GENETIC IMPROVEMENT
OF QUALITY AND AGRONOMIC CHARACTERISTICS
OF DURUM WHEAT FOR ETHIOPIA

by

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The *T. durum* segment of the U.S.D.A. World Wheat Collection totalling 3399 lines was analyzed to study the variability that exists for protein and lysine among durum wheats.

Substantial variability in protein content among these tetraploid wheats was detected. Protein varied from 7.3% to 21.3% with a mean and standard deviation of 12.75% and 2.86, respectively. Lysine (% of sample) ranged from 0.26% to 0.60% with a mean of 0.39% and standard deviation equal to 0.06. Lysine expressed as percent of protein exhibited a range of 2.43% to 4.29% with a mean and standard deviation of 3.15% and 0.27, respectively. These protein and lysine values closely resemble the values for common wheats and other *Triticum* species and genera related to wheat. The nature of the distribution, amount of variability, and the relationship of protein and lysine in these two species also are similar. The magnitude of the correlation between these two traits is, however, larger in durum wheats than in

the hexaploid wheats. The relationship of lysine (% of sample) with protein content is strongly positive and curvilinear ($r^2 = .92$). Lysine (% protein) is negatively correlated with protein with about 75% of its variation being associated with protein variation. The negative relationship of lysine (% protein) and protein content diminishes as protein increases, and virtually disappears above 15% protein.

About 136 or 4% of the World Collection durums exhibit protein contents exceeding 18.47% (two standard deviations above the mean protein percent). Less than 1% of the World Collection durums show significantly higher lysine (% protein) values than the mean lysine. Wheats with such superiority over the ordinary durum wheat were tentatively identified as potentially high lysine lines.

Two hundred entries that exhibited unusual properties of protein and lysine were grown at sites in Ethiopia and U.S.A. Seeds harvested from these locations were analyzed for protein and lysine at the University of Nebraska Wheat Quality Laboratory to determine whether they are genetically superior to ordinary durum and to assess their potential value for genetic improvement of wheats indigenous to Ethiopia. Large effects of environment and genotype x environment interaction were detected.

Varieties that exhibited high protein and normal lysine levels over environments have been identified as high protein lines. These include C.I. 7796 (Ethiopian source), P.I. 192711P, and P.I. 185734P. The latter two varieties (Portuguese source), however, showed poor performance at Awasa and Debre Zeit in Ethiopia.

The stability of C.I. 7796 in different environments was tested using both the Yates-Cochran and Eberhart-Russell procedures. The performance of this variety at the various locations fits the description of a stable variety as determined by the Yates-Cochran procedure but does not conform to that of Eberhart and Russell. It also fits the description of a variety with broad adaptability (Finlay and Wilkinson). This variety will be used as an immediate parent for high protein and, following further investigations on various agronomic and other characteristics, might also be multiplied as a high protein line in Ethiopia.

A breeding program which utilizes back-crossing and mass selection techniques for effective utilization of the superior germ plasm in Ethiopia was initiated at Yuma, Arizona in 1973. This approach which involves the use of chemical male gametocides to enforce genetic recombination will continue in Ethiopia using the seeds harvested from Yuma as the female-parent population. The entries identified as high protein lines (suspected to be also drought resistant) will form the pollen donor lines.

INTRODUCTION

The Ethiopian farmer has been associated with wheat since time immemorial. There has been little or no conscious effort on the part of the farmer, however, to change the agronomic and other characteristics of the wheat plant. Therefore the existing wheat populations are, for the most part, a diversity of adapted genotypes which have been evolving through natural selection on the highland regions where they have been grown.

It was only recently that any organized effort took place to improve the economic value of this important crop through modern plant breeding procedures. As yet very little emphasis has been placed on improving the nutritive quality of wheat although it is a major source of nutrition in the country.

The situation as regards the nutritional improvement of wheat was, until recently, the same in the other areas of the world. Although plant breeders in the various countries have had the means of determining protein content of wheat, breeding for improved protein content and quality was not practiced. This was because known genetic differences in protein content of wheat grain were small in relation to environmental effects (19).

It has since been demonstrated that a soft winter variety, Atlas 66, possesses genetic superiority over ordinary wheat for protein content and that the gene(s) controlling the high protein trait in this variety could be transferred to other winter wheats (17, 19, 20, 22, 23). The

resulting increase in protein content was accomplished without adversely affecting yield (23, 36). Such development has clearly demonstrated that the protein content of wheat can be substantially improved by breeding.

In maize, it has been reported (42) that the opaque-2 gene has significantly higher lysine per unit protein than commonly grown varieties and hybrids. This suggests the possibility that such gene(s) may also exist in wheat. The feasibility of such research has been accentuated by the development of amino acid analyzers which makes it possible to screen large numbers of samples.

In 1973, a study was initiated to identify high protein and lysine varieties among the durum segment of the U.S.D.A. World Collection with the aim of incorporating genes for high quality and other desirable characteristics into wheats indigenous to Ethiopia. The results of the study and a breeding method for effective use of the germ plasm are reported.

LITERATURE REVIEW

Variability of Grain Protein and Lysine

The literature contains a substantial body of information regarding the variability of protein and lysine content in different wheats. Most of the emphasis, however, has been on hexaploids and there is relatively little work reported on spring durum wheat (tetraploids).

