Intl. J. Food. Ferment. Technol. 7(1): 157-163, June 2017

DOI: 10.5958/2277-9396.2017.00017.4

RESEARCH PAPER

A Study on Shelf-life Extension of Sweet Corn

H.P. Geetha*[1], V. Palanimuthu[2] and G. Srinivas[1]

[1]Department of Processing and Food Engineering, University of Agricultural Sciences, Raichur, Karnataka, India
[2]Department of Processing and Food Engineering, University of Agricultural Sciences, Bangalore, India

*Corresponding author: geeta322@gmail.com

Paper No.: 177 **Received:** 18-02-2017 **Revised:** 03-04-2017 **Accepted:** 09-05-2017

Abstract

The freshly harvested Sweet Corns (*Zea Mays L.*) were packed in different packaging materials like low density polyethylene (LDPE) with (0.2%) and without ventilation, MAP using diffusion channel and silicone membrane, vacuum packing and Shrink wrapped materials stored in refrigerated conditions. The temperature 0 °C was maintained to evaluate the nutritional quality of sweet corns. Among six different packaging systems tested for the sweet corn storage, the least value of PLW (0.533%), better retention of total sugar in corn kernels without conversion into starch, maximum shelf-life (16 days) and high sensory quality was documented with shrink wrapping package system which showed encouraging results with respect to physical properties and sensory quality evaluation when compared with the other treatments.

Keywords: Sweet corn, packaging, modified atmosphere packaging, shelf-life, storage temperatures, ventilation

Corn ranks among the most essential crops in the world agricultural economy. It is recognized as the most efficient converter of the sun's energy into food. The United States is the largest corn-producing country, followed by China, Brazil, Russia, Mexico and India (Food Encyclopedia, 1996). Sweet corn also called Indian corn, pole corn or simply corn, is a variety of maize with high sugar content. Sweet corn has a sweeter taste than other corns since the endosperm contains more amount of sugar along with starch (Salunkhe, 1984). Sweet corn is distinguished from other corns by its high sugar content during the milky and early dough stages and kernels are wrinkled and translucent when dry

In India, maize is mainly grown in Karnataka, Andra Pradesh, Bihar, Madhya Pradesh, Uttar Pradesh and Rajasthan. The total area under this crop, in the country, is estimated to be 70 lakh ha with an annual production of 14.8 lakh Million tonne and productivity of 2.11 Million tonne/hectare.

Starch is widely consumed by humans as an inexpensive and stable available carbohydrate source, The conventional sources of starch, such as corn and potato with improved properties are becoming significant to allow simpler and more robust processes (Adina *et al*., 2014). Starch application in industrial-related products dates back to ancient times (Falade *et al*., 2013). For industrial uses, the selection of a starch is made by considering its availability and also its physico-chemical characteristics, which vary depending on the source (Pascoal *et al*., 2013). The inherent functional diversity of materials extracted from different biological sources add to the range of applications. Currently, some uses of starch include the following: as a food additive to control the consistency and texture of sauces and soups, to resist the breakdown of gel during processing and to increase shelf-life of an end product in the food industry (Falade *et al*., 2013). The main botanical source of starch is maize, accounting for about 80%

of the world market. Corn starch is an important ingredient in the production of foodstuffs, and has been widely used as a thickener, stabiliser, colloidal gelling agent, water retention agent and as an adhesive (Zhu *et al.*, 2013). The novel approaches in corn starch application is in noodle industries where Yousif *et al.*, (2012) reported that the pregelatinized corn starches to noodles formulation enhance the noodles quality. Starch-based films play a key role in the food industry because starch is abundant, inexpensive, naturally renewable, biodegradable polysaccharide industries especially food products and more readily available worldwide than other natural resources, in applicability part (Li *et al.*, 2011).

Sweet corn is not stored to any great extent though, can be stored at 0 ˚C and 90-98% relative humidity for a week or more, if precooled immediately after harvesting. Ryall and Lipton (1972) also stated that to maintain the best qualities, sweet corn must be cooled to as near 0˚C as soon as possible after harvest. Time is of critical importance because sucrose rapidly changes to starch after harvesting. Sweet corn must also be kept as close to 0 ˚C as feasible at wholesale and retail market. The storage life of sweet corn is very limited because sweetness and tenderness are lost rapidly. Corn have satisfactory culinary quality for a maximum of 6-8 days at 0˚C, 3-4 days at 5˚C and 2 days at 10˚C. Pantastico *et al.* (1975) recommended temperatures of 0˚C and 0-2˚C for storage of sweet corn for 1-1.5 weeks at 90-95% relative humidity. Wills *et al.* (1989) stated that sweet corn stored well for 1-2 weeks at 4˚C.

