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FOOD SAFETY AND INDUSTRIAL IMPORTANCE OF CORN STARCH. THE IMPACT OF THE HYDRATION PROCESS ON THE STARCH CONTENT IN THE GRAIN

KOBILOV NURBEK

Assistant, Karshi Engineering-Economics Institute, Kashkadarya, Uzbekistan
Phone.: (0893) 909-4444, E-mail.: nurikkab93@gmail.com
*Corresponding author

DODAYEV KUCHKOR

Professor, Tashkent Chemical-Technological Institute, Tashkent, Uzbekistan
Phone.: (0893) 392-4661, E-mail.: dodoev@rambler.ru

Abstract: This article provides information about starch contained in corn, its importance in food production and human health, and its applications in other industries. Additionally, the starch composition of two different corn samples, one unprocessed and another soaked in water for a specific period, was studied and analyzed. For the experiment, corn samples were ground and heated in a 50 ml measuring flask using a water bath to prepare a solution. The solution was then cooled, and Na_2MoO_4 solution was added for clarification before filtering. The starch content in the filtrate was determined by measuring the polarization angle using a polarimeter and applying a special formula. The results showed that the “Makkajuxori-1” sample contained 70.9% starch in its unsoaked state, while the “Makkajuxori-2” sample, which was soaked in water at 26-30°C for 36 hours, contained 62.1% starch. Corn is considered a starch-rich plant among cereal grains, and the resistant starch in its composition is important for human health. Regular consumption of corn in the daily diet plays a significant role in preventing various diseases. Moreover, due to its rheological properties and high gelatinization characteristics, corn starch is widely used in the alcohol industry. It was determined that after soaking corn in water for a certain period, the starch content in the grain decreased by 8.8%.

Keywords: Corn, resistant starch, amylase, gelatinization, acrolein, amylopectin, food, alcohol industry, polarimeter, molybdate.

Introduction. Among all types of starch, corn (*Zea mays* L.) starch is considered a valuable component in food production, accounting for over 80% of the global starch market [1].

Achievements in obtaining starch from grain crops are very important, as this type of starch constitutes 55-75% of the daily food consumed by humans and serves as the main source of feed for domestic animals [2].

Like other cereal crops, the main component of corn grain is starch. It exists in the form of starch granules of a certain size and shape, surrounded by a protein shell. The granules are mainly composed of simple concentric layers, with a cavity in the center from which star-shaped cracks radiate in different directions [3, 4].

From the perspective of specialists in the alcohol industry, the rheological properties of starch and the phenomenon of gelatinization are of great interest. During the process of starch gelatinization, the ability to double refract light in polarized conditions, characteristic of natural granules, is lost. Therefore, the temperature at which secondary light refraction completely disappears is used as the criterion for the completion of gelatinization. This temperature is a characteristic feature of grain starches. Corn grain is boiled at a much higher temperature regime because it absorbs water and swells much slower than rye and wheat grain.

Table 1. The starch content in grains of various cereal crops

№	Grain type	Amount of starch, %
1	Wheat	60-65
2	Rye	46-53
3	Barley	43-55
4	Corn	65-75

The gelatinization of corn starch begins at a relatively high temperature (65-75°C), and the structure of corn grain endosperm is more robust than that of other grain crops. This can also be observed from the fact that the endosperm forms the majority of the grain in its cross-section (Figure 1).

Corn is a traditional starch-containing raw material for the alcohol industry. Corn has significant advantages over other crops, especially due to the content of its main valuable component - starch. However, processing this type of raw material is associated with several difficulties due to the peculiarities of its biochemical composition, particularly its high fat content. This component is a potential source of acrolein formation in the mixture. Acrolein, even in small amounts, sharply deteriorates the quality indicators of alcohol and reduces its grade. Furthermore, unlike wheat and rye starch, corn starch undergoes a more difficult water-thermal and enzymatic processing. For this reason, corn is traditionally processed under harsh conditions at alcohol plants. This process involves boiling the mixture at high temperatures, allowing the starch to dissolve [5, 6].

