INFLUENCE OF PACKAGING MATERIALS ON PHYSICOCHEMICAL PROPERTIES AND SENSORY ACCEPTANCE OF WATERMELON ROLL-UPS DURING STORAGE

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ABSTRACT

The study aimed to investigate the influence of packaging materials on physicochemical properties and sensory acceptance of watermelon roll-up during storage. Samples were prepared by pasteurising the watermelon flesh and rind purees with a predetermined amount of ingredients at 90 °C for 5 min, then dried at 60°C for 11 hours, cut, rolled and packed in two packaging materials, i.e., aluminium polyethene (AL/PE) and nylon polyethene (NY/PE) bags and stored in the chamber (40°C, RH = 75%) using accelerated shelf life testing for 3 months (equivalent to 18 months at ambient temperature). During storage, the watermelon roll-up in the Al/PE bag showed an increment in pH and total soluble solids (TSS) content, while water activity (Aw), moisture content (MC) and L, a* and b* colours showed a decrease throughout storage. In contrast, the sample packed in the NY/PE bag exhibited an increase in pH, Aw and MC whereas the TSS, L*, a* and b* colours demonstrated a decrease during storage. The citrulline content decreases significantly irrespective of the packaging materials used. The sample in the Al/PE bag showed the highest retention of citrulline during storage. For sensory evaluation, both samples received an average score above 5 (like slightly) for overall acceptability throughout 3 months of storage. However, overall acceptability for samples in AL/PE and NY/PE from 0 to 3 months was reduced by about 8.97% and 15.30%, respectively. In conclusion, an AL/PE bag should be chosen as the most suitable packaging material to store watermelon roll-up, as it provides better stability of citrulline content throughout storage.*

Keywords: Watermelon, fruit roll-up, physicochemical, storage, sensory acceptance, packaging materials.

INTRODUCTION

Watermelon, scientifically known as *Citrullus lanatus*, is a tropical fruit that thrives in various regions across Africa and Southeast Asia. The biomass of watermelon can be classified into three primary compositions: flesh, seed, and rind. The watermelon rind is edible, but it is typically discarded because it is bland and lacks flavour. The watermelon rind is rich in nutrients such as potassium, dietary fibre and citrulline, an amino acid that promotes smooth blood circulation and relaxes blood vessels. According to previous research reports, watermelon has a high concentration of citrulline. The citrulline content in the rind, when measured based on dry weight, was found to be higher at 24.7 mg/g compared to the flesh of the watermelon, which had a citrulline content of 16.7 mg/g (Rimando and Perkin-Veazie 2005).

Fruit roll-ups, also known as fruit leathers, are a dried fruit-based confectionery product that is commonly consumed as a snack or dessert (Diamante et al. 2014). In Malaysia, fruit roll-ups are known as ‘gegulung buah’. The fruit roll-ups possess a chewy texture and a pleasant taste while being naturally low in fat and abundant in dietary fibre (Diamante et al. 2014). Additionally, it is lightweight and can be conveniently stored and packed. Consuming fruit leather is a cost-effective and convenient alternative to natural fruits for obtaining a variety of essential nutrients. The initial contribution to fruit leather preparation was provided by the extension services of various universities in the USA and since then the research on fruit leather has evolved (Bandaru and Bakshi, 2020; Raab and Oehler, 1976).

Fruit leathers are produced by dehydrating fresh fruit pulp or a blend of fruit juice concentrates and other ingredients through a complex process (Huang and Hsieh, 2005). Given their short harvest season and susceptibility to spoilage, most fresh fruits can be effectively preserved by making fruit leather (Maskan and Maskan, 2002). The production of fruit leather involves extracting moisture from a fruit puree until it forms a sheet with a texture resembling leather (Diamante et al. 2014). The moist purees are dehydrated by spreading them on a large flat tray until they become cohesive "leathery" sheets. This dehydration process involves extracting moisture from the fruit puree or a prepared pasteurized fruit juice with additives. Various additives can be used in different types of fruit leather, including glucose syrup, maltodextrin, sodium metabisulfite, and sorbic acid (Demarchi, 2013; Valenzuela and Aguilera, 2015; Sharma et al., 2013). Typically, fruit pulps are mixed with appropriate amounts of sugar, pectin, acid, and colourants, and then dehydrated into sheet-like products. There are a wide variety of fruit roll-ups or fruit leather products available in the market, including mango, apricot, grape, berry, kiwifruit, and jackfruit leathers.

