Storage stability of sweet corn (*Zea mays* var *saccharata Bailey*) jam: effect of sugar to inulin ratios on physicochemical, ascorbic acid, β-carotene and sensory characteristics

M K Zainol¹, L N Cheang¹, N Zuraidah², F Yahya¹ and Z M Zin¹,*

¹Faculty of Fisheries and Food Science, Universiti Malaysia Terengganu, Mengabang Telipot, 21030 Kuala Nerus, Terengganu, Malaysia
²Department of Community Nutrition, Faculty of Human Ecology, IPB University, Bogor, Indonesia

*E-mail: zamzahaila@umt.edu.my

Abstract. This study aimed to investigate the effect of different concentrations of inulin on the properties of sweet corn jam from *Zea mays* var *saccharata Bailey* during storage. Six different formulations of sweet corn jam (4.5%, 9%, 13.5%, 18% and 22.5% inulin) along with control samples (0% inulin) were prepared. Physical properties including water activity, total soluble solids, pH, firmness, spreadability and colour analysis together with proximate analysis, ascorbic acid and β-carotene composition were evaluated in 4 weeks of storage. Sensory acceptability test of the samples on colour, spreadability, taste and overall acceptability was carried out. Results showed that addition of inulin in sweet corn jam significantly affecting (p<0.05) the water activity, L* value and texture quality. Inulin could be added up to 9% without significantly affecting (p>0.05) the acceptance of colour and taste of sweet corn jam. Comparative study was done on control and 9% of inulin added sweet corn jam. Sample with 9.0% of inulin gave significantly higher (p<0.05) moisture and ash content. However, samples with 9.0% of inulin gave significantly lower (p>0.05) carbohydrate and β-carotene content. This study shows that inulin is not only good as prebiotic but has the potential to replace sugar added into healthy food products such sweet corn jam, since it could improve the nutritional quality of sweet corn jam with satisfying sensory acceptance.

1. Introduction
Corn is characterized by an abundance of forms with highly differentiated features, both botanical and utility character. Among the subspecies, sweet corn (*Zea mays* ssp. *saccharata*) has become more and more popular due to the taste and nutritional value. It is a yellow variety corn with high significant levels of phenolic flavonoid pigment antioxidants such as β-carotenes, and lutein, xanthines and cryptoxanthin pigments along with pro-vitamin A. A published survey which studied breakfast practices in Asian region found that a more westernized style breakfast; bread or toast with jam, appears to be the most common at-home breakfast for Malaysian [1]. Although several studies [2] have been conducted to develop healthier spread choices such as peanut butter, margarine, butter and fruit jam, however the availability of the development of healthier sweet corn jam was limited. Therefore, it was a big challenge for food manufacturers to develop a healthy product without or less sugar with optima sensory acceptability.
Inulin is a polyfructan industrially produced as a nondigestible carbohydrate containing naturally occurring fructo-oligosaccharides which possess some characteristics of dietary fibres and interest for its metabolic properties [3]. Since inulin is composed of oligofructose and possesses similar functional properties as sugar or glucose syrup. However, it is more soluble than sucrose and provides approximately 10% of the sweetness of sucrose [4].

Health conscious consumers nowadays concern and demand for reduced sugar products or low calories products have significantly risen to alleviate the health problems, to reduce or stabilise the body weight, and to work within the frame of a healthier diet. The role of sugar replacer in the successful manufacture of table spreads is crucial. Therefore, inulin, a sugar replacer is being proposed to partially replace sugar in sweet corn jam in this study.

2. Materials and Methods
2.1 Raw materials
Sweet corn (Zea mays var. saccharata bailey) were purchased from a local farm in Kelantan, Malaysia. Samples were selected with the maturity between 65 to 68 days after plantation with uniform size and weight. They were stored at chilled temperature (2°C to 10°C) until further use. Inulin was purchased from V.I.S Food Tech Ingredients Supplies Sdn. Bhd., Kuala Lumpur, Malaysia.

2.1.1 Catalase test
A small amount of a colony directly transferred to a clean glass slide using a toothpick or a sterile loop or needle. One drop of hydrogen peroxide was added and look for bubbles. Bubbles were a positive result for the presence of catalase [5].