The protein content of maize is reported to be in the range of 8.0 to 18.2 g/100g. Being deficient in certain essential amino acids, cereal proteins are poor in their net protein utilization and protein efficiency ratio (PER). Recent developments in biotechnology have been used to modify the protein functionality in cereals and this has helped enhance utilization of cereal proteins for wider food applications. For example, promoter which is active only during germination has been used for applications in malting process (Pangal and Khatkar, 2006).

Controlled atmosphere (CA) and modified atmosphere (MA), i.e., elevating carbon dioxide levels and reducing oxygen levels around stored vegetables after harvest, can be useful supplements to maintain optimum temperature and relative humidity, is extensively employed to keep post-harvest quality of fresh fruits and vegetables due to reduced respiration and ethylene production and consequently delayed ripening or senescence, reduced weight loss and prolonged shelf-life (Weichmann, 1986; Kader *et al*., 1989). Fresh sweet corn is a perishable food product prone to rapid post-harvest deterioration caused by kernel desiccation, loss of sweetness, husk discoloration and development of decay. Keeping cobs in CA/MA with high CO_2 and/or low O_2 levels could inhibit respiration and consequently, could reduce sugar loss and other metabolic reactions and can slow the growth of pathogens. CA/MA also decreases husk yellowing by inhibiting chlorophyll degradation. The research conducted on this aspect is reported here.

MATERIALS AND METHODS

Procurement of raw material

Fresh, well developed, mature and uniform size sweet corns were procured from a farmer's field near Hoskote, Bangalore. The sweet corns were harvested on the day of experimentation. The cobs were used for experimentation on the same day of purchase.

Treatments for storage studies

Following is the details of treatment used for storage of corn cobs:

Treatments

- T_1- Storage in LDPE (200 G) pouch with 0.2% ventilation
- T_2- Storage LDPE (200 G) pouch with no ventilation
- T_3- MAP storage using diffusion channel of 250 mm length × 5 mm diameter
- T_4- MAP storage with silicone membrane 10 mm × 10 mm in glass jars

T_5-Vacuum packaging in polypropylene 200 gauge film @ 60% vacuum

T_6- Shrink wrapping with LLDPE film

Physical and Biochemical Properties

For determining the physical properties of sweet corn, the standard procedures suggested by Mohsenin (1986) were followed. The sheaths of fresh cobs were removed before measuring physical properties. The properties determined and the methods followed are described here.

Length: Length of ten randomly selected sweet corn cobs were measured with the help of scale and the mean length was computed.

Diameter: A Digital Vernier Caliper having a least count of 0.01 mm was used to find the diameter of sweet corn. Ten cobs of sweet corn were randomly selected for measurement. The diameter was measured at three places of each cob and the readings were used to calculate the mean value.

Bulk density: A perfect rectangular wooden box was taken and its volume was determined by multiplying length, width and height (l × b × h) and then, the box was completely filled with sweet corn. The weight of the cobs required to fill the box was recorded and the bulk density was determined using the following relationship:

$$\text{Bulk Density (kg/m}^3\text{)} = \frac{\text{Weight of cobs (kg)}}{\text{Volume of wooden box (m}^3\text{)}}$$

Unit weight: Randomly selected ten sweet corn cobs were weighed with the help of an electronic balance and the mean weight was computed and recorded as the unit weight of the sweet corn cob.

Ear-to-Kernel Ratio: Randomly selected ten sweet corn cobs were taken and their whole weights were recorded. Then, the kernels were separated from each cob and the weight of kernels was again measured. From the two weights, ear-to-kernel ratio was computed.

Physiological Loss in Weight (PLW): For determining physiological loss in weight (PLW), the weight of sweet corn cobs with package was recorded using an electronic balance at periodic intervals (daily). The PLW of cobs was computed from the difference in weight from first day to the subsequent day. The PLW was expressed in per cent either on daily or on cumulative basis from one period to the other.

