Damaged Starch and Protein Contents in Relation to Water Absorption of Flours of Indian Wheats

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The investigation has shown damaged starch to be a significant factor in the high water absorption by 63 straight-run flours of a number of varieties of Indian wheats. A significantly high positive correlation (r = + 0.81 to + 0.87) was obtained between water absorption and damaged starch contents compared to a value of + 0.50 for water absorption and protein content. The prediction of water absorption from damaged starch and protein contents is discussed.

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Introduction

The high water absorbing capacity of flours of Indian wheats was reported by *Coleman* et al. [1] as long ago as 1930. *Fisher* and *Jones* [2] in 1937 also mentioned the high water absorption of Karachi wheat. *Rattan Singh* and *Bailey* [3] pointedly referred to their findings of the very high water absorptions of the experimentally milled flours of 31 varieties of Punjab wheats which averaged 72.6 %. In subsequent studies of the milling and baking qualities of Indian wheats [4], even higher water absorptions have been recorded. *Bains* and *Irvine* [5] also found the absorptions of flours of seven improved varieties of Indian wheats to be high. The cause of high absorptions of flours of Indian wheats has not been studied so far.

This paper describes the contribution of damaged starch and protein content to the water absorptions of a new series of straight-grade flours of a number of varieties of Indian wheats. A high positive correlation between the water absorptions and damaged starch contents was obtained. Multiple regressions of water absorption on damaged starch and protein content were statistically highly significant.

Experimental

Materials

Sixty three samples of straight grade flours of a number of varieties of Indian wheats collected from the wheat breeders and the mills during the 1969–70 and 1970–71 crop years were used in this investigation. The flours were prepared on the Buhler Laboratory mill after conditioning.

Methods

Moisture, protein (N×5.7) and farinograph water absorptions (FWA) of the flours were determined according to the A.A.C.C. procedures [6]. The constant flour weight (50 g, 14 % moisture) technique was used for determining water absorption and the dough in each case was mixed to the 500 B.U. consistency.

Damaged starch was determined by the enzymatic A.A.C.C. [7], *Stewart* [8], and *Farrand* [9] methods and also by the colorimetric procedure of *Williams* and *Fegol* [10] as described by *Tara* and *Bains* [11].

The results were expressed on 14 % moisture basis. For study of interrelations, correlation coefficients between water absorption, damaged starch and protein content have been calculated. Multiple regression analysis of water absorption on damaged starch and protein content has been tested for significance by the analysis of variance.

Results

Mean values and range for the farinograph water absorption, protein and damaged starch contents are shown in Table 1 and correlation coefficients and multiple regression analysis in Tables 2–5.

Table 1. Mean Farinograph Water Absorption (FWA), Protein and Damaged Starch (DS) Contents of Flours of Indian Wheats.

	Mean %	Range %	Standard deviation (S.D.)	Coefficient of variation (C.V.)*
F.W.A.	62.00	48.0–72.1	5.50	8.9
Protein (N × 5.7)	10.48	7.9–13.3	1.42	13.5
D.S. [12]				
A.A.C.C.	9.2	3.0–16.9	2.57	27.9
Stewart	8.1	2.3–12.9	2.57	31.7
Farrand	14.2	0.5–33.2	7.41	52.3
Williams and Fegol	1.05	0.11–2.38	0.46	43.8

* $\frac{\text{S.D.}}{\text{Mean}} \times 100$

Thirty nine of the flours had absorptions exceeding 60.1 %. Of the remaining 24, that of 17 flours was in the range of 55.1–60.0 %. The protein contents of 27 samples were in the range of 12.1–13.0 %. The mean protein content of 10.48 % was fairly high for the flours of Indian wheats since some of the wheats were from a high protein wheat region [4]. The coefficient of variation for protein was 13.5 % and the protein range was 7.9 % to 13.3 %.

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The damaged starch values determined by the A.A.C.C. [7] and *Stewart* [8] methods were comparable and might be regarded quite high. Comparisons of damaged starch values determined by various methods have been recently discussed by *Tara* and *Bains* [12]. The coefficients of correlation between water absorption and damaged starch values obtained by these widely used methods were statistically highly significant (Table 2). The correlation coefficient between

Table 2. Relationship between Farinograph Water Absorption (FWA), Damaged Starch (DS) and Protein Contents of Flours of Indian Wheats.