2.2 Processing of sweet corn (Zea mays var. saccharata bailey) jam
Six formulations including a control sample were prepared (Table 1). All the treatments contributed to the one-level arrangement and were assigned using Completely Randomized Design (CRD).

| Treatment/Sample  | A   | B   | C   | D   | E   | F   |
|------------------|-----|-----|-----|-----|-----|-----|
| Sugar (%)        | 100 | 95.5| 91.0| 86.5| 82.0| 75.5|
| Inulin (%)       | 0   | 4.5 | 9.0 | 13.5| 18.0| 22.5|

2.3 Physical analysis
2.3.1 pH
The acidity of the samples was determined using a pH meter (Mettler Toledo, Ohio, USA). The samples (1 g) were diluted and homogenized in 20 mL of distilled water. The pH meter was allowed to stable for 30s before reading was taken. All measurements were taken in triplicates [6].

2.3.2 Total soluble solid
Total soluble solid was determined using a refractometer (Atago hand refractometer model N-4E, Japan).

2.3.3 Water activity
Water activity was determined using an AquaLab Cx-2 Water Activity meter [7].

2.3.4 Spreadibility
T.A.X.T Plus® Texture Analyzer using a spreadability rig was employed to analyse the spreadability of jam samples [8].
2.3.5 Firmness
T.A.X.T Plus® Texture Analyzer with multiple puncture probe was used to analyse the firmness of sample [9].

2.3.6 Colour profile
The colour profile of the samples was measured using a colourimeter (Konica Minolta, Tokyo, Japan) based on L*a*b* colour system, where L* (lightness), a* (redness) and b* (yellowness) [10].

2.4 Chemical analysis
2.4.1 Proximate analysis
The moisture, ash, protein, fat and fibre analyses were carried out according to AOAC methods [11].

2.4.2 Ascorbic acid
Iodine titration method was used to determine ascorbic acid content in the samples [12].

2.4.3 β-carotene content
One gram of samples was added into 5 ml of chilled acetone and vortexed at high speed for 10 min, and centrifuged at 1370 g for 10 min. The supernatant was collected and measured at 449 nm [13].

2.5 Sensory evaluation
Sensory evaluation was carried out by 35 untrained panellists to assess the acceptance of sweet corn jam. Panellists were asked to evaluate the sample for their acceptability of colour, spreadability, mouth feel, taste and overall acceptance [14].

2.6 Statistical analysis
All the results were analyzed using MINITAB 14.12.0.0, using a one-way analysis of variance (ANOVA) with Fisher’s least significant difference (LSD) test was used as the post-hoc test to determine the significant difference (p < 0.05 between the mean of samples.

3. Results and Discussion
3.1 Inactivation of enzyme
Prior to jam preparation, the hot water blanching pre-treatment on sweet corn was carried out (Table 2). Pre-treatment of fruits prior to production of jam is highly recommended because it is important in inactivating enzymes, modifying texture, preserving colour, flavour, and nutritional values and removing trapped air [15].

| Time (mins) | 0  | 2  | 4  | 5  | 6  |
|-------------|----|----|----|----|----|
| Production of gas bubbles | ++ | ++ | +  | -  | -  |

Note: ++ vigorously production of bubbles; + slightly production of bubbles; No production of bubbles

3.2 Physical properties of sweet corn jam
3.2.1 pH
The result shows that pH of all formulations decreased during the storage period (Table 3). If the acid value is too high, the gel elasticity increased and the gels become firm and brittle, as pH decrease of during the storage of jam [16]. The decrease in pH might be due to ascorbic acid degradation, pectin hydrolysis and other acidic compounds such as furfural development from sugar components [17].

3.2.2 Total soluble solids
The total soluble solids of the jam gradually decreased to 60.4 during 4 weeks of storage (Table 3). The reduction in soluble solids may be due to chemical hydrolysis caused by the jam's low pH.
Substitution of inulin for sugar did not show a significant effect \( (p > 0.05) \) on the total soluble solids of sweet corn jam except for 22.5% of inulin.