Vogel et. al. (57) analyzed common wheats totalling 12,613 from the U.S.D.A. World Collection for protein and lysine composition. The protein content ranged from 6.9 to 22.0% with a mean of 12.97% and standard deviation 2.019. This wide range of protein suggested significant genetic differences in protein content among the common wheats of the World Collection. They tentatively identified over 500 wheats with more than 17% protein as potentially high protein lines. Lysine content expressed as percent protein ranged from 2.25 to 4.26 with a mean and standard deviation of 3.16 and 0.231, respectively. Lysine content expressed as percent of sample ranged from 0.25 to 0.66 with a mean of 0.40 and standard deviation equal to 0.049. The protein and lysine ranges are in agreement with preliminary results that were previously reported for these wheats. The range of variability in lysine and protein among the common wheats of the World Collection is comparable to that reported for various other *Triticum* species and for genera related to wheat.

A systematic survey of the lysine contents of the proteins of a widely representative group of wheat varieties and related species and

genera has been reported by Lawrence et. al. (31). Over 230 wheat varieties representing recognized market types and classes, 12 different Triticum species other than T. aestivum and T. compactum, 6 varieties of durum, 13 samples of genera related to wheat and 15 hybrids of wheat x Agropyron elongatum were analyzed for their lysine and protein content. The content of lysine expressed as percent of protein of the spring and winter wheats ranged from 2.46 to 3.84 with a mean of 3.10 percent. The durums ranged 2.70 - 3.30% lysine (% protein). The spring wheat varieties varied from 2.48% to 3.54% with an overall mean of 2.91%. Lysine (% of protein) content of the Triticum species, genera related to wheat, and the wheat x Agropyron elongatum hybrids showed a range of 2.21 to 3.98 percent. The range in protein content of these species and hybrids was from 9.8% to 21.6%. However, the wild emmer (T. dicocoids) sample had a protein content as high as 29.6 percent.

Villegas et. al. (56) investigated the variability in the lysine content of spring wheat, durum wheat, other wheat species, rye, and Triticale. The spring and durum wheats included in the study were 12 varieties of hard red spring wheat and 28 lines or varieties of durum. Spring wheat and durum wheat were found to be about equal in their average lysine (% protein) content but slightly less than what has been reported for these species by Lawrence et. al (31). The 64 different Triticum species showed ranges of 8.6 - 24.2% and 2.09 - 3.99% in their protein and lysine (% of protein) contents, respectively, on a 14% moisture basis. Triticale and rye proteins were about 20 to 30% higher than the spring and durum wheats.

Lysine - Protein Relationship

An inverse relationship between protein content and lysine per unit protein of the various wheats, rye, and Triticale has been noted by various investigators. Lawrence et. al. (31) observed that in common wheats a negative correlation existed between lysine expressed as a percent of protein and percent protein. They also showed that there was no significant correlation of lysine (% protein) with protein content for wheat with protein values exceeding 13.5 percent, but below this level a highly significant negative correlation existed.

A similar relationship of lysine and protein among common wheats has been reported by other researchers. Vogel et. al. (57) observed an inverse relationship between lysine content (% protein) and protein content for 12,613 hexaploid wheats. They showed that there is little apparent correlation of lysine (% protein) with protein content for wheats with more than 15% protein. However, this relationship is clearly negative for wheats with less than 15% protein. Vogel et. al. also noted that wheats with the highest lysine percent of sample do in fact have the lowest lysine (% protein).

For the spring and durum wheats, a negative correlation between lysine expressed as % of protein and percent protein was reported by Villegas et. al. (56). Simmonds (48) showed a negative relationship between lysine (% protein) and protein content for six Australian wheats and the flours milled from them. The trend among other amino acids was not so marked, except for glutamic acid which tended to increase with increasing percent of protein. This finding was in agreement with that of McDermott and Pace (39) who worked with flours milled from different wheat varieties.

With the objective of studying the nature of proteins responsible for certain of the variations in amino acid composition, Simmonds (48) analyzed extracts obtained from fractionation of two different flour samples for amino acid composition. He found the albumin and globulin proteins to be higher in lysine content than the glutens. However glutamic acid was higher in the gluten proteins. Similar results were obtained by Mattern et. al. (37) who worked with the flour of a hard red winter wheat variety.

It is also established that gliadin (alcohol soluble protein) is relatively low in lysine and this component forms about 50% of the total endosperm protein. One way to increase the lysine fraction should then be to decrease the gliadin fraction and/or increase any of the components that are higher than gliadin in lysine (personal communication with Professor P. J. Mattern).

The analyses conducted on flour samples of 32 different wheats by Pence et. al. (45) produced values ranging from 13 to 22% for the albumin and globulin content of the total flour protein. They also observed a direct relationship of amount of these water soluble proteins per sample with total protein content of the flour. However, the relationship was negative when albumin - globulin content was expressed as percent of protein. These results are in agreement with the findings of Ulmer and Mattern (55).

McDermott and Pace (39) and Simmonds (48) attribute the variability in lysine content and the protein - lysine (% protein) relationship to variation in the proportion of soluble protein. The increase in lysine as protein concentration decreases is considered to be a reflection of

an increase in the albumin - globulin : gluten ratio. Wheats with low protein content will have a higher proportion of the soluble proteins and are, therefore, higher in lysine per unit protein. On the basis of this explanation, Vogel et. al. (57) reasoned that the albumin - globulin : gluten ratio of the common wheats which they have analyzed should be relatively stable at protein levels higher than 15 percent.

Variation in Protein and Lysine Composition of the Wheat Kernel

Variability in the protein/lysine content of various morphological components of wheat has been studied by various workers. McMasters et. al. (34) concluded on the basis of an extensive survey of literature that such variability does exist. The endosperm is generally lower in protein content and in the lysine fraction per unit protein than the germ and bran. Johnson et. al. (25) indicated that differences in kernel morphology could alter the ratio of endosperm to non-endosperm protein and thus affect the overall lysine content of the kernel.