Variable	Coefficient of correlation (r)*
F.W.A. v Protein	+ 0.50
F.W.A. v D.S.	
A.A.C.C.	+ 0.81
Stewart	+ 0.87
Farrand	+ 0.83
Williams and Fegol	+ 0.84

* Significant at P 0.01.

water absorption and protein content was statistically significant but in magnitude it was lower (+0.50) than the regression coefficient for water absorption and damaged starch contents. *Rattan Singh* and *Bailey* [3] reported a correlation coefficient of +0.67 between water absorptions and protein content of flours of 31 varieties of Punjab wheats milled on the Alli's Laboratory mill. The high positive correlation of water absorption with damaged starch (+0.81 to +0.87) observed in this investigation indicated significant contribution of this factor to the absorptions of flours of Indian wheats in comparison to protein.

Flours of Punjab wheats investigated by *Rattan Singh* and *Bailey* [3] had an average protein content of 9.6 % but a high absorption (72.6 %) compared with an average protein content of 13.0 % and an absorption of 62.3 % typical of the flour of a North American hard wheat. The six improved varieties of Indian wheats according to *Bains* and *Irvine* [5] had an average protein content of 9.7 % and 63.3 % farinograph water absorption. The flour of variety C 591 grown in four locations had a protein range of 7.6 to 10.0 % and absorption range of 58.2 % to 63.3 % and diastatic activity 322 mg to 378 mg maltose/10 g flour, respectively.

Information on damaged starch contents of the flours of Indian wheats studied by the previous authors [1–5] was not available. It is possible that damaged starch content of those flours must have been a significant factor contributing to enhanced water absorption. This probability is further supported by the relatively high diastatic activities of these flours [3–5] despite absence of sprouting.

The association between damaged starch and protein contents was poor, the correlation coefficients being statistically non-significant (Table 3). Similar correlations were obtained by *Tara* and *Bains* [11] in respect to 46 Indian commercial flours from wheats imported from the U.S. *Dodds* [13] reported significant positive correlation coefficients varying from 0.47 to 0.56 and 0.52 to 0.65 for two separate series

Table 3. Relationship between Protein and Damaged Starch (DS) Contents of Flours of Indian Wheats.

Variable	Coefficient of correlation (r)
Protein v D.S.	
A.A.C.C.	+ 0.24 NS
Stewart	+ 0.28 NS
Farrand	+ 0.25 NS
Williams and Fegol	+ 0.28 NS

NS = Non-significant

of U.K. flours. The author attributed the high correlations to the inclusion in the grist of a high protein imported wheat having starch granules susceptible to damage during milling. The flours comprising the present investigation, however, consisted of several varieties from different locations and represent a wide spectrum of protein and damaged starch contents. The poor association observed in this work was without any prejudicial factor in the grist.

The multiple regression analysis of water absorption on damaged starch and the protein contents was statistically highly significant as shown by the "F" values which ranged from 87.5 to 137.8 compared to 2.66 necessary for significance at P = 0.01. Mean variance due to deviations from the regressions varied between 7.06 (*Stewart*) to 8.16 (*Williams* and *Fegol*).

From the error standard deviations (ESD) of absorption predicted from regressions (Table 4), the *Stewart* method

Table 4. Error Standard Deviation (E.S.D.) of Prediction of Water Absorption.

D.S. Method	E.S.D.	E.S.D. as % of observed S.D.
A.A.C.C.	2.86	52.0
Stewart	2.39	43.4
Farrand	2.66	48.4
Williams and Fegol	2.66	48.4

seems to be slightly better. The other three methods namely A.A.C.C., *Farrand* and *Williams* and *Fegol* were comparable to each other for the prediction of water absorption.

The magnitude of error standard deviation of prediction of water absorption was somewhat high, probably because of the wide variations in the absorptions; 48.0 % to 72.1 %. Expressed as percentage of the observed standard deviation, error standard deviations ranged from 43.3 % to 48.4 %. *Dodds* [13] reported a wide range of standard deviations of errors in water absorption prediction by several regressions (0.5 to 2.39) including the model equation of *Farrand* [13]. In the case of Indian commercial flours from imported US wheats it ranged from 1.15 to 1.5 [11]. The farinograph absorption of these flours showed a range of 9.4 % (52.6 % to 62.0 %) which was considerably below the range for the straight grade flours of a number of varieties of Indian wheats. It is noteworthy that percentage error of standard deviations of prediction reported by *Dodds* [13] for 51 varied flours ranged from 13–17 % compared with another

series of 26 bread flours, where it was from 41 to 54 %. An interesting point emerges from the regression equations in Table 5 regarding the coefficients of protein which varied

Table 5. Multiple Regression Equations of Farinograph Water Absorption (FWA) on Damaged Starch (DS) and Protein (P) Contents of Flours of Indian Wheats.