### 3.2.3 Water activity, \( a_w \)

Table 3 also depicts water activity was lower than 0.95 which can prevent the growth of pathogenic bacteria [18]. Sample with 18.0% and 22.5% of inulin have higher water activity than other samples which is concurrent with results obtained. These results are in accordance with [19] who reported that water activity increased in mango jam.

#### Table 3. pH, total soluble solid and water activity of sweet corn jams from week 0 to week 4.

| Treatment       | pH               | Water activity, \( a_w \) |
|-----------------|------------------|---------------------------|
|                 | Week 0 | 1    | 2    | 3    | 4          | Week 0 | 1    | 2    | 3    | 4    |
|-----------------|--------|------|------|------|-----------|--------|------|------|------|------|
| Control         | 3.27±0.04\( ^a \) | 3.18±0.02\( ^a \) | 3.06±0.02\( ^{ab} \) | 3.20±0.03\( ^a \) | 3.12±0.01\( ^b \) | 0.893±0.00\( ^b \) | 0.893±0.01\( ^a \) | 0.889±0.01\( ^a \) | 0.894±0.00\( ^{ab} \) | 0.894±0.00\( ^{ab} \) |
| 5% inulin       | 3.29±0.02\( ^a \) | 3.22±0.08\( ^a \) | 3.18±0.02\( ^a \) | 3.21±0.08\( ^a \) | 3.27±0.05\( ^a \) | 0.880±0.00\( ^{ab} \) | 0.888±0.00\( ^{ab} \) | 0.876±0.00\( ^{bc} \) | 0.894±0.00\( ^{ab} \) | 0.890±0.01\( ^a \) |
| 9.0% inulin     | 3.15±0.02\( ^a \) | 3.00±0.03\( ^{c} \) | 2.93±0.03\( ^{b} \) | 3.07±0.06\( ^{a} \) | 3.03±0.05\( ^{c} \) | 0.884±0.01\( ^{b} \) | 0.883±0.00\( ^{b} \) | 0.872±0.01\( ^{c} \) | 0.896±0.00\( ^{c} \) | 0.900±0.00\( ^{a} \) |
| 13.5% inulin    | 3.20±0.01\( ^a \) | 3.12±0.04\( ^{ac} \) | 3.00±0.04\( ^{a} \) | 3.22±0.06\( ^{a} \) | 3.28±0.04\( ^{a} \) | 0.884±0.01\( ^{b} \) | 0.883±0.03\( ^{b} \) | 0.884±0.01\( ^{ab} \) | 0.883±0.00\( ^{bc} \) | 0.892±0.00\( ^{a} \) |
| 18.0% inulin    | 3.26±0.05\( ^a \) | 3.21±0.04\( ^{ab} \) | 3.12±0.08\( ^{ac} \) | 3.11±0.03\( ^{a} \) | 2.92±0.04\( ^{d} \) | 0.894±0.01\( ^{a} \) | 0.894±0.02\( ^{a} \) | 0.871±0.00\( ^{e} \) | 0.879±0.00\( ^{c} \) | 0.892±0.01\( ^{a} \) |
| 22.5% inulin    | 3.17±0.06\( ^a \) | 3.09±0.06\( ^{bc} \) | 2.92±0.04\( ^{ab} \) | 3.22±0.10\( ^{a} \) | 3.20±0.01\( ^{ab} \) | 0.896±0.00\( ^{a} \) | 0.893±0.00\( ^{a} \) | 0.884±0.00\( ^{a} \) | 0.888±0.00\( ^{a} \) | 0.890±0.01\( ^{a} \) |

Means followed by different superscript letters in the same column of each property are significantly different \( (p<0.05) \).

#### Table 4. Firmness and spreadability of sweet corn jam from week 0 to week 4.

| Treatment | Firmness, g | Spreadability, g |
|-----------|-------------|------------------|
|           | Week 0 | 1    | 2    | 3    | 4    | Week 0 | 1    | 2    | 3    | 4    |
|-----------|--------|------|------|------|------|--------|------|------|------|------|
| Control   | 241.5 ±0.00\( ^{c} \) | 254.5 ±0.00\( ^{d} \) | 273.0 ±0.01\( ^{a} \) | 271.0 ±0.02\( ^{d} \) | 285.0 ±0.03\( ^{d} \) | 402.5 ±10.61\( ^{c} \) | 540.0 ±14.1 \( ^{c} \) | 735.0 ±7.1 \( ^{c} \) | 835.0 ±35.4 \( ^{d} \) | 955.0 ±35.4 \( ^{d} \) |
| 4.5%      | 264.0 | 297.5 | 338.5 | 412.0 | 392.0 | 455.5 | 745.0 | 785.0 | 835.0 | 970.0 |
Table 5. Lightness, L*, Greenness, a* and Yellowness, b* of sweet corn jam from week 0 to week 4.

