Effect of Fermentation Time on Certain Chemical Constituents of Pre-ferments Used in Breadmaking

JOHN A. JOHNSON, BYRON S. MILLER, FAWZY Y. REFAI[1], and DONALD MILLER

Department of Flour and Feed Milling Industries, Kansas State College, Manhattan, Kan.

The use of pre-ferments to replace sponge fermentation in breadmaking has created a demand for knowledge concerning the chemical changes that occur. The utilization of sugars was followed by chromatographic methods, showing that the types of ferment and sugars affected the rate of sugar utilization. In the presence of milk or flour the rate was retarded slightly. Dextrose was utilized in fermentation at slightly greater rates than sucrose. At the end of 5 hours of fermentation at 30° C., all but 5 to 17% of the sugars were fermented. Carbon dioxide production continued for 6 hours. The rate of gas production was slightly greater when milk was used in the pre-ferment. The total gas production was the same for all types of ferment. The presence of milk prevented large decreases in pH, but total acidity was essentially the same for all ferments. Total organic acid production was followed both by direct potentiometric titration of the ferments and by isolation of the acids using ion exchange resins. Total acidity increased to a maximum after 3 hours of fermentation and then decreased steadily.

Breadmaking methods of most recent interest have included procedures that use a pre-ferment (*5*, *8*, *13–15*). Such procedures are not new, but at present they are attracting widespread attention because of their adaptability to bulk handling methods. New plants can economize on space and equipment and at the same time employ a simpler and more easily controlled operation (*4*).

Jago and Jago (*10*) described a process in which a pre-ferment was prepared by adding yeast to a liquid mixture of boiled macerated potatoes and flour. The preparation of "Parisian Barm," a leavening ferment (*10*), was introduced from Paris to Scotland in 1865 and was made of malt, flour, and water, mixed and stored under specified conditions (*10*). It was used mainly as a source of yeast, but also because of its contribution to bread flavor.

It is the opinion of the authors that a pre-ferment in some form eventually will be used in the usual commercial baking process. It may replace only the sponge, or it may be used to provide flavor for a continuous process (*2*, *3*, *8*). This study represents one of a series of investigations undertaken to obtain basic information on some of the changes that occur in pre-ferments with different formulations. It also is hoped that such data will be useful in evaluating the need, or lack of need, for flours with characteristics different from those now available.

Materials and Methods

Three different ferments were used. These were the American Dry Milk Institute (ADMI) (*6*) sugar and flour ferments. Each was formulated into two types, one with glucose, the other with sucrose. The formulas are shown in Table I. Each ferment was mixed for 1 minute in a Waring Blendor and poured into glass jars stored in a constant temperature water bath maintained at 30° C.

Determination of Residual Sugar Samples (20 grams) were taken from each ferment at 0, 0.5, 1.0, 1.5, 2, 3, 4, and 5 hours to determine residual sugar. Each sample was treated with 25 ml. of hot ethyl alcohol and boiled gently on an electric hot plate for 20 minutes. After cooling, the solution was adjusted to 40-ml. volume with ethyl alcohol and centrifuged. A 25-ml. portion of the supernatant liquid was evaporated to dryness under reduced pressure. The residue was dissolved in 25 ml. of water and deionized by passing it through a column of Dowex 50 and Duolite A_4 in a 25-cm., 6-mm. inside diameter glass tube. Approximately 0.5 gram of each resin was packed dry into the tube with Duolite A_4 on the bottom. The resins were held in place with glass wool. Sugars were separated chromatographically (*8*, *9*) and determined quantitatively by the phenol–sulfuric acid method (*7*).

Gassing Power Gassing power was determined using the pressuremeter technique (*7*). Each ferment (5 grams) was weighed in duplicate into 50-ml. glass beakers, which were placed in the pressuremeter cups.

Determination of pH and Total Acidity of Pre-ferments The pH of each ferment was determined at hourly intervals using a Beckman Model GS pH meter. The total acidity was determined by titrating 25-ml. portions of each ferment at hourly intervals with 0.2*N* sodium hydroxide. The end point at pH 8.0 was determined after 3 minutes using a Beckman automatic titrator.

The total milliequivalents of acid produced after different time intervals were determined using ion exchange resins.