Relationship of Lysine/Protein Content with Other Traits

McNeal et. al. (41) suggested in their study of quality response of 5 spring wheat varieties that short plants are generally less capable of translocating protein into their grains. They found short plant height to be positively correlated with low kernel protein content. Johnson et. al. (28) on the other hand found a significant negative correlation of 0.24 between plant height and protein content in a cross of Nap Hal with C.I. 13449. They indicated that this negative correlation suggests some association of shortness with high protein content.

Johnson et. al. (27) studied the effect of kernel size and plumpness on protein/lysine content of various wheats from the World Collection. Kernel size alone did not appear to exert a significant influence on either lysine or protein content. Degree of plumpness however was shown to strongly affect protein content and lysine percent of sample. No effect on lysine per unit protein was detected.

Clark (5) studied the relation of awnedness to yield and protein content of the grain. Awned wheats exceeded the awnless varieties by 21.4% in yield. The crude protein content was higher by 10.9% in the awnless varieties.

Yield and protein content have been reported to be frequently but not always negatively correlated (9, 54). It has been possible however to maintain high grain protein percentage without significant yield reductions over many environments as reported for the variety Atlas 66 (23, 43, 52). The high protein of this variety has also been transferred to other wheats, with high heritability values, without affecting their yield (20, 27). The amino acid composition also was found to be not adversely affected by increase in protein content (23, 36). There are numerous reports demonstrating that increase in protein content while maintaining a high yield level is possible (22, 24, 26, 28).

Genetic Studies of Protein and Lysine

Studies involving two wheat varieties (Wichita and Atlas 66) have produced evidence that protein is under polygenic control with no dominance present. Heritability values ranging from 68 - 83% were

observed for protein content. On the other hand, studies involving various other crosses of wheat have provided evidence for the presence of either dominant or recessive genes for protein expression (27).

Crosses made with Nap Hal and Atlas 66 at Nebraska (27) have exhibited transgressive segregation for both high and low protein content. Studies of populations derived from crosses of these varieties indicated that different genes are involved. These findings have suggested to Johnson et. al. that higher protein levels than what was provided by Atlas 66 are possible. They also indicated that Nap Hal possesses a heritable high lysine in combination with high protein.

In 1964, Mertz et. al. (42) discovered that maize homozygous for the opaque-2 gene is significantly higher in lysine content of protein than ordinary varieties and hybrids. This finding suggests the possibility that such genes may also exist in wheat.

Amino acid analyses of lines derived from Atlas 66 have shown that increase in protein content is possible without adversely affecting its quality (36). These various findings suggest that protein content of wheat can be significantly improved through breeding.

Effect of Environment on Protein/Lysine Content

Variation in protein quality and quantity of wheat is definitely influenced by environment. Johnson et. al. (27) indicated in their report on World Wheat Collection study that the effect of environment is probably larger than the genetic effect, tending to mask genetic differences. McElroy et. al. (40) reported significant lysine (percent of sample) differences among samples of the hard red spring wheat variety Marquis grown at 9 different locations in Alberta, Canada, during

the same year. A range of 1.94 to 4.03% in percent nitrogen of sample was observed for this variety grown at the nine locations. Johnson et. al. (19) have identified wheat varieties which yielded significantly higher lysine (% protein) than other varieties over a wide range of environments.

Lawrence et. al. (31) reported that the lysine percent of protein is not influenced by environment except as the latter affected the protein content. (There is inverse relationship between lysine per unit protein and percent protein).

Soil Fertility and Protein/Lysine Content

The protein and lysine values of wheat have been shown to be influenced by soil fertility levels. Haunold et. al. (17) attribute the higher protein content of the kernel of some wheats to more efficient translocation of nitrogenous compounds through the plant. They suggest that an internal protein-fixing threshold, representing the genetic potential for grain protein content, is operative in wheat. A variety with a high threshold will be expected to store more grain protein with adequate soil nitrogen availability. On the basis of this assumption they determined the protein threshold for Atlas 66 in their study to be 3 percentage points higher than that of Wichita. Johnson et. al. (27) obtained results from their study of Atlas 66 which suggested that wheat with high protein content (14 - 17%) can be achieved from genetically high protein cultivars grown under high soil fertility levels.

The ARS-Nebraska wheat research program has developed winter wheats with higher grain protein potential than ordinary wheats. The research

has also pointed to increased nitrogen translocation capacity as the physiological reason for the higher grain protein content of these lines. According to Johnson and Mattern (27), these findings provide evidence for phenotypic expression of the high protein trait in a wide range of soil fertility and production environments.

Hojjati (18) observed an inverse relationship between nitrogen fertilization and lysine percent of protein. This is to be expected since various reporters have indicated that protein content and lysine per unit protein are negatively correlated. He also reported that increasing potassium from 0 to 100 kg/Ha resulted in a 29% increase in lysine percent of protein when no nitrogen was applied. High level of nitrogen application reduced the effect of potassium application on lysine. Wheat grown on soil with available phosphorous of 12.5 ppm or more showed higher lysine per unit protein and higher yields, but also resulted in low grain protein content.

According to Pisareu (46) and Waldron (58), moisture and geographical influences are important factors contributing to variability of protein content in wheats. They observed that wheat grain protein is higher in dry years. Pisareu reported that protein content increased from about 14% in wet years to 20% in dry years. The kernel protein also decreased from dry warm geographical regions toward cooler and moister regions.