Physiological loss in fruit weight was calculated using the formula:

$$\text{PLW (\%)} = \frac{\text{Initial weight} \quad \text{Weight after storage}}{\text{Initial weight}} \times 100$$

Determination of Respiration Rate

The uniform sized sweet corns harvested on the day of experimentation were used for the respiration study. The respiration rates of the cobs were measured at five different temperatures (ambient (30 °C), 20, 10, 5 and 0 °C). Sweet corn cobs with and without sheath were enclosed in glass jars of 2000 ml capacity and sealed airtight for 2-6 h depending up on the temperature to allow them to respire. The head space gas composition i.e.O_2 and CO_2 concentrations inside the jars was measured using O_2 - CO_2 Analyzer (make: PBI Dansensor, Denmark). Respiration rate of the cobs was recorded daily both under ambient condition (30°C) as well as at four other selected temperatures till the end of shelf-life of corns. Respiration rate of the cobs was then calculated by using the formula:

$$\text{Respiration Rate \{ml } CO_2\text{/ (kg – h)\}} = \frac{\text{Change in } CO_2 \text{ concentration in headspace} \times \text{Free volume (ml)}}{\text{[[Fruit mass (kg)]} \times \text{[(Duration of respiration) (h)]}}$$

Where, Free Volume = (Container Volume - Fruit Volume)

Statistical analysis

The experimental data were analyzed by one way analysis of variance (ANOVA) and completely Randomized Design (CRD) was followed for analyzing the data of the present study. Mean differences among treatments and storage periods were tested for significance. The data were analyzed for main and interaction effects at probability level of 5%.

RESULTS AND DISCUSSION

Physiological loss in weight of stored sweet corn in various packages

The PLW (%) of sweet corn cobs with husk intact in different packaging systems stored at 0°C is presented in Fig. 1 and 2. Though on every alternate day PLW was assessed, comparison between treatments was made only on 10th day twice, the cobs in all the packages were reasonably in good condition up to this day. Beyond 10 days of storage, in some treatments T_1, T_3 and T_4, the cobs showed fungal growth. The results further indicated that the sweet corn stored in treatment T_6 showed the least PLW (0.533%) on the 10th day of storage. The treatment T_3 showed highest PLW (1.708 %) followed by T_1 (1.546%), T_4 (0.838%), T_2 (0.814 %) and T_5 (0.539%) except on 2nd day of storage, there was a significant difference between packages as for as PLW of sweet corn was concerned at any given period of storage.

Respiration Studies of Sweet Corn

The respiratory pattern (Fig. 3 and 4) showed varied physiological response of the cobs towards the modified atmosphere. The respiration peak of sweet corn cob with husk in ambient condition (30°C) was very high 416.71 ml CO_2 kg^{-1} h^{-1} recorded on third day after harvest. It was 265.47 ml CO_2 kg^{-1} h^{-1} on 4th day of harvest at 20°C, 188.4 ml CO_2 kg^{-1} h^{-1} on 6th day of storage at 10°C, 170.4 ml CO_2 $kg^{-1}h^{-1}$ on 8th day of storage at 5°C, whereas at 0°C, it was only 162.1 ml CO_2 kg^{-1} h^{-1} on 11th day of storage. Peak respiration rate of sweet corn cob without husk was 493.47 ml CO_2 kg^{-1} h^{-1} at ambient condition on 3rd day of storage, 378.85 ml CO_2 kg^{-1} h^{-1} at 20°C on 3rd day of storage, 200.3 ml CO_2 kg^{-1} h^{-1} at 10°C on 6th day of storage, 188.1 ml CO_2 $kg^{-1}h^{-1}$ at 5°C on 8th day of storage and 182.9 ml CO_2 kg^{-1} h^{-1} at 0°C on 9th day of storage. The lower respiration rate observed in sweet corn with and without husk at lower temperatures is in tune with general observation on many fruits and vegetables.

The results in previous sections indicated that the cob with husk intact could be stored better than without husk. Among the storage temperatures studied, at 0°C, the PLW was low 1.92%, the peak respiration rate was minimum 162.1 ml CO_2 $kg^{-1}h^{-1}$ and the sweet corn cobs with husk could be stored for as high as 16 days without affecting the visual quality. Based on the above facts, the storage temperature of 0°C was selected as the optimum temperature for sweet corn storage with husk. However, the conversion of sugar into starch could not be altogether prevented at 0°C temperature though it was retarded compared to other storage temperatures tested. Therefore, packaging study of sweet corn was conducted only at 0°C with husk intact.

