COMPUTER EVALUATION AND MACHINE LISTING OF WHEAT QUALITY DATA[1]

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ABSTRACT

A program is described which uses IBM equipment for reporting the evaluation and certain mathematical calculations involving large numbers of different wheat varieties. In addition to this, a new format for collecting and recording laboratory data is given.

This entire program is fast; it can provide any number of printed reports and is virtually error-free if the cards are punched correctly. The mathematical portion of the program computes the data probably 30 times faster than the older method which used an electric calculator. The complete program is flexible and can be modified to suit a number of different applications. In addition, both the laboratory data cards and the punched cards are easily stored and readily available for recall.

A problem that faces cereal chemists who work with large numbers of samples for wheat quality evaluation is the recording, reporting, and evaluation of accumulated data. To facilitate this task, work cards for recording laboratory baking data and the mixing properties of flours were designed by Kilborn and Aitken (1). One of these cards contained an actual mixograph curve made from each flour sample. These cards were applicable, however, for one specific test in each instance, namely, baking and mixogram data. The authors stated that the cards may take the place of laboratory notebooks or other work sheets and, in addition to providing a permanent record, can be assembled readily for tabulation and report writing. One concluded from this part of the paper that their main objective was to obtain a better method of recording certain laboratory data.

The usual procedure in many laboratories and, indeed, in this one until recently, was to prepare suitable work sheets for each independent determination and then to summarize these data on large sheets preparatory to typing. This was a cumbersome method and necessitated the recording on each sheet of the laboratory number, variety or cross, and the origin of each sample. Consequently, if one had six or eight work sheets, the laboratory numbers and other pertinent data would, of necessity, be rewritten each time. This not only was very time-consuming and repetitious, but also introduced the possibility of errors.

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The over-all quality evaluation or ranking of large numbers of samples was also very time-consuming. The usual procedure has been for an experienced technologist to make a visual comparison of data of the named standard varieties and new wheats under test. Major and minor faults, if any, were noted and a suitable classification assigned.

It was sometimes desirable also to calculate standard deviations and correlation coefficients for these data. Therefore, the adoption of the computer for evaluation and listing of wheat-quality data would have a threefold objective.

The first was the development of an "all-purpose" work sheet or card for each sample which would contain all the pertinent data for all the laboratory determinations performed. However, not all the data required for the laboratory determinations are used in the report. Therefore, these data that are reported should be assembled in a manner suitable for easy transfer into punched cards and for subsequent recall.

The second problem was to devise a suitable format for a printed copy that would be applicable to most of the hard red spring wheat studies. Formerly, typed tables contained information which defined the data in each of the columns, as well as complete column headings and superscript numbers which referred to footnotes.

The third problem was to develop a suitable program for evaluating the laboratory data and to present them in printed form, clearly and succinctly listing the faults or deficiencies, the classification, and the conclusions.

Materials and Methods

To accomplish the work involving these interrelated problems, an IBM 1620 computer and 407 accounting machine were employed.

Cards. Numerous set-ups for an all-purpose work sheet or card were tried. Figure 1 shows a typical laboratory work card as finally adopted for the recording of data on nursery samples of hard red spring (HRS) wheat. The form is a standard IBM card, printed to accommodate the data desired. A separate card is used for each sample. Approximately midway on the card is a horizontal dotted line. The information above it contains data which are transferred to IBM punched cards. The numbers listed under each column heading are the digits allotted for each of the items. Provision is made for an additional digit in certain columns to handle specific footnotes. The section below the dotted line is used for recording laboratory data and certain information which is important only for the individual determination; for ex-

ample, wheat moisture is essential for proper tempering of a milling sample, but is nonessential as a quality factor and need not be in the final report. Container number (Ctr. No.) and loaf number are also in this category.