Genotype x Environmental Interaction

Comstock and Moll (10) refer to genotype x environment interaction as the interplay in effect of genetic and nongenetic factors on development of the plant. They pointed out that genotype x environment

interaction reduces the correlation between phenotype and genotype with the result that valid inference becomes more complicated. In addition to the basic causes and effect of interaction, Comstock and Moll also indicated that the magnitudes and the ways in which this factor influenced genetic improvement efforts would determine whether the breeder should aim at developing genotypes of narrow adaptability or the ones of broad or general adaptability. Frankel (15) indicated that the plant breeder's choice is limited to breeding either for closely defined ecological conditions or for more extensive conditions that require genotypes possessing adaptability to a broad spectrum of environments. There are various other reports also discussing genotype x environment interactions and their implications for applied plant breeding (3, 16). They indicate that the plant breeder has to define the most appropriate scheme for evaluation of genotypes according to their response to environment.

Genotype x environment interaction estimates have been reported by various researchers. First and second order interactions involving variety, yield, and location have been shown to be important sources of variation in plant breeding problems (10). Estimates of genotype x environment interactions have also been shown to vary from one area to another. Baker (6), for instance, observed differences among estimates of the ratio of genotype x environment interaction relative to experimental error. These were estimates taken from experiments conducted in Western Canada as well as those obtained by other researchers. He attributed these differences to either wide environmental differences or differences in experimental technique.

Miller et. al. (44) reported that important genotype x environment interaction variations exist for lint yield in cotton, but they are less important for the various yield components and fiber traits. Extensive studies were conducted by Abou-El-Fittouh et. al. (1) on the performance of 4 upland cotton varieties across the Cotton Belt of the Southern United States. They reported that a 3-factor interaction was the most important interaction variance for all traits except yield. Among the two-factor interactions, genotype x year interaction was shown to be the least important for all traits other than seed index and lint percent. They also indicated that genotype x location interaction should be expected to increase with the expansion of the reference base of locations.

Variety x environment interactions were also reported for wheat by Anand (5). Twelve varieties of wheat were grown at 4 locations for three years in India. Analysis of variance of data from these trials showed variety x location x year and variety x location interactions to be significant, indicating that varieties performed differently in different environments. The variances of the interactions were found to decrease with increasing number of locations.

Significant two-factor and 3-factor interactions involving variety, location, and yield have been reported for yield of fall rye tested in Western Canada by Kaltsikes (30). By testing for three years in twenty locations with four replications, Kaltsikes was able to detect yield differences as low as 10% of the mean of the highest yielding cultivar. He pointed out that further reduction of the yield difference detectable would require more locations.

In his study of yield stability of winter wheat grown in different localities in Czechoslovakia, Smocek (49) observed that the experiments involving one, two, and three years were inconsistent with respect to variety ecovalence. There was significant agreement, however, between ecovalences from two and three year results. Smocek concluded that genotype x year interaction is a main influence in the overall adaptability of the varieties.

Genotype x environment interaction in different cereal species was studied in Switzerland by Bieri (8). He reported that this factor was an important source of variation in most of the cereals studied. Location was found to be important for spring wheat and barley. With winter wheat, genotype x year interaction was significant. In the case of oats, however, both year and location appeared to be moderately significant. These results indicate that the importance of each component of environmental variance with respect to genotype x environment interaction varies among species.

Phenotypic Stability Measurements

Lewis (32) defines phenotypic stability as the ability of an individual to produce a certain narrow range of phenotypes in different environments. Various ways of measuring varietal stability have been proposed in the literature.

Plaisted and Peterson (47) proposed a technique for evaluating the consistency of yield of varieties over a number of locations and seasons. They estimated variety x location interaction variances for potato varieties tested at different locations in the same year. An estimate of genotype x location interaction was determined for each

pair of varieties on the basis of a combined analysis of variance. The arithmetic mean of these estimates was used to evaluate variety stability. A variety with comparatively small genotype x location interaction variance would be regarded as relatively "stable."

Dracea and Saulescu (11) studied yield stability of five winter wheat varieties during a period of six years in Romania. The best measurement of stability of these varieties was obtained by finding the total yield variance of each variety and calculating the regression of yield on the average yield of the experiment.

Another approach, originally proposed by Yates and Cochran (59), involves the use of regression of yield on environmental index. This technique was applied by Finlay and Wilkinson (14) to evaluate the stability of a set of varieties grown over locations and seasons. The environmental index was measured by determining the mean yield of all varieties per location/season and grading the environment accordingly. Variety mean per location/season was then regressed on this index. Beside providing a quantitative grading, the mean yield of all varieties per location/season would enable one to describe the environment. A high mean yield per location/season, for example, would indicate a high yielding environment. Finlay and Wilkinson were able to obtain better linearity of the regression of individual means on location means by transforming the yield data into a logarithmic scale.

Finlay and Wilkinson also classified varieties with either specific adaptability to high or low yielding environments or general adaptability or poor adaptability to all environments. They were able to do so by using the regression coefficients of variety mean yields over all

environments. The regression coefficients also provided a measure of cultivar phenotypic stability. A regression coefficient of b = 1.0 indicated average phenotypic stability for the whole set of varieties tested. Varieties with b<1.0 are above average and b>1.0 below average, in this respect. Complete phenotypic stability, i.e., a constant grain yield in all environments, is indicated when b = zero. Finlay and Wilkinson described the ideal genotype as one having maximum genetic potential in the highest yielding environment as well as maximum phenotypic stability.

From his study of 277 barley varieties in Australia, Finlay (13) found that the variety with the highest mean yield over all environments failed to fit the above mentioned description of an ideal genotype. He also indicated that the hybrid populations were not only superior to their homozygous parents in average overall yield but also more stable over all environments. The author noted that much of the phenotypic stability of the hybrid populations can be due to heterotic effects that would be accentuated in genotypes that are specifically adapted to low yielding environments.