Gas composition inside packages during storage of sweet corn

The O_2 and CO_2 concentrations inside packages during storage of sweet corn cobs (with husk intact) at

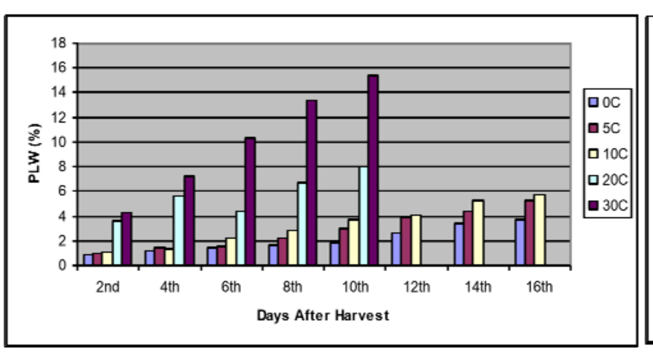

Fig. 1: Physiological loss in weight of sweet corn cob with husk stored at different temperature

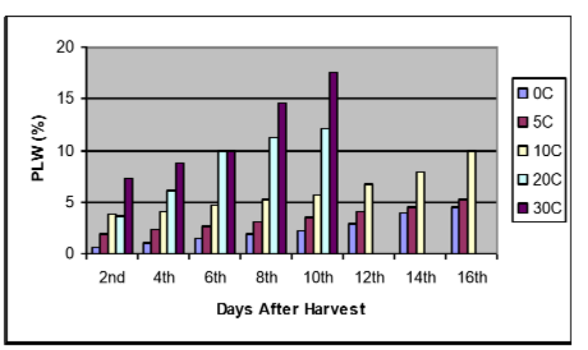

Fig. 2: Physiological loss in weight of sweet corn cob without husk stored at different temperature

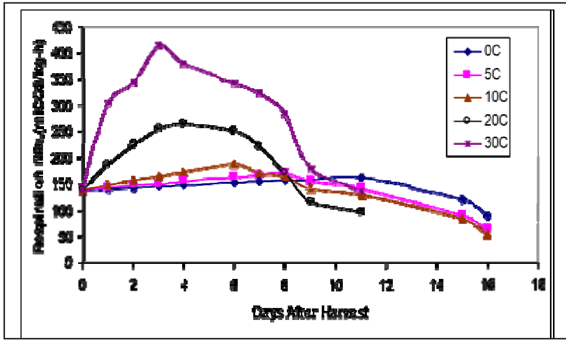

Fig. 3: Respiration rates of sweet corn with husk stored at different temperatures

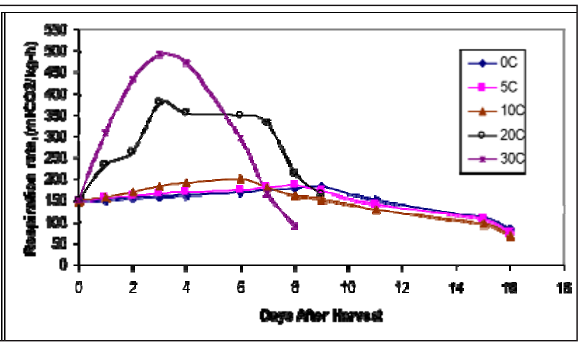

Fig. 4: Respiration rates of sweet corn without husk stored at different temperatures

0°C were periodically measured except in treatments T_5 (vacuum package) and T_6 (shrink wrapping). It was observed that the O_2 concentration inside the LDPE package with 0.2% ventilation (T_1) varied from 20.8-21.1%, same as that of normal atmosphere, during 12 days of storage. However, the CO_2 concentration was higher at 0.1-0.16%. In the case of LDPE package (without ventilation – T_2), the concentration of O_2 was in the range of 10.9-18% while the CO_2 concentration was in the range of 5.5-6.5%. In case of diffusion channel storage system (T_3), the concentration of O_2 was very low at 2.11-5% during 12 days of sweet corn storage where the CO_2 concentration was significantly high at 8.5- 25.66%. The O_2 and CO_2 concentrations inside silicone membrane storage system (T_4) was studied throughout the storage period and the results indicated that the concentration of O_2 decreased from 21.0 to 3.0-8.5% during 12 days of storage whereas, the CO_2 concentration significantly increased from 0.03% to 6.5 -15.2 %.