Packaging plays a crucial role in food products as it protects them against biological, chemical, and physical damage while providing essential information about attributes, nutrition, and ingredients (Anin et al., 2010). The packaging material prevents product deterioration and enhances shelf life by maintaining its quality. It serves as a barrier against chemical, physical, and biological effects, including minimizing changes in product composition due to environmental factors such as gas, moisture, or light exposure. Additionally, it acts as a shield, safeguarding against mechanical damage, impacts, crushing, and other potential forms of harm (Bandaru and Bakshi, 2020). Aluminum polyethene, nylon polyethene plastics, high-density polyethene, polypropylene, low-density polyethene, polyester, and butter paper are commonly used packaging materials for fruit roll-ups (Bandaru and Bakshi, 2020). Each type of packaging material has a distinct impact on the stability of fruit roll-ups. Therefore, this study aimed to investigate the influence of packaging materials on the physicochemical properties and sensory acceptance of watermelon roll-ups during storage.

MATERIALS

Watermelons were purchased from Pasar Borong Selangor, Seri Kembangan, Selangor, Malaysia. Chemicals used such as HPLC-grade acetonitrile and orthophosphoric acid were purchased from Merck (Darmstadt, Germany). Food-grade chemicals such as citric acid, pectin, maltodextrin, flavour and potassium sorbates were purchased from Meilun Food Chemical Sdn. Bhd. (Klang, Selangor, Malaysia) while packaging materials were purchased from Falcon Kitchenware and Packaging Sdn. Bhd. (Setapak, Kuala Lumpur, Malaysia).

METHODS

PREPARATION OF WATERMELON FRUIT ROLL-UPS

The watermelons were washed thoroughly, and the outer green rind was peeled. The flesh and rind were blended separately until they became slurry-like purees. Watermelon fruit roll-up was produced based on the proportion of watermelon flesh (70%) and rind purees (10%). The sample was prepared by pasteurising the watermelon flesh and rind purees with a predetermined amount of ingredients, namely sugar, glucose syrup, maltodextrin, citric acid, vegetable oil, pectin, water, flavour and potassium sorbates at 90 °C for 5 min, then dried at 60°C in the cabinet dryer for 11 hours, cut, rolled and packed in two different packaging materials, namely aluminium polyethene (AL/PE) and nylon polyethene (NY/PE) bags. The samples were stored in a climatic chamber (40°C, relative humidity = 75%) via accelerated shelf-life testing for 3 months (equivalent to 18 months at ambient temperature). For up to three months, a few samples of each packaging material were withdrawn for monthly analysis.

DETERMINATION OF TOTAL SOLUBLE SOLIDS AND PH

The total soluble solid (TSS) contents were measured using a pocket refractometer (Atago, Tokyo, Japan) with a scale of 0–53°Brix. The pH of the samples was measured using a pH meter (FE20, Mettler Toledo, Switzerland).

DETERMINATION OF MOISTURE CONTENT

The moisture content was determined using the air oven method (AOAC 2000). The moisture content was calculated from the weight difference between the original and dried sample by the following equation:

$$\text{Moisture content (\%)} = \frac{(mw - md)}{mw} \times 100$$

Where mw is the wet mass and md is the dry mass of the sample.

DETERMINATION OF WATER ACTIVITY

The water activity (Aw) of watermelon roll-up samples was determined using a Labswift-aw hygrometer (Novasina, Switzerland). The equilibrium of the air humidity over a sample (water-vapour pressure), which is proportional to the Aw value, was measured. Samples were mashed and placed into three individual sample cups. The first replicate of the sample was placed in the measurement chamber (left side) while the second replicate was placed in the preconditioning chamber (right side). The machine's cover was then closed before the 'START' button could be pressed to analyse the sample. The steps were repeated for the second and third replicates to be placed in the measurement chamber (left side) to be analysed. Values were taken after constant readings were obtained.

DETERMINATION OF COLOUR INTENSITY

The colour intensity of the fruit-roll samples was measured using Chroma Meter Minolta CR- 400/410 (Minolta Co., Osaka, Japan) based on L^* a^* b^* colour system. L^* denotes the lightness on a 0 – 100 scale from black to white, while a^* and b^* denote the redness (+) or greenness (–) and yellowness (+) or blueness (–) hues, respectively.