Starch consists of a mixture of amylose and amylopectin and is the most common reserve carbohydrate found in corn kernels. The amounts of amylose and amylopectin provide specific properties in food production and industrial applications. The starch content in the endosperm of common corn is about 25% amylose and 75% amylopectin [7].

The ratio of amylose to amylopectin is important for the structure and quality of food and processed products. The amount of amylose determines the firmness of the starch, while amylopectin is responsible for the formation of crystalline granules and the thickening of the dough [8,9].

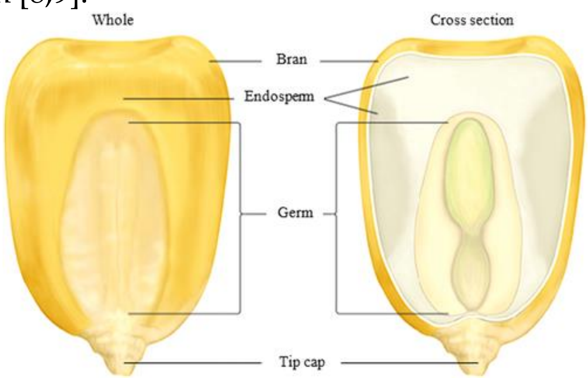

Figure 1. Anatomy of corn grain

The beneficial properties of resistant starch in corn have been thoroughly studied. Consuming an average amount of corn starch (about 10 grams) per day can help reduce blood glucose and insulin levels. Higher consumption of corn starch (20 grams per day) improves digestive system health [10, 11].

Commercial corn varieties contain starch composed of 100% amylopectin. Processing other commercial varieties allows for the production of starch with an amylose mass fraction of up to 70%. These types of starch have different specific properties: for example, starch from waxy corn, like traditional corn starch, transitions to a gelatinous state, but forms gels with higher viscosity [12].

According to the Corn Refiners Association of the USA, starch obtained from grains with a high mass fraction of amylose does not gelatinize even when boiled and possesses high resistance properties [13].

Unlike glycemic starches, resistant starches do not break down in the human gastrointestinal tract, but improve its peristalsis and are used by intestinal bacteria to form short-chain fatty acids. These fatty acids can reduce the level of oncogenic molecules that cause the development of rectal and colon cancer [14].

Resistant starch from corn (RS), also known as high-amylose corn, has various health benefits. Corn endosperm contains 39.4 milligrams of RS per 100 grams [15, 16].

It is indigestible, and its consumption alters intestinal microflora, reduces cholesterol levels and increases its excretion through the digestive system, increases fermentation in the colon and production of short-chain fatty acids, and reduces symptoms of diarrhea [17].

All of this reduces the risk of complications associated with colon cancer, atherosclerosis, and obesity [18].

Its consumption affects cholesterol metabolism, reduces fat accumulation in the body, thus lowering the risk of atherosclerosis, hyperlipidemia, diabetes, and obesity [19].

Research methodology. For the study, two types of corn samples were taken to determine the amount of starch in their composition: unprocessed (“Makkajuxori-1”) and soaked in soda water for 36 hours (“Makkajuxori-2”).

The method for determining the mass fraction of starch in grain samples is applied to products with a mass fraction of starch exceeding 10% [20]. The amount of starch is determined by the polarimetric method through hydrolysis with a hydrochloric acid solution.

Materials needed for analysis: A saccharimeter or polarimeter. A saccharometer or polarimeter.

A laboratory mill that ensures the required degree of grinding. A wire mesh sieve No. 08 according to TU 14-4-1374-86.

Hydrochloric acid according to GOST 3118-77, a solution with a mass concentration of 11.24 g/dm^3, for potato analysis - 3.77 g/dm^3.

Potassium ferrocyanide according to GOST 4207-75, a solution with a mass concentration of 150 g/dm^3.