Table I. Ferment Formulas

Ingredients	Grams: ADMI (6)	Sugar	Flour
Water	320.0	320.0	320.0
Glucose or sucrose	21.0	21.0	21.0
Arkady[a]	3.5	3.5	3.5
Malt	1.8	1.8	1.8
Salt	7.0	7.0	7.0
Dry milk solids	42.0	...	...
Compressed yeast	14.0	14.0	14.0
Flour (hard red winter patent)	...	...	42.0

[a] A commercial mineral yeast food used widely by the baking industry.

[1] Present address, Chemical Section, Ministry of Agriculture, Giza (Orman), Cairo, Egypt.

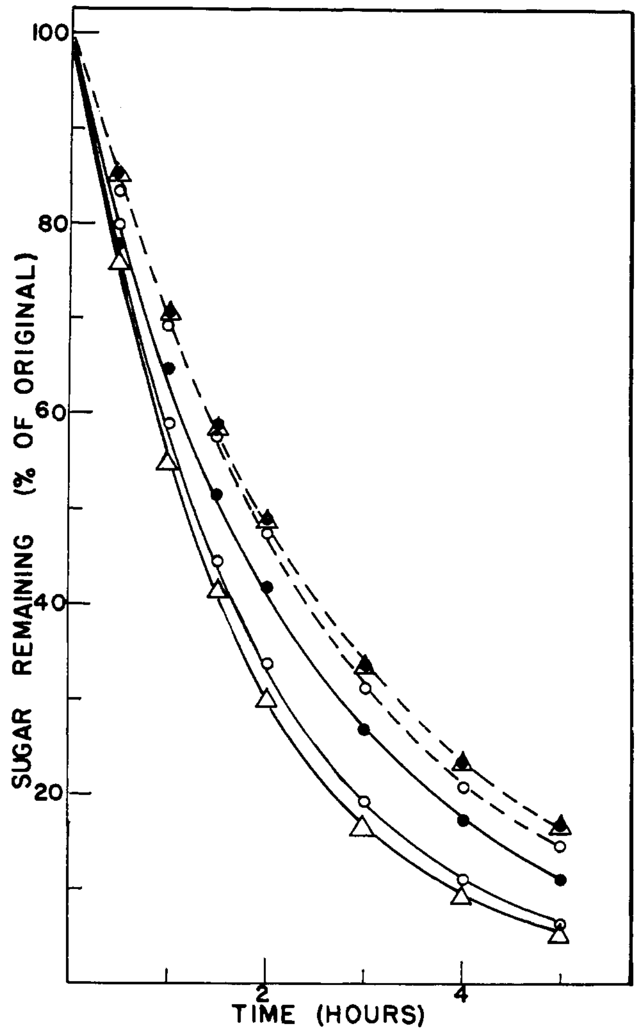


Figure 1. Effect of fermentation time on amount of sugar remaining in different ferments

○ ADMI ferment
● Sugar ferment
△ Flour ferment
—— Ferments containing glucose
- - - Ferments containing sucrose

Nitrogenous material was removed by the use of Dowex resin in the sodium form. The sodium salts of the acids were adsorbed on Deacidite in the ammonium form, washed with distilled water, and eluted with 1N ammonium hydroxide. The free acids were released by passing the eluate through Dowex resin in the hydrogen form. They were titrated using standardized sodium hydroxide with phenolphthalein as the indicator.

Results and Discussion

Sugar Content of Ferments Figure 1 shows the percentage of sugars remaining in the ferments after different periods of fermentation. There was no evidence of sucrose in those ferments to which sucrose was added even at the 0-hour sampling. This corroborates the work of Koch, Smith, and Geddes (*12*), who reported that sucrose is inverted within a few minutes after it is mixed with yeast. Maltose was found in the flour ferment but was not determined quantitatively. Likewise lactose, which is not fermented by yeast was found in the American Dry Milk Institute ferment, but was not determined quantitatively.