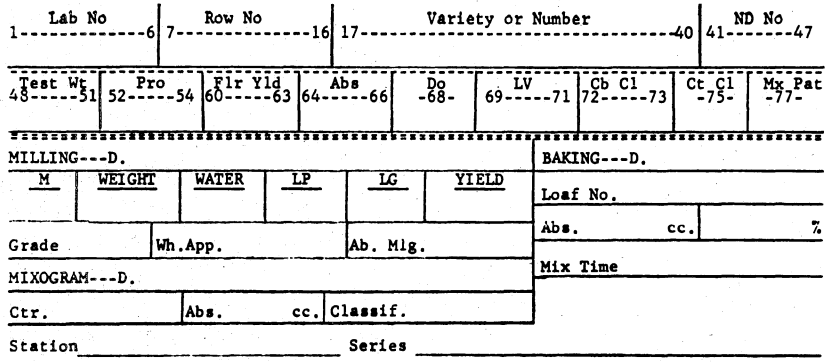

Fig. 1. Laboratory data card for hard red spring wheat nursery samples.

Code. This new method of recording laboratory data made it difficult, if not impossible in some instances, to include all desirable information on the print-out copy. A code was devised which listed definitions for column heading abbreviations, deficiencies or faults in kernel characteristics and milling properties, and the method used for obtaining and expressing the data. This code became a part of the program, and a code sheet accompanies every report. The terms and symbols applicable to the code follow:

ND NO	Identification number.
TEST WT	Test weight.
PRO	Wheat protein (%) AACC Method 46-10 (2).
FLR YLD	Flour yield (% of clean tempered wheat).
ABS	Water absorption (% of flour).
DO	Dough-handling characteristics at panning time (1 = poor, 2 = fair, 3 = good, 4 = very good).
LF VOL	Loaf volume (cc.) AACC Method 10-10 (2).
CB CL	Crumb color judged against a standard (expressed in units 1 to 10 in increments of 0.5).
CT CL	Crust color judged against a standard (1 = pale or pale and dull, 2 = dull, 3 = slightly pale, 4 = satisfactory).
MX PT	Mixogram pattern (3).
EV NO	Quality evaluation number determined by the computer (1 = no promise, 2 = little promise, 3 = some promise, 4 = good promise).
1–7	Fourth digit in test weight column refers to abnormal kernel appearance (1 = heavy damage, 2 = poor appearance, 3 = pale and dark mixture, 4 = trace of ergot, 5 = trace of blackpoint, 6 = slightly bleached or pale, 7 = bleached or pale).
8	Fourth digit in flour yield column refers to abnormal milling characteristics.

Cards similar to that shown in Fig. 1 accommodate all phases of this department's wheat quality evaluation program. In some instances, however, two cards are needed to record all the laboratory data; hence, two IBM punched cards are used for each sample. Because not all columns on the cards have been used, this arrangement can be accommodated easily on the final print-out.

Program. Quality evaluation of the various wheats by the computer, though somewhat complicated, has been successfully employed for data for 3 crop years. Limitations, divided into major and minor faults, are established for each quality factor. These are needed for input data preparation and are in accordance with results obtained on the named varieties (controls) which, of course, have been grown comparably in the series or experiment. Consequently, each series, of necessity, has different limitations for each of the quality factors examined. Figure 2 shows a typical completed card used for listing these various limitations which, in this case, are directly applicable to Table I. As previously stated, these limitations are divided into major (Mj) and minor (Mi) faults. For example, Test Wt (Mj) is the maximum test weight resulting in a major fault. Test Wt (Mi) is the maximum test weight resulting in a minor fault. Digits 4 and 8 are reserved for numerical expression of visible kernel damage. To assist in the evaluation computation, the decimal points are omitted from these variable figures but are reinserted in the print-out copy. It is desirable, when using the IBM 407, to have panels wired more or less permanently and kept available in storage for each different report.

A detailed description of the program used for the evaluation of HRS wheat nursery samples follows.