Using a similar procedure, Johnson et. al. (21) studied the general adaptation of 12 hard red winter wheat varieties for the Great Plains of the United States. They were able to show substantial progress in developing varieties with improved stability performance and high yield potential.

The use of regression of a varietal yield on an environmental index to measure stability among varieties was proposed also by Eberhart and Russell (12). They further recognized a second parameter,

i.e., deviations from the regression, as a secondary measure of cultivar stability. The following model was used to define these parameters:

$$Y_{ij} = \mu_i + B_i I_j + \delta_{ij},$$

where Y_{ij} is the variety mean of the ith variety at the jth environment, μ_i is the mean of the ith variety over all environments, B_i is the regression coefficient that measures the ith variety response to varying environments, I_j is the environmental index (mean of all varieties at the jth environment minus the grand mean), and δ_{ij} is the deviation from regression of the ith variety at j^{th} environment.

The environmental index (proposed by Eberhart and Russell) was obtained as a coded deviation of each environment from the grand mean over all environments. The regression of the mean of all varieties on the environmental index will thus be forced to have unit slope ($b_i = 1$). They described a "stable variety" as one having a high mean yield, a regression coefficient close to unity, and a non-significant deviation mean square.

Stroike and Johnson (51) utilized stability parameters following the Eberhart-Russell procedure to study environmental influence on protein and lysine content of wheat. They computed variety mean performance, regression coefficient, and regression deviation mean square for each of these traits. The deviation mean square is believed to provide evidence of predictability of variety response to environment according to the regression coefficient. The varieties studied showed differences in their sensitivity to change in environment as well as in predictability of response for both lysine and protein content. However, a relatively high degree of repeatability of performance in different environments was shown by the varieties in regard to these traits.

A procedure similar to that of Eberhart and Russell was used by Tai (53) to study the stability as well as predictability of potato varieties over a range of environments. Wide variation in deviation from the linear response, as well as unpredictability of these deviations, was found to exist for each variety grown in different localities. Tai, therefore, concluded that the deviation mean square was more important than the relatively predictable regression coefficient of the linear response.

In his study of genotype x environment interaction with respect to yield, Baker (7) proposed that variety stability is inversely proportional to the sum of squares for genotype x environment interaction ascribable to that particular variety. The magnitude of covariance of genotype x environment effects with environmental effects was considered useful as a measure of variety stability -- a low covariance would indicate a stable variety.

The yield stability of selected spring wheat varieties grown in the Uniform Regional Spring Wheat Nurseries from 1959 to 1968 was studied by Joppa et. al. (29). The use of regression analysis following the Eberhart-Russell procedure was found to be useful in making decisions with respect to variety release.

MATERIALS AND METHODS

Materials

Durum wheats totalling 3399 that were previously analyzed at the University of Nebraska Wheat Quality Laboratory were used to determine the variability that exists in the World Collection for protein and lysine content. These wheats were grown in different years at Mesa, Arizona as part of the World Collection accessions that are routinely increased under irrigation.

The wheats that were grown at 6 different localities in Ethiopia and the United States in this study were from this durum segment of the World Collection. They were selected primarily on the basis of combined high protein and lysine values. Although these entries (listed in Table A4) represent the various wheat growing areas of the world, 71 were contributions from Ethiopia and 67 from Portugal. The contributions from Ethiopia are listed in Table A5.

The 200 selected lines were inter-crossed with a composite of durums from the following sources (listed in Table A6.1 - 7):

1. Sixty-nine indigenous wheats from Ethiopia representing the various wheat growing regions (supplied by Dr. Taye Bezunech of Debre Zeit Experimental Station, Ethiopia).
2. Eleven durums possessing various desirable agronomic characteristics such as drought resistance, earliness, and day length insensitivity (supplied by Dr. James Quick, University of North Dakota).

3. Fifty-three lines which were planted along with 147 other World Collection durums at the University of Nebraska farm at Lincoln during the spring of 1973 and were able to survive severe drought stress and produced seed.

A chemical male gametocide, RH-531, was used to enforce hybridization of the composite with the 200 selected lines. A new chemical male gametocide, RH-532, is presently under investigation as a possible substitute for RH-531.

Methods

Planting of Selected Durums

Seed samples of the 200 selected lines were obtained from the U.S.D.A. World Collection, Washington, D. C. Seeds were classified as to plumpness and size. Ten-gram samples of each of the selected lines were planted in a single 10-ft. row at each of the following locations:

Location	Altitude (Meters)	Planting Date
Debre Zeit (Ethiopia)	1860	Late July
Areka "	1775	Late June
Awasa "	1680	" "
Kulumsa "	2200	" "
Holletta "	2390	" "
Alemaya "	2075	" "
Lincoln (Nebr., USA)	360	Mid May
Fort Collins (Colo., USA)	1225	Early May

The wheats grown at Awasa, Ethiopia received a 41-46-0 (kg/Ha) fertilizer application during the growing season. This is a normal rate of fertilizer application for wheats grown in that area. Field

notes on germination, heading, and plant height were taken during the growth period at each locality. Scores for stem rust (*P. graminis tritici*) and *Septoria tritici* also were taken for the wheats grown at Holletta due to a high incidence of the diseases in that area during the growing season.

Wheats that were grown at Lincoln and Fort Collins were harvested in the summer of 1973. Harvesting of the wheats grown at the various localities in Ethiopia took place during early and late December, 1973. A ten-gram sample of each of the wheats that were harvested was brought to Lincoln, Nebraska. Seeds were then classified as to plumpness and size at the Seed Laboratory of the University of Nebraska.