Quality of sweet corn during storage in different packages

During storage study of sweet corn cobs (with husk) in different packages at 0°C temperature, the quality of cobs was periodically assessed in terms of visual, biochemical and sensory qualities were presented below.

Biochemical qualities: The influence of different packages on biochemical quality parameters like starch, reducing sugar, non-reducing sugar and total sugars of stored sweet corn cob during storage are shown here.

Reducing sugars: During storage of sweet corn at 0°C in different packaging systems, the reducing sugars of corn kernel were found to decrease with storage period. On 6th day of storage, the reducing sugar content (initially 2.8%) was just 0.4% in treatments T_1, T_3 and T_4 where as in treatment T_6, it was 2.0%. The rate decrease in reducing sugar content is relatively slow in shrink wrapped corn. The rate decrease in reducing sugar content is relatively slow in shrink wrapped corn. Statistically, there was a significant difference between packages as far as reducing sugars of sweet corn was concerned during storage.

Non-reducing sugars: The non-reducing sugar content of sweet corn (initially 34.7%) was found to decrease with storage duration in all the tested packaging systems. On 6th day of storage, the nonreducing sugar content was maximum in T_2 followed by T_6 (20.5%) and T_5 (18.4%) and in other 3 treatments namely, T_1, T_3 and T_4, the non-reducing sugars content was very low. Nearly 2/3 of the non-reducing sugars were lost on 10th day of storage. Statistically, there was significant difference amongst the treatments with respect to non-reducing sugar at all storage duration.

Total sugars: A decrease in total sugar content was recorded in the sweet corn stored in all the packages namely LDPE (with & without ventilation), vacuum packaging, MAP using diffusion channel, MAP using silicone membrane and shrink-wrapping. Among the packaging treatments, the maximum total sugar

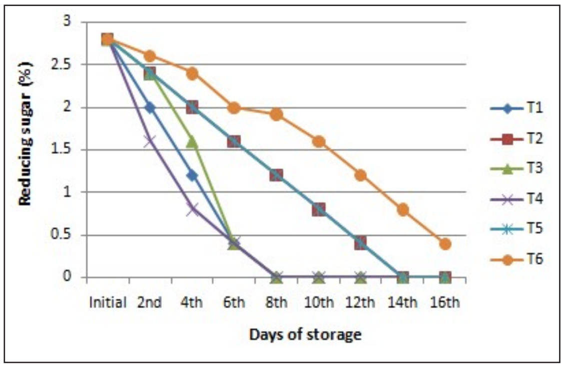

Fig. 5: Effect of storage on reducing sugar of corn cobs of different treatments

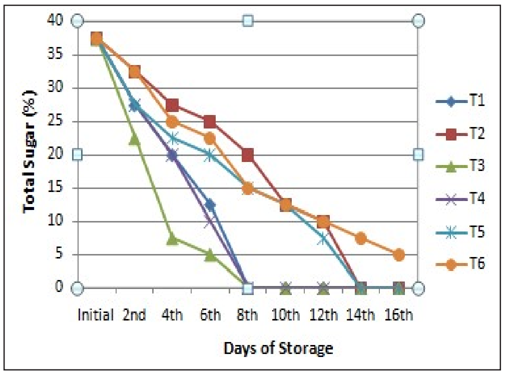

Fig. 6: Effect of storage on total sugar of corn cobs of different treatments

content was observed in shrink- wrapped corn (T_6) and hence it was considered to be the best package treatment based on the total sugar content.

Starch: During storage of sweet corn cobs at 0°C in different packaging systems, the starch content was found to increase with duration of storage. On 6th day of storage, the starch content of corn, initially 14.62%, increased to as high as 45% in treatment T_3 and the least increase was in treatment T_6 (27%) followed by T_5 (28.1%) and T_2 (29.25). There was a significant difference between packages with regard to starch content of sweet corn at any given point of storage.

Sensory quality

The sweet corn stored at 0°C in different packaging systems were subjected to organoleptic evaluation on 6th day of storage by a panel of judges and the mean sensory scores for various treatments were presented in Table. The shrink-wrapped sweet corn in treatment T_6 obtained highest mean sensory scores for all attributes namely, colour (4.1), texture (4.1), flavour (3.5) and overall acceptability (4.0) when compared with other treatments, whereas the treatment T_5 (Vacuum Packaging), recorded second best mean sensory scores of 3.8, 3.5, 3.2 and 3.7, for the above sensory attributes.