Identifying information and test values for eleven properties of HRS wheat and its flour are input to this program. Nine of these

Faulting Information - NDS8.4.009 - HRS Nursery (Regular & Sawfly) 3

Series: 3rd Lot F13 Series Lab. Nos. 63-618-63-867

Test wt (Mj) 1---------4	Test wt (Mi) 5---------8	Pro (Mj) 9---------11	Pro (Mi) 12---------14	Flr Yld (Mj) 15---------18	Flr Yld (Mi) 19---------22	Abs (Mj) 23-----25
5230	5330	138	148	5160	5360	545
Abs (Mi) 26---------28	**Do (Mj) 29---------30**	**Do (Mi) 31---------32**	**L. Vol. 33---------35**	**L. Vol. 36---------38**	**L. Vol. 39---------41**	**Cb Cl (Mj) 42-----43**
555	1	2	(MVOL) 165	(MVOL 2) 175	MVOL (3) 186	55
Cb Cl (Mi) 44---------45	**Ct Cl ( ) 46---------47**	**Mx Pat (Mj) 48---------49**	**Mx Pat (Mi) 50---------51**	**Crop year 52---------55**	**Mlg. Method 56---------57**	
65	2	4	5	1963	01	

Note: Omit decimal points: 01=Quadruplex Mlg. Method: Blank= Micro Allis Mlg.Method

Fig. 2. Laboratory card listing faulting information.

eleven properties are compared with minimum values (also input to this program) which are acceptable for each property. If the test value for any property for a given wheat sample is less than or equal to the minimum value, the sample is given a "minor fault"; if less than or equal to a subminimum value (also input to this program), the sample is given a "major fault."

In addition to the comparisons made with these minimum and subminimum values, each wheat sample is also given a minor fault if it has a trace of blackpoint,[5] indicated in the input by a "5" in the fourth digit in the test-weight figure, or has abnormal milling properties, indicated in the input by a fourth digit of "8" in the flour-yield figure.

After major and minor faults (if any) have been determined, a wheat sample is given an evaluation rank of 1, 2, 3, or 4. The basis for this evaluation is as follows:

1. Any major fault causes a rating of 1. Also, if the loaf volume is less than or equal to the maximum loaf volume, which would cause the sample to be evaluated as having no promise (MVOL), this is a major fault and causes a rating of 1.
2. If loaf volume is greater than MVOL but less than the maximum loaf volume, which determines an evaluation of 2 rather than 3 (MVOL2), the sample is rated 2, regardless of the number of minor faults.
3. If loaf volume is greater than MVOL2 and there are *three or fewer* minor faults, the sample is rated 3.
4. If loaf volume is greater than the minimum loaf volume (MVOL3) and there are no minor faults, the sample is rated 4.

Input Data Preparation. The data are presented to the computer by means of a series of punched cards. The first three input cards provide the appropriate heading for each table. The alphabetic or numerical information for the headings should be centered on column 45. The information appears only on the first tabulated page (Table I).

Cards 1 to 4 provide the following information: card 1, source of samples (fourth line of heading); card 2, crop year (fifth line); card 3, lot and series numbers (sixth line); card 4, milling method (seventh line).

Card 5 contains information which governs the evaluation number: the data, punched without decimal points, which establish the limits for major and minor faults. In the system, 57 of the 80 available columns are punched for this information. The specific designation for each column follows:

[5] Blackpoint is a plant disease which causes a black discoloration to the germ and crease of the kernel.

Column No.	*Input Control Data*
1–3	Maximum test weight (0.1 lb.) which would cause a major fault.
5–7	Maximum test weight (0.1 lb.) which would cause a minor fault.
4,8	Numerical expression of visible kernel damage.
9–11	Maximum protein content (0.1%) which would cause a major fault.
12–14	Maximum protein content (0.1%) which would cause a minor fault.
15–17	Maximum percent flour yield (0.1%) which would cause a major fault.
19–21	Maximum percent flour yield (0.01%) which would cause a minor fault.
18,22	Numerical expression of abnormal milling characteristics.
23–25	Maximum absorption rating (0.1%) which would cause a major fault.
26–28	Maximum absorption rating (0.1%) which would cause a minor fault.
29–30	Maximum rating of dough characteristics which would cause a major fault (01 = poor; 02 = fair; 03 = good; 04 = very good).
31–32	Maximum rating of dough characteristics which would cause a minor fault.
33–35	MVOL, maximum loaf volume (cc.) which would rank 1.
36–38	MVOL2, maximum loaf volume (cc.) which determines a rank of 2 rather than 3.
39–41	MVOL3, minimum loaf volume (cc.) when equaled or exceeded in conjunction with no minor faults, is ranked 4.
42–43	Maximum rating of crumb color which would cause a major fault.
44–45	Maximum rating of crumb color which would cause a minor fault.
46–47	Maximum rating of crust color which would cause a minor fault (01 = pale; 02 = slightly pale; 03 = dull; 04 = satisfactory).
48–49	Maximum mixogram pattern which would cause a major fault.
50–51	Maximum mixogram pattern which would cause a minor fault.
52–55	The year the wheat sample was grown.
56–57	Milling code: blank = micro Allis milling, 01 = Quadruplex milling.