		Calculated mean W.A. %
F.W.A., %	34.65 + 1.24 P + 1.56 DS (A.A.C.C.)	62.0
	37.02 + 1.07 P + 1.70 DS (Stewart)	62.0
	41.11 + 1.20 P + 0.58 DS (Farrand)	61.9
	40.09 + 1.10 P + 9.13 DS (W & F)	62.0

narrowly between 1.07 to 1.24 compared to the high coefficients for damaged starch determined by the A.A.C.C. [7], *Stewart* [8] and *Williams* and *Fegol* [10] methods. The coefficient for damaged starch by the *Farrand* method as applied to these flours was 0.58 compared to 1.20 for protein in the equation. The coefficients of damaged starch by the A.A.C.C. and *Stewart* methods were comparable (1.56 and 1.70). The low and high coefficients for the damaged starch for the Farrand and Colorimetric procedures are due to the units in which the values are expressed.

Discussion

Water absorbing capacity of a flour is a composite effect of several defined and undefined factors. For many years protein has been considered as the most important constituent influencing absorption. Thus, *Finney* [15] in an extensive study, demonstrated the linear relation between protein content and water absorption in 1945 within the genetic framework of a variety. Presumably, the flours comprising these studies contained comparable levels of damaged starch, else deviations would have been observed. The status of damaged starch in these flours was not determined. Though damage to starch granules during milling of wheat into flour was reported by several investigators, its contribution to water absorption relative to protein was first shown by *Greer* and *Stewart* [16]. This evoked major interest in the concept of water absorbing capacity of flours. Several methods of determining damaged starch have been developed [7–10, 16–20] and used for study of interrelations and regressions for prediction of water absorption of flours [11–14, 16, 20, 21]. Based on certain assumptions of a reference flour, *Farrand* [14] developed a model equation for calculation of water absorption from the protein and damaged starch contents expressed in *Farrand* units. The results of the present study relate damaged starch as an important factor in the water imbibing capacity of the straight grade flours of a number of varieties of Indian wheats. The use of multiple regression equations for prediction of water absorption from one series of flours to another has to be considered with discretion because of differences caused by the methods of estimation of damaged starch and interactions of the undefined factors responsible for variations in the water absorption of a particular set of flours.

The contribution of undamaged starch, pentosans and glycoprotein fractions to the water absorbing capacity of flours has not received as much attention as protein and damaged starch components. The effect of pentosans on the rheological properties of dough ascribed to their high affinity for water has been reported [22, 23]. Their role in the water absorption of flours of sound wheat as an additional factor for prediction purposes remains to be elucidated. The results of this study indicate damaged starch as an important factor in water absorption of flours of the Indian wheats.

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Zusammenfassung

Gehalte an beschädigter Stärke und Protein im Verhältnis zur Wasserabsorption von Mehlen aus indischem Weizen.

Untersuchungen haben gezeigt, daß die beschädigte Stärke ein wichtiger Grund für die hohe Wasserabsorption von 63 Passagenmehlen aus einer Anzahl indischer Weizensorten ist. Eine hoch signifikante positive Korrelation (r = + 0.81 bis + 0.87) wurde zwischen Wasserabsorption und Gehalt an beschädigter Stärke gefunden gegenüber einem Wert von + 0.50 für die Beziehung zwischen Wasserabsorption und Proteingehalt. Die Möglichkeit der Voraussage der Wasserabsorption aus den Gehalten an beschädigter Stärke und Protein wird diskutiert.

Résumé

Amidon endommagé et teneur en protéines en relation avec l'absorption de l'eau des farines provenant de blés Indiens.