Zinc sulfate according to GOST 3765-78, a solution with a mass concentration of 150 g/dm^3.

Ammonium molybdate according to GOST 3765-78, solution with a mass concentration of 100 g/dm^3.

Sodium molybdate according to GOST 10931-74, a solution with a mass concentration of 150 g/dm^3.

Phosphotungstic acid, a solution with a mass concentration of 40 g/dm^3.

Samples with moisture content above 17% are pre-dried in air or in one of the following devices: a drying oven, a thermostat, or a laboratory drying apparatus, with an air temperature not exceeding 50°C. The sample is thoroughly mixed, and all the ground material is milled so that it passes through a No. 8 wire mesh sieve. The sample is thoroughly mixed, and all the ground material is ground so that it passes through a mesh sieve No. 8.

Simultaneously with the collection of samples for analysis, samples for moisture determination are also taken. Moisture determination is carried out according to the GOST adopted in the relevant field.

A 5 g sample with an error of no more than 0.01 g is taken from the analytical sample, placed in a 100 cm^3 centrifuge tube, and 18 cm^3 of 10% ethanol solution is added (when determining the mass fraction of starch in bran - 28 cm^3 ethanol solution) and mixed with a glass rod. The glass rod is rinsed with 2 cm^3 of ethanol solution. The centrifuge tube is closed with a rubber stopper and vigorously shaken by hand for 2 minutes.

After shaking, the wall of the centrifuge tube and the rubber stopper are washed with 25 cm^3 of ethanol. The sample is then centrifuged at 4000 rpm for 20 minutes, after which the clear supernatant is discarded. 20 cm^3 of hydrochloric acid is gradually added to the residue, stirred with a glass rod until a suspension is formed, and transferred to a 100 cm^3 volumetric flask. The residue of the sample adhering to the wall of the centrifuge tube and the glass rod is washed several times with a hydrochloric acid solution with a mass concentration of 11.24 g/dm^3 and poured into the volumetric flask; the total amount of hydrochloric acid solution is 50 cm^3.

The volumetric flask is immersed in a boiling water bath while constantly shaking. The boiling process of the water bath should not be disturbed due to the immersion of the volumetric flask: it should be kept as closed as possible using special sealing rings. The volumetric flask is shaken for 3 minutes according to a stopwatch without lifting the flask from the water bath. After that, the flask for all starch samples is held for 12 minutes without shaking.

After a total of 15 minutes for all starch-containing samples, the flask is removed from the bath and cold water is quickly added to about 10-15 cm^3 below the mark. The liquid inside the flask is cooled to 20°C under running water. The protein substances in the solution are precipitated by adding 2 cm^3 of potassium ferrocyanide solution (150 g/dm^3) and after mixing, 2 cm^3 of zinc sulfate solution (150 g/dm^3).

The volumetric flask is then held at room temperature for 10-15 minutes, after which it is allowed to settle for 10-15 minutes at room temperature and is filled to the mark with distilled water, mixed, and allowed to settle for 5 minutes. In the absence of the two mentioned reagents, 5 cm^3 of ammonium molybdate solution (100 *g/dm3*), or 5 cm^3 of phosphotungstic acid solution (40 g/dm^3), or 3 cm^3 of sodium molybdate solution (165 g/dm^3) are added to the flask to precipitate proteins and clarify the solution. When using molybdates as protein precipitants, it is recommended to prevent sunlight from reaching the reagents. The liquid inside the flask is filtered through a dry pleated filter into a dry conical flask, discarding the first few drops of the filtrate. The polarimeter tube is filled with the clear filtrate and the optical rotation is measured in the polarimeter. The angle of rotation of the sample solution is measured 5 times in the polarimeter tube.

Before and after every second measurement, the polarimeter is checked for zero setting. The average value of the 5 measurements serves as the initial value for further calculations of the mass fraction of starch.