Card 6 and all subsequent cards in the series contain the laboratory data for each individual wheat sample. There are as many cards as there are wheat samples. The specific laboratory data punched in each column follow:

Column No.	*Input Laboratory Data*
1–2	Last two digits of the year in which the sample was grown.
3–6	Laboratory number of the sample.
7–16	Row number.
17–40	Variety or number of cross.
41–47	North Dakota number.
48–50	Test weight of sample (0.1 lb.).
51	Digit denoting code of types of visible damage.
52–54	Protein content (0.1%).
60–62	Long patent flour yield (0.1%).
63	Digit denoting abnormal milling characteristics.
64–66	Absorption (0.1%).
68	Dough characteristics (1 = poor, 2 = fair, 3 = good, 4 = very good).
69–71	Loaf volume (cc.).
72–73	Crumb color rating.
75	Crust color rating (1 = pale; 2 = slightly pale; 3 = dull; 4 = satisfactory).
77	Mixogram pattern rating.

Output Information. All output consists of punched cards. To facilitate listing the cards on the IBM 407, various codes are punched in column 80 of many of the output cards. The tabulated and analyzed data are received from the IBM 407 as multicopied typed tables, suitable for inclusion in reports. Table I is a typical illustration of a wheat quality report produced by this program.

In the summary of milling, baking, and analytical data for the HRS

TABLE I
TYPICAL WHEAT QUALITY REPORT PRODUCED BY THIS PROGRAM

NORTH DAKOTA STATE UNIVERSITY
AGRICULTURAL EXPERIMENT STATION
DEPARTMENT OF CEREAL TECHNOLOGY

MILLING, BAKING (MICRO METHOD) AND ANALYTICAL DATA FROM NURSERY SERIES
1963 CROP

3RD LOT F13 SERIES
QUADRAPLEX MILLING METHOD

LAB NO		ROW NO	VARIETY	ND NO	TEST WT	PRO	FLR YLD	ABS	DO	LF VOL	CB CL	CT CL	MX PT	EV NO
63	618	F13-2	2350X(2350)RU-K338X3880		59.0	16.3	59.5	60.0	4	180	7.0	4	6	3
63	619	F13-3	ND81SIB.XND1		60.0	17.0	57.2	60.0	4	190	7.5	4	6	4
63	620	F13-18	ND140XND138	229	55.05	15.7	58.9	58.0	4	144	6.0	3	8	1
63	621	F13-31	CONLEYXND42-3-1-5		58.5	14.7	56.6	58.0	4	170	7.5	4	5	2
63	622	F13-120	SELKIRK		54.0	15.7	56.6	56.0	4	190	7.5	4	7	4
63	623	F13-46	LEEXFPI186035		57.0	16.4	40.08	54.0	4	196	8.0	4	5	1
63	624	F13-47	ND138XLEEXFPI186035	264	59.0	15.5	56.8	58.0	4	181	7.0	4	6	3
63	625	F13-48	ND138XLEEXFPI186035	264	57.0	15.2	53.4	56.0	3	180	7.0	4	6	3
63	626	F13-55	ND138XLEEXFPI186035	401-S	55.57	16.0	35.38	56.0	3	210	8.0	4	7	1
63	627	F13-100	JUSTIN	102	55.5	16.7	53.7	56.0	4	225	7.5	4	8	4
63	628	F13-129	ND42-3-1-5XJUSTIN	390	59.0	15.2	56.4	58.0	4	182	6.5	4	6	3
63	629	F13-76	CONLEYXND122		59.0	15.3	59.4	56.0	4	136	7.5	4	3	1

Note: The program is designed to group the data in units of ten to facilitate checking the results.