Laboratory Analysis

The durum segment of the World Collection totalling 3399 varieties was initially analyzed for protein and lysine by routine analytical procedures followed by the Wheat Quality Laboratory of the University of Nebraska (4, 27).

Protein and lysine content of seeds of the selected lines grown at sites in Ethiopia and the United States also were analyzed at the University of Nebraska Wheat Quality Laboratory using the following procedure:

Whole kernel 7-gram samples were ground, utilizing a newly-designed Udy Cyclone Sample Mill and passed through a 0.04 inch screen. The ground material was blended by brushing samples through two stacked sieves after which they were placed in a controlled humidity cabinet in order to maintain uniform moisture levels of approximately 11.25% (35).

Protein values were determined using the Macro-Kjeldhal procedure AACC method 46-12 which is a modification of the Boric Acid method (4).

All samples were determined in duplicate. The method for a single sample was as follows. One gram finely ground sample was wrapped in a nitrogen-free paper and placed in a digestion flask. It was digested for 60 minutes using a commercial catalyst preparation Kel-Pak-2P (Curtin-Matheson Scientific Company) and 25 ml of concentrated sulfuric acid. The flask was cooled and 250 - 300 ml tap water added (the Kel-Pak-2P contains ground pumice which provides antibumping capability in the distillation). Fifty ml of 50% concentrated NaOH was added and the flask connected to a condenser with tight fitting rubber stopper and swirled. The ammonia was distilled into a 4% boric acid solution and determined by appropriate titration with a standard acid solution. The ammonia value is calculated as %N and converted to % protein by using a conversion factor of N x 5.7. A blank determination was run for each set of 12 samples using all ingredients except the sample. The blank was subtracted from the sample titration before calculations were made.

Lysine values were determined by Dye-Binding Method utilizing the Mossberg-Munk procedure (27). Crude protein value was determined by the Kjeldhal Method. A ground wheat sample containing 65 mg of protein was mixed with a 25 ml solution containing 1.3 mg/ml of dye (Udy Analyzer Company commercial dye) in a 50 ml polycarbonate centrifuge tube. The tubes were capped, shaken, and placed in an Eberbach reciprocating shaker to be agitated in a horizontal position at 146 excursions per minute for one hour. The tubes were then centrifuged for 15 minutes at 5000 rpm. The supernatant dye solution was read in a Udy colorimeter

and % light transmission recorded. Lysine values were calculated from a standard curve which was a plot of % light transmission versus lysine as determined by ion-exchange chromatography.

Initiation of Project at Yuma, Arizona

The recipient composite population and a bulk of the 200 selected pollen donor lines were planted in alternating one hundred foot rows at Yuma, Arizona in the Fall of 1973. The bulk of the donor lines was formed by mixing mechanically 10-gram samples from the 200 lines. A composite of 15-gram samples involving 133 lines formed the recipient population.

The chemical male gametocide, RH-531, was applied to the foliage of the composite recipient population at 4000 ppm at the early boot stage to induce male sterility. Earlier, during the summer of 1973, the effects of a new chemical male gametocide (RH-532) on wheat was studied at the University of Nebraska farm in Lincoln. The effects at various levels of application of this chemical on self-fertility and female receptivity were also studied.

Statistical Analyses

Analysis of World Collection Durums - The data were computerized for rapid statistical computations and permanent printouts. Means, standard deviations, and frequency distributions of the 3399 durums were determined for percent protein, percent lysine of sample and percent lysine of protein. The frequency distributions of each of these variables was tested for normality by plotting the relative frequencies on probability graph paper (33).

The correlations of protein content, lysine (% protein), and lysine (% sample) were determined using simple r values. The following models (50) were tested to determine more precisely the effect of protein on either lysine per unit protein or lysine expressed as percent of sample:

a. Linear model:

$$Y_i = a + b_1X_i + e_i$$

b. Quadratic model:

$$Y_i = a + b_1X_i + b_2X_i^2 + e_i$$

c. Cubic model:

$$Y_i = a + b_1X_i + b_2X_i^2 + b_3X_i^3 + e_i$$

where Y_i is % lysine of the ith sample; a is the intercept; X_i is % protein of the ith sample; e_i is the residual error; and b values are regression coefficients. The model providing the best fit for lysine/protein relationship was chosen on the basis of a significant F test, significant regression coefficients using the 't' test, and, finally, the largest coefficient of determination (r^2). The regression sums of squares were partitioned to test the significance of the regression coefficients.

The regression lines for protein and lysine (% protein/lysine (% sample)) were plotted and deviations from regression calculated on the basis of predicative values obtained by using the appropriate regression equation.

Lysine per unit protein values for the wheats were adjusted to the mean protein value in order to have a more valid basis of comparisons among samples differing in protein content. The following equation was applied:

$$Y_i \text{ adj.} = Y_i - b_1 (X_i - \overline{X}) - b_2 (X_i^2 - \overline{X}^2)$$

where Y_i adj. is the ith adjusted lysine value; Y_i is the observed lysine per unit protein value of the ith sample; X_i is percent protein of the ith sample; and b values are the regression coefficients.

The average error variance for an adjusted value was determined from the following equation provided by Snedecor and Cochran (50):

$$S^2_{adj.} = S^2_{y \cdot x} (1 + c_{11} S^2_X + c_{22} S^2_{X2} + c_{12} \text{ cov } XX^2)$$

where $S^2_{adj.}$ = error variance for an adjusted lysine per unit protein value; $S^2_{y \cdot x}$ is the error mean square from regression; and c values are elements of the inverse matrix of the independent variables used in calculating the regression equation. The S^2 and cov terms denote variance and covariance, respectively, of the independent variables used in the regression analysis.