Results and discussion. 5.0 *g* of ground corn is weighed on a technochemical balance. The sample is placed in a 50 *ml* measuring flask (ρ=1.125 g/cm^3), stirred in a water bath for 3 minutes, and heated for 15 minutes. The starch in the sample transitions into a solution upon heating. The flask is removed from the water bath, and distilled water is added to cool it to 90 *ml*. To clarify the solution in the flask, 3 *ml* of 15% Na_2MoO_4 solution is added, then distilled water is added up to the flask's mark, mixed, and filtered. The polarimeter tube is filled with the clear filtrate. It is placed in the polarimeter to measure the angle of rotation of the polarized plane.

When using a circular scale polarimeter, the mass fraction of starch (*X*) in percentages is calculated using the following formula:

$$X = (K \times a) / 0.3468,$$

Where: *K* is the transfer coefficient, which equals 1.9 for a tube length of 2 *dm*; a is the reading on the saccharimeter or polarimeter scale (for a tube length of 1 *dm*, the transfer coefficients *K* are multiplied by 2). The permissible differences (*r*) between the results of two parallel determinations should not exceed the following values:

Metrological characteristics. The permissible differences (*r*) between the results of two parallel determinations should not exceed the following values:

$$r = 0.03 + 0.04 \times X_1,$$

Where X_1 is the arithmetic mean of two parallel determinations. However, the absolute difference in starch content in the sample should not exceed 0.5%.

The permissible difference between the measurement results of two different laboratories should not exceed the following values:

$$R = 0.05 + 0.06 \times X_2,$$

Where X_2 is the average value of the results of measurements conducted in two different laboratories. However, the absolute difference in starch content in the product should not exceed 1.2%.

Table 2. Amount of starch detected in two different samples

№	Samples	Starch amount, %
1	"Makkajuxori-1"	70,9
2	"Makkajuxori-2"	62,1

The decrease in starch content within the grain can be explained by the hydrolysis of starch due to water penetration into corn kernel cells and the activation of enzymes during soaking in soda water. During the hydrolysis process, starch molecules break down into glucose and maltose.

Conclusion. The rich starch content of corn has made it a primary source of raw materials in the global food and alcohol industries. The high proportion of amylose and amylopectin, which are the main components of corn kernel starch, determines the specific characteristics of its use in food production and industrial applications as a valuable carbohydrate reserve. Furthermore, including corn starch in the diet serves as an important factor in preventing diseases such as diabetes, colon cancer, obesity, diarrhea, and atherosclerosis due to its resistant starch content. It was found that during the process of soaking corn at a temperature of 26-30°C for 1.5 days, the amount of starch in the grain decreased by almost 9%. This decrease can be attributed to the reduction of starch content for energy production in the organism, with sugars and other carbohydrates taking its place.

References

1. Scrob S., Muste S., Haș I., Mureșan C., Socaci S., Fărcaș A. The Biochemical Composition and Correlation Estimates for Grain Quality in Maize, Journal of Agroalimentary Processes and Technologies, 2014, No. 20(2), -P.150-155.
2. Pan D. Starch synthesis in maize, In (eds) Gupta A.K., Kaur N., Developments in Crop Science, Elsevier, 2000, No.26, -P.125-146.
3. Xatamova D.M., Abdulxayev I.A., Makkajo'xorining kimyoviy tarkibi va tabobatda ishlatilishi. O'zbekistonda fanlararo innovatsiyalar va ilmiy tadqiqotlar jurnali, 2022, №12, -B.298-300.
4. Qaxxorova U.R. Zea mays L. Saccharata ning ayrim morfologik va fiziologik xususiyatlari, "Talqin va tadqiqotlar" ilmiy-uslubiy jurnali, 2022, №14, 7-9 b.
5. Șchiop (Lazăr) T., Haș I., Haș V., Coste I.D., Chicinaș (Racz) C., Tritean N., Valoarea fenotipică şi genetică a unor linii consangvinizate isonucleare de porumb V. Studiul fenotipic şi genetic al conţinutului de amidon, Analele I.N.C.D.A. Fundulea, 2011, No. 79(2), -P.31-48.
6. Krikunova L.N., Kuzmenkova N.M., Gernet M.V. Issledovaniye protsessa predobrabotki zerna kukuruzi na osnove metoda gidrotermicheskoy obrabotki. Texnika i texnologiya pishevix proizvodstv. 2011. № 4, 1-5 p.
7. Nelson O. and Pan D. Starch synthesis in maize endosperms, Annual Review of Plant Physiology ans Plant Molecular Biology, 1995, No. 46, -P.475–496.