DETERMINATION OF CITRULLINE

The L-citrulline content is determined via high-performance liquid chromatography (HPLC) As described by Rasdin et al. (2018). A customizable automatic infusion system and a Waters 2695 HPLC system with a photodiode array detector are utilized. HPLC-grade acetonitrile and 0.1% orthophosphoric acid mobile phase are utilized in conjunction with a C18 column to separate the samples. Elimination by gradient is required for the determination of L-citrulline. Using a calibration graph comprised of standard L-citrulline concentrations, the content is quantitatively evaluated by peak area in the chromatogram.

SENSORY ACCEPTABILITY TEST

The sensory evaluation was carried out at the Food Science and Technology Research Centre, MARDI Serdang Selangor, Malaysia by 40 untrained panellists. Sensory attributes were evaluated according to the degree of liking in colour, aroma, texture, sweetness, sourness and overall acceptability. All samples were served and coded with random three-digit numbers. The sensory attributes of the samples were evaluated using a 7-point category hedonic scale (1 = dislike very much; 4 = neither like nor dislike; 7 = like very much) as described by Meilgaard *et al*. (1999).

STATISTICAL ANALYSIS

All analyses were done in triplicate. Experimental data were subjected to the analysis of variance (ANOVA), and the significant differences among means were determined by the Least Significant Difference (LSD) at $p \leq 0.05$ using SAS software (Ver. 9.4., SAS Institute, Cary, NC, USA).

RESULTS AND DISCUSSION

TOTAL SOLUBLE SOLIDS AND PH

There were no significant differences in total soluble solids (TSS) content between the watermelon rolls-up samples packed in different packaging materials, as shown in Table 1. Collectively, the TSS content slightly increases with storage time regardless of the packaging material used. The result showed that TSS value increased in both packaging materials during the first month of storage time but dropped slightly in the second and third months of storage in the climatic chamber. The pH of the watermelon rolls-up samples ranged from 3.26 to 3.93, which could be classified as high-acid food (pH < 4.6) (Babajide *et al*., 2013), thus rendering the samples resistant to microbial spoilage. The result revealed that pH values significantly increased in both packaging materials during 3 months of storage time in the climatic chamber (*Table 1*). The increment in pH value may be due to acid hydrolysis of some polysaccharides such as starch, cellulose, and pectin into disaccharides and monosaccharides, which are accountable for the increase in sweetness and decrease in sourness (Pareek et al. 2011).

Table 1. Result of pH and TSS of watermelon rolls-up throughout storage in different packaging materials

Storage Time (month)	pH		TSS (°brix)	
	AL/PE	NY/PE	AL/PE	NY/PE
0	3.26 ± 0.01Ab	3.22 ± 0.02 Bb	8.03 ± 0.76Aa	7.87 ± 0.67Aa
1	3.93 ± 0.02Aa	3.91 ± 0.05Aa	8.43 ± 0.15Aa	8.60 ± 0.56Aa
2	3.93 ± 0.02Aa	3.93 ± 0.01Aa	8.23 ± 0.95Aa	8.23 ± 1.04Aa
3	3.93 ± 0.02Aa	3.93 ± 0.02Aa	8.23 ± 0.57Aa	8.03 ± 0.32Aa

Means within a row with the same upper-case letters are not significantly different at $p>0.05$; Means within a column with the same lower-case letters are not significantly different at $p>0.05$.

MOISTURE CONTENT AND WATER ACTIVITY

Dehydration is the essential process for removing moisture from the fruit roll-up. Increased moisture content correlates with greater microbial activity, resulting in product spoilage. FAO (2007) states that fruit leather or fruit roll-ups should have a moisture content ranging from 15% to 25% to facilitate an extended shelf life and inhibit microbial deterioration. The moisture content of the watermelon fruit roll-up varied significantly depending on the packaging materials used, with values ranging from 18.21% to 20.82% (Table 2). The sample stored in an AL/PE bag exhibited a reduction in moisture content throughout storage. Conversely, the sample contained in the NY/PE bag exhibited an increase in moisture content over three months of storage. This finding is consistent with Kumar et al. (2007), who discovered that guava leather packed in aluminium foil experienced the least moisture loss during storage compared to guava leather packed in polypropylene and butter paper packaging materials.