The 95% confidence interval about the mean lysine percent of protein was calculated as $\overline{X} \pm t_{.05} \cdot s_d$ using standard error of a difference value derived from:

$$s_D = \sqrt{2s^2_{adj.}}$$

<u>Analysis of Selected Durums</u> - The data from the 200 selected lines grown in various localities also were computerized. Lysine per unit protein, lysine percent of sample, and protein content were determined for each location. Lysine (% protein) values were adjusted to 13.5% protein for a more valid basis of comparison of lines differing in their protein contents.

The mean and standard error of a difference between two adjusted values, s_D, for 3399 World Collection durums were used to determine the cut-off point with respect to high and low lysine levels. Wheats with adjusted lysine (% protein) values equal to or larger than $\overline{X} + t_{.05}\ s_D$

are significantly higher than ordinary durum wheat. Those which showed consistently such high lysine values over all environments would be considered as potentially high lysine lines.

The standard used to determine the high protein levels was different for each location, depending upon the limit set by the variation in protein content and various other factors such as degree of shrivelling. For wheats grown at Holletta, a significantly higher protein value than the mean for the World Collection durum wheats was used to identify the high protein lines. For wheats grown at each of the other localities, a protein value higher than the mean for the World Collection durums by either one or two or three standard deviations was tentatively regarded as the cut-off point. Only lines with at least normal lysine per unit protein levels were considered. Finally, lines which performed relatively well according to these standards in all environments would be regarded as potentially high protein lines. Lines with shrivelled kernels and/or other defects were generally disregarded.

Stability parameters were computed following either the Yates-Cochran or the Eberhart-Russell procedure to describe the performance of a high protein - normal lysine variety over environments.

RESULTS

Analysis of World Collection Durum Wheats

Means, standard deviations, and range values for protein and lysine content of 3399 U.S.D.A. World Collection durum wheats are shown in Table 1. Frequency distributions of percent protein, percent lysine, and lysine percent of protein are shown in Figures 1, 2, and 3, respectively. The frequency of percent protein and lysine percent of grain weight does not appear to be normally distributed. However, the frequency distribution of lysine percent of protein does approximate normal distribution.

Correlation coefficients for percent protein, lysine percent of sample, and lysine percent of protein are given in Table 2. A high positive correlation existed between protein content and lysine expressed as percent of sample. The relationship of percent protein and lysine percent of protein was highly negative. The same relationship, though to a lesser degree, holds for lysine percent of sample and lysine percent of protein.

The quadratic model provided the best fit for the regression of lysine percent of sample on percent protein. The analysis of variance for this regression is shown in Table 3. Regression coefficients, standard errors of the regression coefficients, and the computed "T" values are given in Table 4. About 92% of the total variation in lysine percent of sample is ascribable to variation in protein content as indicated by the coefficient of determination value ($r^2 = 0.92062$).

Table 1. Means, standard deviations, and the range for % protein, % lysine, and lysine % of protein for 3399 U.S.D.A. World Collection durum wheats.

	Mean	Standard deviation	Range
% protein[1/]	12.75	2.86	7.30 - 21.30
% lysine[1/]	0.39	0.06	0.26 - 0.60
Lysine % of protein	3.15	0.27	2.43 - 4.29

[1/]Dry weight basis.