| Colour profile | Lightness, L* |
|----------------|--------------|
|                | 0            | 1            | 2            | 3            | 4            |
| Control        | 62.54±0.15 b | 53.50±0.35 c | 54.54±0.25 d | 54.28±0.11 d | 53.54±0.38 c |
| 5% inulin      | 51.01±0.09 f | 54.07±0.67 d | 55.22±0.01 e | 55.07±0.04 e | 54.82±0.10 b |
| 9.0% inulin    | 63.97±0.26 ab| 54.30±0.06 de| 56.23±0.03 c | 57.11±0.01 a | 56.19±0.37 ab |
| 13.5% inulin   | 52.31±1.44 d | 54.93±0.34 cd| 55.29±0.35 d | 55.88±0.16 b | 55.16±0.23 ab |
| 18.0% inulin   | 64.87±0.10 a | 56.35±0.06 b | 57.28±0.49 b | 57.23±0.74 a | 56.26±0.39 ab |
| 22.5% inulin   | 54.56±1.42 c | 58.00±0.78 a | 57.95±0.08 b | 57.77±0.21 t | 57.07±1.95 a |

Means followed by different superscript letters in the same column are significantly different (p<0.05).

3.2.4 Texture

Firmness of jam was observed to increase with inulin concentration as well as the storage time over 4 weeks. In terms of firmness, inulin substitution shows significant effect (p < 0.05) on all the formulations of sweet corn jam. Sample with 18.0% and 22.5% of inulin show significant higher firmness compared to other samples. Generally, it increases the firmness of the jam, which may be explained by the effect of inulin gel formation [2]. The substitution of inulin significantly (p < 0.05) affects the spreadability value of sweet corn jam during the 4 weeks shelf life (Table 4). Addition of inulin tends to increase firmness of sweet corn jam which also reduces the ease of spreading the sweet corn jam. Kim et al. [18] also found that inulin concentration increased gel strength in margarine.

3.2.5 Colour profile
Table 5 shows that significant differences were observed among samples with different inulin concentration in terms of lightness, ($L^*$ values) during 4 weeks of storage. Samples with added inulin which are 9%, 13.5%, 18% and 22.5% exhibited higher $L^*$ value due to a greater number of reducing ends in inulin involved in Maillard reaction. The values of greyness ($a^*$) obtained for all formulations were negative, indicating a colour variation towards green, but colour changes towards red during storage. After 4 weeks of storage, samples with added inulin showed significantly higher yellowness ($b^*$ value) ($p < 0.05$) than control samples, indicating the destruction of carotenoid [19], due to the heating without time control before the desired soluble solid of jam is reached.

3.3 Chemical properties of sweet corn jam
3.3.1 Ascorbic acid content

The concentration of ascorbic acid significantly ($p<0.05$) increases with concentration of inulin (Table 6). This could be due to the oxidation process within the sample as the presence of residual oxygen in the headspace of the container. In addition, during storage, enzymatic catalytic reaction also occurred within the jam mass [17].

3.3.2 Beta-carotene content

Beta-carotene content increased significantly ($p<0.05$) steadily during 4 weeks of storage (Table 6). This is due to the cell membranes being damaged by homogenization and heat treatment, leading to protein-carotenoid complex cleavage. Gao and Vasantha Rupasinghe [20] reported the retention of beta-carotene in apple carrot juice during 4 weeks of storage.
Table 7. Proximate composition of 0% and 9% inulin of sweet corn jam.

| (%)        | Moisture (%) | Protein (%) | Fat (%) | Ash (%) | Fiber (%) | Carbohydrate (%) |
|------------|--------------|-------------|---------|---------|-----------|------------------|
| Control    | 41.32±0.226^a | 2.16±0.001^a | 1.70±0.013^a | 0.55±0.005^a | 49.14±0.035^a | 5.29±0.024^a |
| 9.0% inulin| 42.26±0.092^b | 2.26±0.040^a | 1.72±0.012^a | 0.58±0.004^b | 49.63±0.410^a | 3.55±0.550^b |

Means followed by different superscript letters in the same row are significantly different (p<0.05).