L'étude a montré que l'amidon endommagé est un facteur significatif au niveau de la forte absorption de l'eau de 63 farines de passage provenant d'un certain nombre de variétés de blés indiens. Une corrélation positive hautement significative (r = + 0.81 à + 0.87) a été obtenue entre l'absorption d'eau et les teneurs en amidon endommagé, par contre, la corrélation entre l'absorption de l'eau et la teneur en protéines était de l'ordre de + 0.50. Une possibilité de prévoir l'absorption de l'eau à partir des teneurs en amidon endommagé et en protéines est discutée.

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Schwefeldioxidaufnahme bei der Maisquellung

1. Verteilung in den Fraktionen

Von W. Nierle, Detmold

Absorption of SO_2 During Swelling of Maize. Part 1. Distribution in Fractions. *It has been shown by means of S-35-labelled SO_2, that protein and germ take up most of SO_2 during the swelling of corn. The uptake by the maize kernels is only 6% from the amount solved in swelling water. The swelling process does not change the fatty acids composition of the total lipids of corn. There are only traces of sulfur in the extracted fats.*

(Zusammenfassung siehe Seite 347; Résumé à la page 347)

1. Einleitung

Die verstärkten Bestrebungen des Gesetzgebers nach Umwelt- und Verbraucherschutz erfordern auf den verschiedensten Gebieten der Nahrungsmitteltechnologie fundierte Kenntnisse über das Verhalten von Inhaltsstoffen oder sogenannten technischen Hilfsstoffen während der Verarbeitung. Ein bis heute noch unersetzbarer technischer Hilfsstoff bei der Naßverarbeitung von Industriemais ist das Schwefeldioxid. In früheren Untersuchungen [1, 2] mit SO_2 und verschiedenen Zuckern konnte festgestellt werden, daß bereits unter sehr milden Bedingungen mannigfache und bisher nicht bis ins einzelne geklärte Reaktionen ablaufen können, die eine gewisse Veränderung der Inhaltsstoffe zur Folge haben und eine Modifizierung des technischen Prozesses der Stärkehydrolyse und Siruplagerung erforderlich machen.

Ähnliche Überlegungen führten zu den im folgenden beschriebenen Untersuchungen, zumal bekannt ist, daß der technische Maisquellprozeß und damit die Naßverarbeitung ohne die Mitwirkung von SO_2 nicht durchzuführen sind. Obwohl diese Tatsache längst bekannt ist und es auch Theorien über die Wechselwirkung von SO_2 und Eiweiß gibt, liegen über die Aufnahme von Schwefeldioxid bzw. Schwefel und eventuelle Veränderungen von Inhaltsstoffen des Maises während der Quellung wegen der analytischen Schwierigkeiten keine näheren Angaben vor. Durch den Zusatz von Tracern, in diesem Falle von Schwefel-35 markiertem SO_2, ist dem Analytiker eine elegante und zuverlässige Methode in die Hand gegeben, derartige Fragen aufzuklären.

2. Experimenteller Teil

Im Laboratorium wurde nach der bekannten Methode von *Lindemann* und *Pelshenke* [3] Mais in 0,2%iger schwefliger Säure unter Zusatz von radioaktiv-markiertem SO_2 50 Std. gequollen und in die einzelnen Fraktionen aufgearbeitet. Vor und nach dem Ansatz wurde der Gehalt des Quellwassers an Radioaktivität untersucht, wobei sich herausstellte, daß nur 9% der ursprünglich zugesetzten Aktivität verschwunden war.

Die Bestimmung der Radioaktivität erfolgte wie auch in allen nachfolgenden Fraktionen durch Aufschluß mit Salpetersäure, Perchlorsäure und anschließender Fällung des gebildeten Sulfates mit Bariumcarbonat nach Zugabe von Trägerlösung in einem Low-Level-β-Counter. Die mit diesem Verfahren erhaltenen Meßwerte sind direkt miteinander vergleichbar, da so unterschiedliche Ausbeuten bei der Messung wegen der Verschiedenartigkeit des Probenmaterials vermieden werden können.

Hydrolyse der Eiweißfraktion

Ein aliquoter Teil des getrockneten Kiebers (1 g) wurde 4 Std. bei 145 °C mit 20 ml 6 N HCl in verschlossenen

Vortrag, gehalten auf der Stärke-Tagung 1972 der Arbeitsgemeinschaft Getreideforschung in Detmold.

Nr. 3923 der Veröffentlichungen der Bundesforschungsanstalt für Getreideverarbeitung in Berlin und Detmold.