There were significant differences in the water activity of the watermelon fruit roll-up in different packaging materials, ranging from 0.58 to 0.64 (Table 2). Similar trends were seen in the results for moisture content, with the sample kept in an AL/PE bag exhibiting a decrease in water activity over time. In contrast, the sample stored in the NY/PE bag demonstrated a rise in water activity during the period of storage. This could be attributed to the fact that the AL/PE bag has a lower permeability to oxygen and water vapour than the NY/PE plastic bag. This finding aligns with the study by Irwandi et al. (1998), which investigated durian fruit leather during storage over 12 weeks at room temperature using various packaging materials. They observed that laminated aluminium foil showed the least decrease in water activity and changes in moisture content, enabling it to preserve the desired textural characteristics of the fruit leather. In contrast, low-density polyethene led to the highest changes in moisture and water activity.

Table 2. Result of moisture content and water activity of watermelon rolls-up throughout storage in different packaging materials

Storage Time (month)	MC (%)		Aw	
	AL/PE	NY/PE	AL/PE	NY/PE
0	19.61 ± 0.09Aa	18.31 ± 0.11Bb	0.60 ± 0.01Aa	0.60 ± 0.01Ac
1	18.72 ± 0.14Abc	18.82 ± 0.85Ab	0.58 ± 0.01Bb	0.61 ± 0.02Abc
2	18.21 ± 0.22Bc	19.24 ± 0.84Ab	0.56 ± 0.01Bb	0.62 ± 0.02Aab
3	18.95 ± 1.14Bab	20.82 ± 1.68Aa	0.58 ± 0.02Bb	0.64 ± 0.01Aa

Means within a row with the same upper-case letters are not significantly different at $p>0.05$; Means within a column with the same lower-case letters are not significantly different at $p>0.05$.

COLOUR INTENSITY

Lightness (*L*)* for watermelon roll-up stored in both packaging materials ranged from 41.90 to 51.88 after storage for three months in the climatic chamber (Table 3). The *L** values slightly decreased with the storage period, which means that the watermelon roll-up in both types of packaging turned darker over time. The *a** value decreased with longer storage duration regardless of the packaging material used. It can be seen that the watermelon roll-up packed in AL/PE bag significantly had the highest *a** value, while the watermelon roll-up packed in NY/PE bag had the lowest *a** value after three months of storage. Visibly, watermelon roll-ups packaged in both materials exhibit a deterioration in their red hue. It was demonstrated by the similar decreasing trend of *a** values during storage. Yellowness (*b*)* for the watermelon roll-up packed in different packaging materials ranged from 25.28 to 29.17 after storage for three months (Table 7). The result demonstrated the *b** value of the watermelon roll-up slightly decreased regardless of packaging materials.

Table 3. Result of colour intensity of watermelon rolls-up throughout storage in different packaging materials

Storage Time (month)	*L** (lightness)		*a** (redness)		*b** (yellowness)	
	AL/PE	NY/PE	AL/PE	NY/PE	AL/PE	NY/PE
0	43.76 ± 2.86Bb	51.88 ± 2.08Aa	37.75 ± 2.66Aa	35.50 ± 2.88Aa	26.21 ± 2.48Ba	29.17 ± 1.36Aa
1	47.94 ± 2.51Ba	50.96 ± 1.48Aa	33.35 ± 1.23Ab	31.26 ± 2.16Bb	25.35 ± 1.88Aa	25.97 ± 0.95Abc
2	50.07 ± 2.76Aa	46.06 ± 0.98Bc	27.25 ± 1.75Ac	30.58 ± 1.52Bb	26.83 ± 2.68Aa	24.81 ± 1.83Ac
3	41.90 ± 5.22Bb	49.46 ± 1.72Ab	28.29 ± 1.52Ac	25.33 ± 0.99Bc	25.28 ± 3.75Aa	27.27 ± 3.33Ab

Means within a row with the same upper-case letters are not significantly different at $p>0.05$; Means within a column with the same lower-case letters are not significantly different at $p>0.05$.