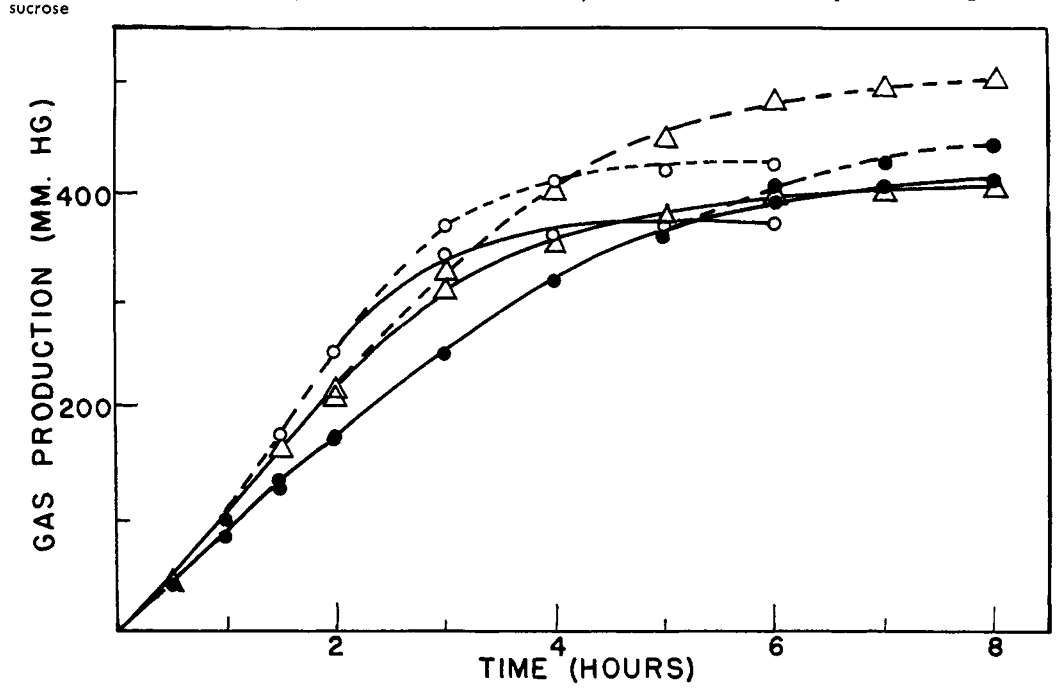
It is apparent that, within 1.5 hours, approximately 50% of the sugars were completely fermented. At the end of 5 hours only about 10% of the glucose and fructose resulting from the inversion of sucrose, remained in the ferment. In the ferments made with glucose about 5% of the glucose remained unfermented at the end of 5 hours.

Gas Production The gas production data are shown in Figure 2. A maximum was reached for the American Dry Milk Institute ferment after 6 hours. Two additional hours were required for the sugar and flour ferments to reach the maximum. Although the amount of gas produced by each ferment containing sucrose was slightly higher than for the similar ferment containing glucose, this difference is probably unimportant. In view of the low concentrations of sugar remaining after 5 hours of fermentation, the low rate of gas production at a similar time interval seems logical. The slow steady increase in carbon dioxide developed in the flour ferment is due to the gradual release of maltose from the starch as a result of the action of the amylases (*11*).

pH and Total Acidity of Ferments The changes in the pH of the different ferments are shown in Figure 3. The pH of the American Dry Milk Institute ferment remained relatively constant at a level of 5.4 for 9 hours, thus indicating the high buffering capacity of milk. The flour ferment maintained a constant pH level of 5.0 for the first hour and then rapidly decreased. Thus, flour had much less buffering capacity than dried skim milk on an equivalent weight basis