Kernel damage by blackpoint is shown for the sample 63-620; this is denoted by 0.05 in the test weight column.

Abnormal milling is shown for the samples 63-623 and 63-626; this is denoted by 0.08 in the flour yield column.

wheat program (NDS 8.4.009),[6] columns 1 through 77 of the output cards for wheat samples are identical to the same columns of the corresponding input cards. Column 79 of the output contains the evaluation number assigned to that sample of wheat.

For evaluation and fault identifications of HRS nursery samples (NDS 8.4.010), columns 1 through 47 of the output cards for wheat samples are identical with the same columns on the corresponding input cards. Columns 48 through 77 contain abbreviations for the faults determined by the program to be possessed by that particular wheat sample. Column 79 contains the evaluation number assigned to that sample of wheat.

Discussion

Table II is a typical print-out listing the faults and the classification or evaluation number for each sample. In some instances, this

TABLE II

TYPICAL WHEAT QUALITY EVALUATION REPORT. THE FAULTS AND EVALUATION RANK ARE LISTED FOR EACH SAMPLE

NORTH DAKOTA STATE UNIVERSITY
AGRICULTURAL EXPERIMENT STATION
DEPARTMENT OF CEREAL TECHNOLOGY

MILLING, BAKING (MICRO METHOD) AND ANALYTICAL DATA FROM NURSERY SERIES
1963 CROP
3RD LOT F13 SERIES
QUADRAPLEX MILLING METHOD

LAB NO	ROW NO	VARIETY	ND NO	PRINCIPAL FAULT(S)	EV NO
63 618	F13-2	2350X(2350)RU-K338X3880		VL	3
63 619	F13-3	ND81SIB.XND1			4
63 620	F13-18	ND140XND138	229	CBCL VL BP	1
63 621	F13-31	CONLEYXND42-3-1-5		PR MX VL	2
63 622	F13-120	SELKIRK			4
63 623	F13-46	LEEXFPI186035		YLD ABS MX ABMG	1
63 624	F13-47	ND138XLEEXFPI186035	264	VL	3
63 625	F13-48	ND138XLEEXFPI186035	264	YLD VL	3
63 626	F13-55	ND138XLEEXFPI186035	401-S	YLD ABMG	1
63 627	F13-100	JUSTIN			4
63 628	F13-129	ND42-3-1-5XJUSTIN	390	CBCL VL	3
63 629	F13-76	CONLEYXND122		MX VL	1

is the only table used by plant breeders, because it gives a concise over-all evaluation of samples. Poor-quality wheats can be detected easily and, if desired, they can be removed immediately from the program. Conversely, wheat showing good promise can be advanced more rapidly.

Another program involving durum wheat quality has been developed and put into use, similar in some respects to the one reported here. No useful purpose would be served by including it as part of

[6] Listings and computer programs NDS 8.4.009 and NDS 8.4.010 can be obtained by writing to the author.

this paper, but it will be made available upon request (NDS 8.4.015).

This type of program also has been found useful for statistical studies. Details pertaining to the quality of past years' crops may be recalled and processed readily. Moreover, a procedure exists for obtaining standard deviations and correlation coefficients with the use of the IBM 1620 computer. Pertinent data from previously punched cards are repunched by means of a short computer program (NDS 8.4.020) into new cards, and these are used for the statistical analysis under the program (No. 6.0.038) from the 1620 Users Group Library.

With this new data-processing procedure, large numbers of data from wheat samples can be listed and evaluated and transferred directly from the laboratory work card to the IBM card; this eliminates the tedious, time-consuming procedure of tabulating data prior to typing. The automatic evaluation is a very desirable aspect of the program and eliminates any bias that might possibly be present in another subjective form of quality evaluation.

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