CITRULLINE CONTENT

There was a significant difference observed in the watermelon roll-ups that were packed using various packaging materials throughout the storage duration. The citrulline content in the watermelon roll-up decreased over time in both types of packaging materials. Although exhibiting a declining trend, the citrulline content in watermelon roll-up packaged in AL/PE material was significantly higher than that in watermelon roll-up packaged in NY/PE plastic. These findings indicate that the AL/PE packaging material provides superior protection for the citrulline content in the watermelon roll-up compared to NY/PE plastic. This is because AL/PE is opaque, besides has a lower permeability to oxygen and water vapour than NY/PE plastic.

Table 4. Result of citrulline content of watermelon rolls-up throughout storage in different packaging materials

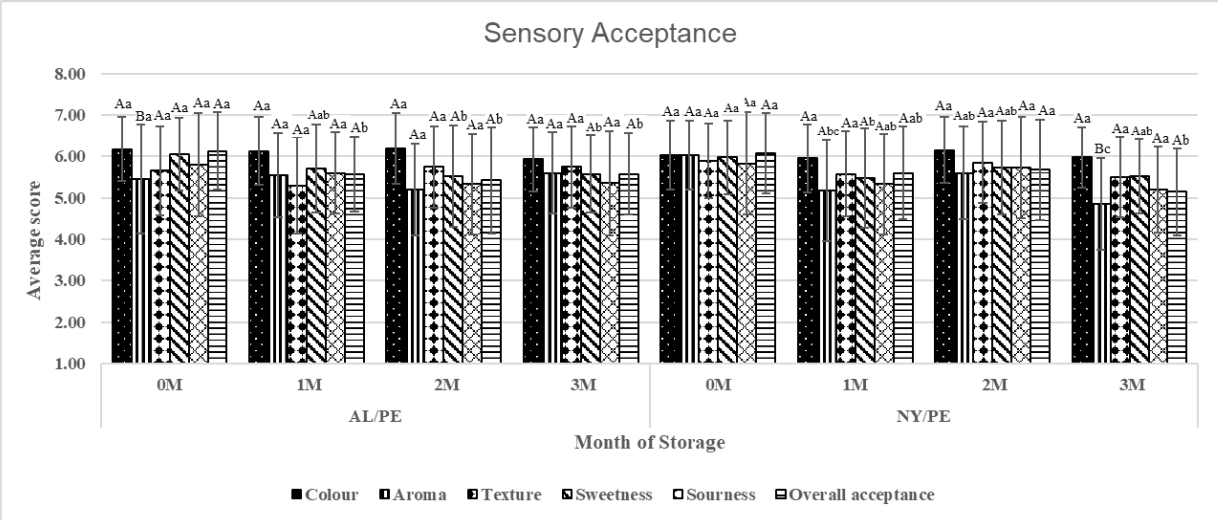
Storage Time (month)	Citrulline (µg/g)	
	AL/PE	NY/PE
0	2249.43 ± 30.41Aa	2119.20 ± 63.83Ba
1	1556.93 ± 19.13Ab	933.92 ± 42.91Bb
2	1019.47 ± 37.14Ac	788.40 ± 21.50Bc
3	709.07 ± 44.46Ad	544.72 15.08Bd

Means within a row with the same upper-case letters are not significantly different at $p>0.05$; Means within a column with the same lower-case letters are not significantly different at $p>0.05$

SENSORY ACCEPTANCE

Throughout the three-month storage time, the panellists gave the watermelon roll-up in both packaging materials an average score of 5 to 6 (slightly like to like) for almost all attributes (apart from aroma). There was no significant difference in the average scores of colour, texture, sweetness, sourness and overall acceptance between watermelon roll-up samples packed in both materials during the storage period. However, overall acceptability for samples in Al/PE and Ny/PE from 0 to 3 months was reduced by about 8.97% and 15.30%, respectively. The watermelon roll-up in AL/PE packaging material received a higher average score at the end of the storage period compared to the watermelon roll-up in NY/PE plastic. In general, the watermelon roll-up packaged in AL/PE material was favoured by the panellists. The aforementioned sample received higher scores in terms of aroma, texture, sweetness, sourness, and overall acceptability, despite being stored for 3 months in the climatic chamber.

Figure 1. Result of sensory acceptance of watermelon rolls-up throughout storage in different packaging materials



Different uppercase letters in the same bar between the packaging materials (AL/PE and NY/PE) within the same month are significantly different at $p<0.05$. Different lowercase letters in the same bars within the same packaging material are significantly different at $p<0.05$.