8. Keenan M. J., Zhou J., McCutcheon K. L., Raggio A. M., Bateman H. G., Todd E., Hegsted M. Effects of resistant starch, a non-digestible fermentable fiber, on reducing body fat. Obesity. 2006, No.14, p. 1523–1534.

9. Whitt S.R., Wilson L.M., Tenaillon M.I., Gaut B.S. and Buckler E.S.T. Genetic diversity and selection in the maize starch pathway, Procedings of the National Academy of Sciences, USA, 2002, No. 99(20), -P.12959–12962.

10. Li C., Huang Y., Huang R., Wu Y., Wang W. The genetic architecture of amylose biosynthesis in maize kernel, Plant Biotechnology Journal, 2018, No. 16(2), -P.688-695.

11. Siyuan Sh., Tong L., Rui H.L. Corn phytochemicals and their health benefits. Food Science and Human Wellness. 2018, Volume 7, Issue 3, -P.185-195.

12. Gonikova M.R., Xoreva B.I., Goldshteyn B.G., Nosovskaya L.P., Adikayeva L.V., Xatefovyu E.B. Izucheniye xozyaystvenno sennix priznakov i texnologicheskix svoystv kolleksii Zea mays L. VIR. Trudi po prikladnoy botanike, genetike i seleksii, 2020, No.181(4), 56-64 p.

13. Corn Starch. 11th ed. Corn Refiners Association; 2006. Available from: Accessed May 5, 2020. https://corn.org/wp-content/uploads/2009/12/Starch2006.pdf.

14. Koptelova Ye.K. Kuzmina L.G., Gulakova V.A., Lukin N.D. Otsenka amilorezistentnosti kraxmalov razlichnogo proisxojdeniya i modifikatsii. Dostijeniya nauki i texniki APK. 2017, No.31(5), 60-62 c.

15. Kim, W. K., Chung, M. K., Kang, N. E., Kim, M. H., & Park, O. J. (2003). Effect of resistant starch from corn or rice on glucose control, colonic events, and blood lipid concentrations in streptozotocin-induced diabetic rats. The Journal of Nutritional Biochemistry, 14, -P.166–172

16. Jiang H., Junyi L., Blanco M., Campbell M.R. and Jane J.L. Resistant-starch formation in high-amylose maize starch. Journal of Agricultural and Food Chemistry. 2010, No.58(13), -P. 8043-8047.

17. Murphy M. M., Douglass J. S. and Birkett A. Resistant starch intakes in the United States. Journal of the American Dietetic Association, 2008. No.108, -P.67–78.

18. Wang X., Brown I. L., Khaled D., Mahoney M.C., Evans A.J. and Conway P.L. Manipulation of colonic bacteria and volatile fatty acid production by dietary high amylose maize (amylomaize) starch granules. Journal of Applied Microbiology. 2002, No.93, -P.390–397.

19. Higgins, J. A. Resistant starch: Metabolic effects and potential health benefits. Journal of AOAC International, 2004, No.87, p. 761–768.

20. Rukovodstvo po metodam kontrolya kachestva i bezopasnosti biologicheski aktivnix dobavok k pishe. M.: Federalniy sentr gossanepidnadzora Minzdrava Rossii. 2004, 240 s.

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