CONCLUSION

Among the tested packages, the shelf-life of sweet corn was found to be maximum (up to 16 days) with shrink wrapping. However, the sweetness of the corn kernels did not last that long and may be considered poor beyond 6th day of storage during which the total sugar content was 22.5%. The next best shelf-life was found with vacuum packaging and LDPE package without ventilation (both 12 days). The package systems namely, MAP using silicone membrane, diffusion channel and LDPE with 2% ventilation were found to be inadequate for storage of sweet corn with husk intact. Based on physiological loss of weight, biochemical quality, sensory scores and microbial infestation, the treatment T_6 i.e. shrink wrapping, proved to be the best packaging treatment for storage of sweet corn cob with husk intact.

REFERENCES

Adina, L., Santana, M., Angela, A and Meireles. 2014. New starches are the trend for industry applications: A review. *Food and Public Health*, **4**(5): 229-241.

AOAC. 1960. Official Methods of Analysis. 8th ed, Association of Official Analytical Chemists, Washington, D.C.

Falade, K.O. and Okafor, C.A. 2013. Physicochemical properties of five cocoyam (*Colocasia esculenta* and *Xanthosoma sagittifolium*) starches. *Food Hydrocolloids*, **30**(1): 173-181.

Food Encyclopedia, 1996. Corn. Les editions Quebec / Amerique, Inc. Montreal, Quebec, Canada, pp. 685.

Kader, A.A., Zagory, D. and Kerbel, E.L. 1989. Modified atmosphere packaging of fruits and vegetables. *Critical Reviews in Food Sci. and Nutrition*, **28**(1): 1-30.

Li, M., Liu, P., Zou, W., Yu, L., Xie, F., Pu, H., Liu, H. and Chen, L. 2011. Extrusion processing and characterization of edible starch films with different amylose contents. *J Food Eng.*, **106**: 95–101.

Mohsenin, N.N. 1986. Physical Properties of Plant and Animal Materials. 2nd ed., Gordon and Beach Science Publishers, New York, USA.

Pangal, A. and Khatkar, B. 2006. *Cereal proteins and their role in food industry*, **25**(5): 58-62.

Pantastico, E.B. 1975. Post Harvest Physiology, Handling and Utilization of Tropical and Subtropical Fruits and Vegetables. AVI Pub. Co., Westport, Connecticut, USA.

Pascoal, A.M., Di-Medeiros, M.C.B., Batista, K.A., Leles, M.I.G., Lião, L.M. and Fernandes, K.F. 2013. Extraction and chemical characterization of starch from *S. lycocarpum* fruits, *Carbohydrate Polymers*, **98**(2): 1304-1310.

Perez-Pacheco, E., Moo-Huchin, V.M., Estrada-Leon, R.J., Ortiz-Fernndez, A., May-Hernandez, L.H., Rios-Soberanis, C.R. and Betancur-Ancona, D. 2014. Isolation and characterization of starch obtained from *Brosimum alicastrum* Swarts Seeds, *Carbohydrate Polymers*, **101**: 920-927.

Ryall, A.L. and Lipton, W.J. 1972. Handling, Transportation and Storage of Fruits and Vegetables. Vol. 1, AVI Publishing Co., Westport, Connecticut, USA.

Salunkhe, D.K. and Desai, B.B. 1984. Postharvest Biotechnology of Vegetables. Vol. 1, CRC Press, Inc., Boca Raton, Florida, pp. 194.

Weichmann, J. 1986. The effect of controlled-atmosphere storage on the sensory and nutritional quality of fruits and vegetables. *Hort. Rev.,* **8**: 101-127.

Wills, R.B.H., Mcglasson, W.B., Graham, D., Lee, T.H. and Hall, E.G. 1989. Postharvest: An Introduction to the Physiology and Handling of Fruits and Vegetables. 3rd ed., AVI New York, pp. 174.

Zhu, F. and Wang, Y.J. 2013. Characterization of modified high-amylose maize starch-α-naphthol complexes and their influence on rheological properties of wheat starch, *Food Chemistry*, **138**(1): 256-262.