Figure 2. Effect of fermentation time on gas production in different ferments

Symbols same as for Figure 1



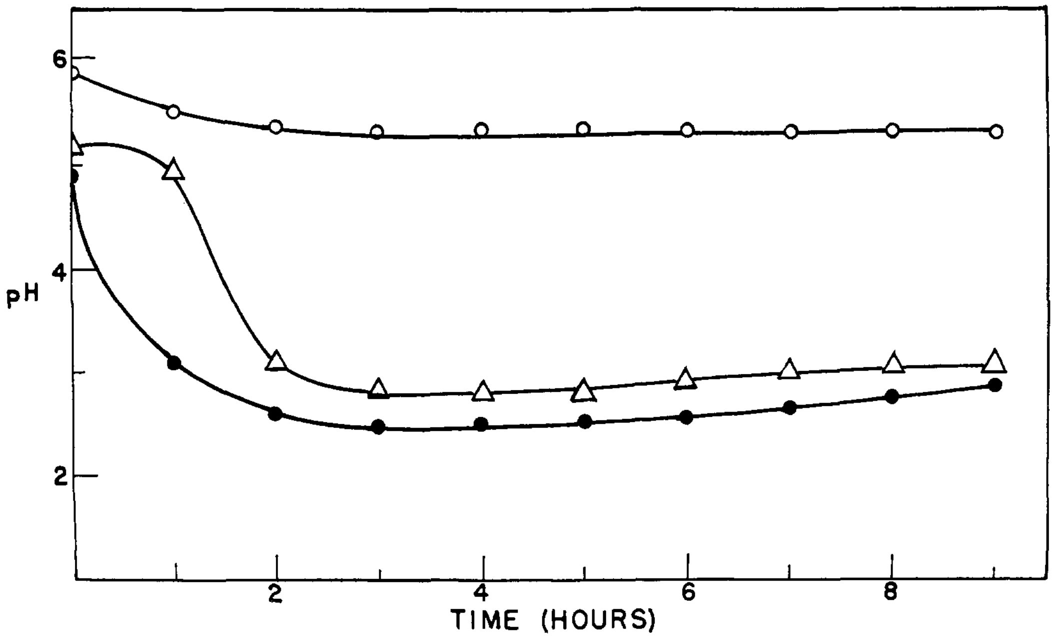


Figure 3. Effect of fermentation time on hydrogen ion concentration of different ferments

○ ADMI ferment
● Sugar ferment
△ Flour ferment

The pH of sugar ferment decreased rapidly, reaching a constant low pH level of 2.5 after 3 hours of fermentation. This indicated a lack of a buffering system in the sugar ferment. In the flour and sugar ferments, there was a noticeable increase in pH after approximately 4 hours of fermentation. This may be because of utilization of a small amount of the acids by the organisms present in the ferments. There was no significant effect due to different sugar types.

The total acidity of the ferments at different time intervals is shown in Figure 4. The values increased to a rather sharp maximum after 3 hours of fermentation and then decreased nearly to the starting level after 24 hours. The same sharp increase in acidity at 3 hours and the rapid decline thereafter were confirmed by the titration of acids separated from the ferments with resins. A total of 6.7 meq. of acid was extracted from the entire American Dry Milk Institute ferment which had stood 3 hours. Although the decrease in total acidity with time is not thoroughly understood, it is presumed that the acids are converted to other compounds by the organisms present in the various ingredients of the ferments.

Acknowledgment

Financial assistance from Corn Products Sales Co. is gratefully acknowledged.

Literature Cited

(1) American Association of Cereal Chemists, St. Paul, Minn., "Cereal Laboratory Methods," 5th ed., 1947.
(2) Baker, J. C., U.S. Patent **403,055.**
(3) Barnard, T. H., *Baker's Dig.* **28,** 61–4, 79 (1954).
(4) Barnard, T. H., *Baking Ind.* **103,** No. 1294, 67–8 (1955).
(5) Barnard, T. H., *Trans. Am. Assoc. Cereal Chemists* **13,** 43–53 (1955).
(6) Choi, R. P., 39th Annual Meeting, Am. Assoc. Cereal Chemists, Denver, Colo., May 1954.
(7) Dubois, M., Gilles, K., Hamilton, J. K., Rebers, P. A., and Smith, F., *Nature* **168,** 167 (1951).
(8) *Food Eng.* **25,** 60, 183 (1953).
(9) Griffith, T., and Johnson, J. A., *Cereal Chem.* **31,** 130–4 (1954).
(10) Jago, W., and Jago, W. C., American ed., Baker's Helper Co., Chicago, 1911.
(11) Johnson, J. A., and Miller, B. S., *Cereal Chem.* **26,** 371–83 (1949).
(12) Koch, R. B., Smith, F., and Geddes, W. F., *Ibid.*, **31,** 55–72 (1954).
(13) McLaren, L. H., *Baker's Dig.* **28,** 41–2, 48 (1954).
(14) Pirrie, P., *Bakers' Weekly* **164,** No. 2, 26–9 (1954).
(15) Pirrie, P., and Glabau, C. A., *Ibid.*, **163,** Nos. 5–7, 25–8, No. 8, 29–32, No. 9, 25–8, No. 10, 29–31 (1954).

Received for review August 25, 1955. Accepted November 4, 1955. Division of Agricultural and Food Chemistry, 128th Meeting, ACS, Minneapolis, Minn., September 1955. Cooperative investigations between Section of Cereal Crops and Diseases, Field Crops Research Branch, Agricultural Research Service, U. S. Department of Agriculture, and the Department of Flour and Feed Milling Industries, Kansas Agricultural Experiment Station, Manhattan. Contribution 263, Department of Flour and Feed Milling Industries, Kansas Agricultural Experiment Station, Manhattan.

Figure 4. Effect of fermentation time on total acidity of different ferments

Symbols same as for Figure 3