3.4 Sensory acceptability of sweet corn jam

The sensory acceptability analysis showed that the colour attributes of sweet corn jam were not affected by different levels of inulin concentration (Table 8). Inulin would not participate in Maillard reactions and hence would not contribute to colour due to the reaction [22]. Jam containing 9 % inulin had higher spreadability acceptance and that the control sample and sample with 4.5 % inulin were not substantially different. However, slightly better than high levels of inulin samples were approved. It was observed that these samples had lower firmness and higher spreadability than high inulin sample concentrations. The taste of sweet corn jam is not affected by different levels of inulin concentration. It is difficult to distinguish between varying sugar concentration in food products even for trained panellists [23]. Greater acceptance with 9 % of inulin was observed compared to the control sample. The sample earned scores higher than 5 with 9 % of inulin, which is marginally comparable for all characteristics, suggesting that customers (untrained panellists) like the products well. There was no substantial difference in the 9.0 % inulin sample between the control and the 4.5 %, 13.5 and 18 % inulin sample, yet there was a significant difference between the 22.5 % inulin samples.

Table 8. Effect of different concentration of inulin on sensory acceptability of sweet corn jam.

| Sample      | Colour (L*) | Texture (Spreadability) | Taste (a) | Overall acceptability (b) |
|-------------|-------------|-------------------------|-----------|--------------------------|
| Control     | 5.06±1.75^a | 5.10±1.47^a             | 4.80±1.78^a | 5.00±1.59^ab             |
| 4.5% inulin | 5.36±1.15^a | 5.10±1.26^ab            | 4.93±1.61^a | 4.93±1.46^ab             |
| 9.0% inulin | 5.03±1.18^a | 5.50±1.38^ab            | 4.96±1.75^a | 5.27±1.61^a              |
| 13.5% inulin| 4.93±1.08^a | 3.96±1.60^bc            | 4.67±1.44^a | 4.60±1.52^ab             |
| 18.0% inulin| 5.00±1.17^a | 4.40±1.54^cd            | 4.63±1.37^a | 4.90±1.34^ab             |
| 22.5% inulin| 4.76±1.33^a | 3.43±1.52^d             | 4.33±1.29^a | 4.40±1.38^b              |

Means followed by different superscript letters in the same column are significantly different (p<0.05).

4. Conclusion

The addition of inulin into sweet corn jam had caused significant effect (p < 0.05) on the water activity, L* value, firmness and spreadability of the jam. Sensory evaluation exhibited inulin containing jam were more accepted based on their texture and overall acceptability. Sample with 9.0% inulin was suggested as the best formulation because it had higher mean scores in terms of spreadability and overall acceptance in the sensory acceptance test. Sweet corn jam containing inulin has shown its potential in providing consumers with a better variety of healthy food.

Conflict of interest

The authors declare that there is no conflict of interest in conducting this study.

Acknowledgments

The authors would like to thank the Faculty of Fisheries and Food Sciences (FPSM) as well as UMT Research and Field Service Centre for the facilities to conduct this study.
References

[1] Chong Y H, Howden, J A, Leung, S F, Rabuco, L B, Sakamoto, M and Tchai, B S 1993 Breakfast practices in the Asian region J. Clin. Nut. 2 77-84

[2] Phang Y L and Chan H K 2009 Sensory description analysis and consumer acceptability of original "kaya" and "kaya" partially substituted with inulin Int. Food Res. J. 16 483-92

[3] Ishak R, Mustafa S, Sipat A, Syed Muhammad S K and Abdul Manap M Y 2006 Influence of inulin addition on physical properties and sensory of ‘Dadhi’ J. App. Sci. 6 1128-31