CONCLUSION

The study compared the effects of different packaging materials on watermelon roll-up during a 3-month storage period using accelerated shelf-life testing. The watermelon roll-up stored in the AL/PE bag maintained better stability in pH, total soluble solids (TSS), and citrulline content, while the Ny/PE bag showed variations. Despite sensory scores above 5 (like slightly), overall acceptability decreased by 8.97% (AL/PE) and 15.30% (NY/PE). In conclusion, AL/PE is recommended for watermelon roll-up packaging due to excellent citrulline retention and overall stability during storage.

REFERENCES

Anin, S. K. , Ellis, W. O. and Adubofuor, J. (2010). Effects of two packaging materials and storage conditions on the quality of fresh taste, a natural and locally produced orange drink in Ghana. *African Journal of Food Science and Technology*. 1(6), 132-138.

AOAC. (2000). Official method of analysis of AOAC International. 17th Edition. Gaithersburg, MD, USA: Association of Analytical Communities.

Babajide, J. M., Olaluwoye, A. A., Taofik Shittu, T. A. and Adebisi, M. A. (2013). Physicochemical properties and phytochemical components of spiced cucumber-pineapple fruit drink. *Nigerian Food Journal.* 31, 40– 52.

Bandaru, H. and Bakshi, M. (2020). Fruit Leather: Preparation, packaging and its effect on sensorial and physico-chemical properties: A review. *Journal of Pharmacognosy and Phytochemistry*, 9(6): 1699-1709.

Demarchi, S. M., Quintero Ruiz, N. A., Concellon, A. and Giner, S. A. (2013). Effect of temperature on hot air drying rate and on retention of antioxidant capacity in apple leathers. *Food and Bioproducts Processing*. 91, 310-318.

Diamante, L. M., Bai, X. and Busch, J. (2014). Fruit Leathers: Method of preparation and effect of different conditions on qualities. *International Journal of Food Science*. 2014, 1-12.

FAO. (2007). Fruit Leather. Fruit Processing Toolkit. Food and Agriculture Organizations of the United Nations.

Huang, X. and Hsieh, F. H. (2005). Physical properties, sensory attributes and consumer preference of pear fruit leather. *Journal of Food Science*. 70, 177-186.

Irwandi, J., Che Man, Y. B., Yusof, S., Jinap, S. and Sugisawa, H. (1998). Effects of type of packaging materials on physicochemical, microbiological and sensory characteristics of durian fruit leather during storage. *Journal of the Science of Food and Agriculture*. 76(3), 427-434.

Kumar, R., Jain, R. K. and Mandal, G. (2007). Storage stability of guava leather in different packing materials. Acta Horticulturae. 735, 621-625.

Maskan, A., Kaya, S. and Maskan, M. (2002). Effect of concentration and drying processes on color change of grape juice and leather (pestil). *Journal of Food Engineering*. 54(1), 75–80.

Meilgaard, M., Civille, G. V. and Carr, B. T. (1999). Sensory evaluation techniques, 3rd ed. Boca Raton, Florida: CRC Press.

Pareek, S., Ravinder, P. and Subrata, M. (2011). Effect of juice extraction methods and processing temperature-time on juice quality of Nagpur mandarin (*Citrus reticulata Blanco*) during storage. *Journal of food science and technology.* 48(2), 197-203.

Raab, C. and Oehler, N. *Making Dried Fruit Leather*, Fact Sheet 232, Oregon State University Extension Service,Tillamook, Ore, USA, 1976.

Rasdin, R. Hairil Rashmizal, A. R., Mohd Ilham, A. and Wan Mazlina, M. S. (2018). Development of isocratic RP-HPLC Method for separation and quantification of L-Citrulline and L-Arginine in watermelons. *International Journal of Analytical Chemistry.* 2018, 1-9.

Sharma, S. K., Chaudhary, S. P., Rao, V. K., Yadav, V. K., Bisht, T. S. (2013). Standardization of technology for preparation and storage of wild apricot fruit bar. *Journal of Food Science and Technology*. 50:784-790.

Rimando, A. M., and Perkins-Veazie, P. M. (2005). Determination of citrulline in watermelon rind. *Journal of Chromatography A.* 1078(1-2), 196-200.

Valenzuela, C. and Aguilera, J. M. (2015). Effects of maltodextrin on hygroscopicity and crispness of apple leathers. *Journal of Food Engineering*. 144, 1-9.

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