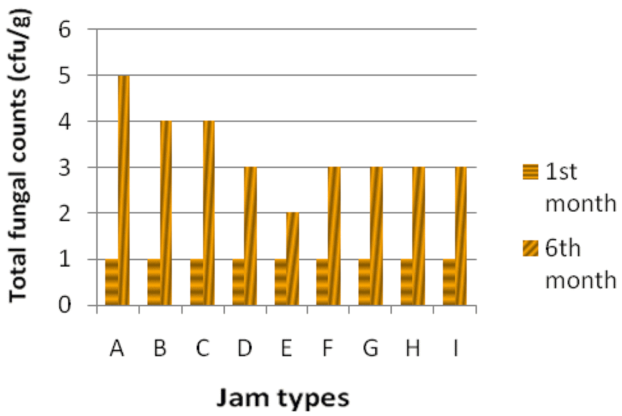

Fig. 5. Range of total fungal counts (CFU/g) on different jams at six months storage

The shelf life of the fruit jams is indicated by the microbiological quality. Fig. 4. And 5. show the total bacterial count and total fungal count of different jam types during storage period. The total plate counts were in the range of $1.x10^{1}$±0.03 to $2x10^{1}$±0.32–1x 10^{1}±0.03- $6x10^{1}$± 1.9 CFU/g during the six month period and it was below the rejection levels of consumption. The change of total bacterial count levels were similar in carrageenan incorporated jam and market jam. Among the agar incorporated fruit jams the lowest value were indicated in mango followed by orange and wood apple jams. Among carrageenan incorporated fruit jams, highest value was found in mango jam (F) followed by wood apple jam (E). The market jam recorded highest shelf life during the six month period.

The other visible sign of spoilage were form of mold or yeast. All the samples showed more than six months of shelf life. The fungi count was ranging from 1x 10^{1}±0.2-6 x 10^{3}±.1.2 CFU/g during the storage period. The higher fungus count observed in fruit jams, compared to the *Ulva* jam (A).

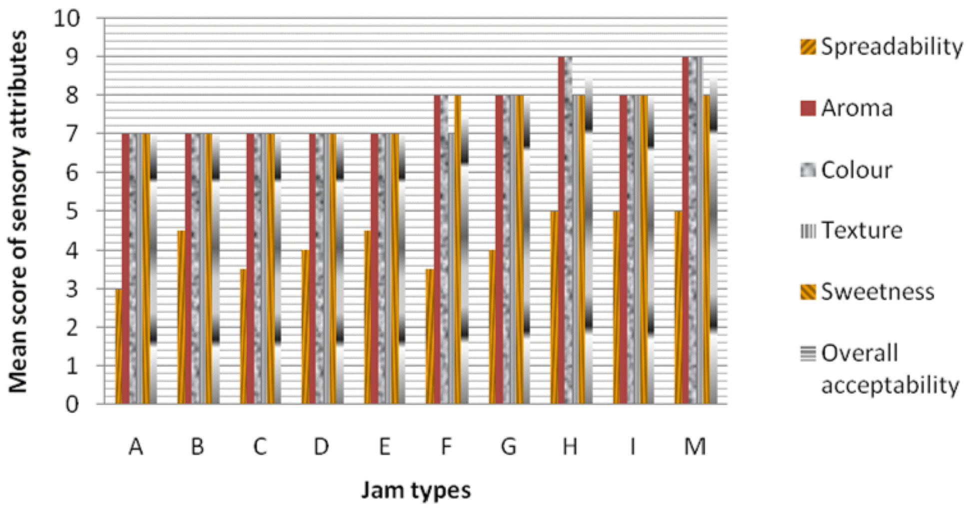

Fig. 6. Mean sensory score in (9-point-hedonic scale) overall acceptability at the six month storage period of different jams.

The overall acceptability of different jams during six months storage period was given in Fig. 6. The overall acceptability was decreased in all the samples with storage period. The maximum value 9 was obtained during the first two months in all the treatments except *Ulva* jam. The slight decrease in acceptability started after two months. The *Ulva* jam (A), two commercial jams (I and M) started after three months period. Statistical analysis revealed that treatments and storage effect on all the samples weren't significant. For the best quality commercial jam according to the labeling, the expiry period is one year. The difference between shelf life of jam types depend on correct composition of sugar and other preservatives. All the jam treatments were observed quite stable for more than six months.

Conclusion:

The two seaweed extracts of carrageenan and agar were most affordable nutritive thickener of the food substitute industry. The texture and spreadability can be also improved by addition of agar agar or carrageenan powder and sugar in the acceptable ratio. *Ulva* and agar based jams provide good source of carbohydrate, fat, protein and minerals. It can be concluded that *Ulva* jam and seaweed extracts incorporated jams are healthy and high in nutritional values and properties. They are five times higher than that of the commercially available jam in the market. It can also concluded that consumption of seaweed base jams can give more health benefits. The shelf life of the different seaweed based jam concentrations was for more than six month skeeping quality acceptable to the consumers, if stored at ambient temperature.

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