[4] O’Neill J 2008 Using inulin and oligofructose with high-intensity sweeteners Functional Ingredients

[5] Subbarayyan P R and Sarkar M 2004 A comparative study of variation in codon 33 of the rpoS gene in Escherichia coli K12 stocks: implications for the synthesis of sigma(s) Mol.Genet. Genomics 270 533–38

[6] Zainal Abidin N A, Mohd Zin Z, Abdullah M A A, Rusli N D and Zainol M K 2020c Physicochemical properties and sensory acceptance of Canavalia ensiformis tempah energy bar Food Res. 4 1637-45

[7] Zainol M K, Che-Esa N S, Azlin-Hasim S, Zamri A I, Mohd Zin Z and Abdul Majid H A 2020b The ramification of Arabic gum and gelatine incorporation on the physicochemical properties of Belimbing Buluh (Averhoa belimbi) fruits pastilles Food Res. 4 532-38

[8] Javanmard M and Koohikamali S 2011 A study on the effect of native sago starch on the mechanical properties of modified mango jam Aust. J. Basic and App. Sci. 5 501-7

[9] Mamat H, Akanda J M H, Zainol M K and Yu A I 2018 The influence of seaweed composite flour on the physicochemical properties of muffin J. Aquatic Food Prod. Tech. 27 635-42

[10] Hau E H, Mohd Zin Z, Zuraiddah N, Shaharuddin N A and Zainol M K 2018 Physicochemical properties of powdered protein hydrolysate from Yellowstripe scad (Selaroides leptolepis) fish Int. Food Res. J. 25 2555-61

[11] AOAC 2000 Official Methods of Analysis (17th edition) Association of Official Analytical Chemists, Washington DC

[12] Biswas A K, Sahoo J and Chatli M K 2011 A simple UV-Vis spectrophotometric method for determination of beta-carotene content in raw carrot, sweet potato and supplemented chicken meat nuggets Food Sci. and Tech. 44 1809-13

[13] Chew R M, Mohd Zin Z, Ahmad A, Mohtari N F, Rusli N D and Zainol M K 2020 Physicochemical and sensory properties of deep fried battered squid containing Brownstripe red snapper (Lutjanus vitta) protein hydrolysate Food Res. 4 1245–53

[14] Safdar M N, Mumtaz A and Hameed T 2012 Storage studies of jam prepared from different mango varieties Pakistan J. Nut. 11 555-61

[15] Souad A M, Jamal P and Olorunnisola K S 2012 Effective jam preparations from watermelon waste Int.Food Res. J. 19 1545-49

[16] Correa R C G, Sora G T S, Haminuik C I W, Ambrosio-Ugri M C B, Bergamasco R and Vieira A M S 2011 Physico-chemical and sensorial evaluation of guava jelly made without added sugar Chem. Eng. Trans. 24 505-10

[17] Kersdorp P and Nakneen P 2012 Effect of sorbitol substitution on physical, chemical and sensory properties of low-sugar mango jam Proc.Sci. and Tech.12 12-18

[18] Kim B H, Shewfelt R L, Lee H and Akoh C C 2005 Sensory evaluation of butterfat-vegetable oil blend spread prepared with structured lipid containing camola oil and caprylic acid J. Food Sci. 70 S406-12

[19] Javanmard M, Chin Y L, Mirhosseini S H and Endan J 2012 Characteristics of gelling agent substituted fruit jam: studies on the textural, optical, physicochemical and sensory properties International J. Food Sci. and Tech.47 1808–18

[20] Gao J and Vasantha Rupasinghe H P 2012 Nutritional, physicochemical and microbial quality of ultrasound-treated apple-carrot juice blends Food and Nut. Sci. 3 212-18

[21] Megala P and Hyamavathi T V 2011 Inulin and fructooligosaccharides incorporated functional fruit bars World Acad. Sci. Eng. and Tech. 59 600-5
[22] Shu C K 1998 Flavor components generated from inulin *J. Agric. and Food Chem.* 46 1964-5
[23] Bolenz S, Amtsberg K and Schape R 2006 The broader usage of sugars and fillers in milk chocolate made possible by the new EC cocoa directive. *Inter. J. Food Sci. and Tech.* 41 45-55