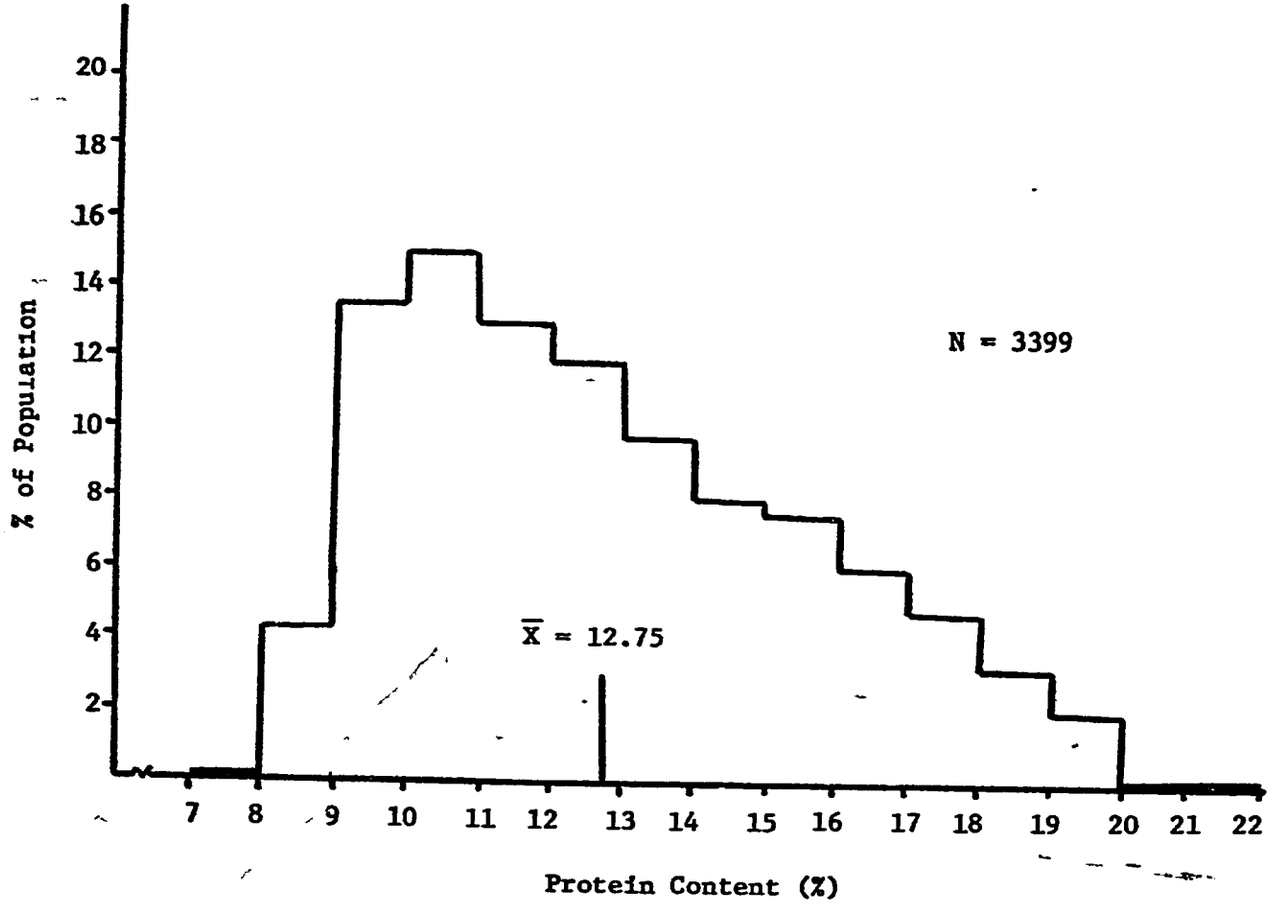

Figure 1. Frequency distribution for whole grain protein content among 3399 durum wheats in the U.S.D.A. World Collection.

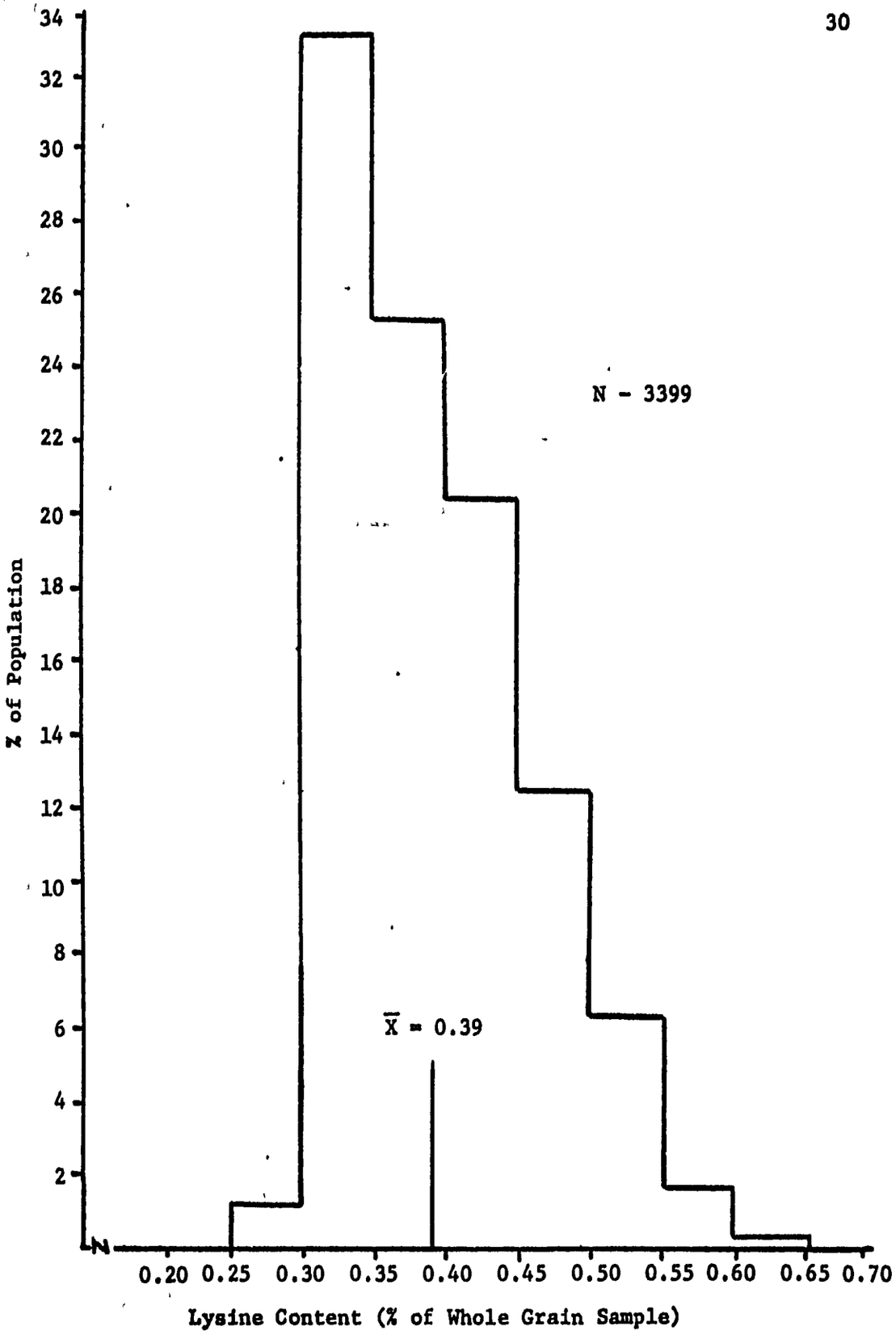

Figure 2. Frequency distribution for lysine expressed as a percent of whole grain sample among 3399 durum wheats in the U.S.D.A. World Collection.

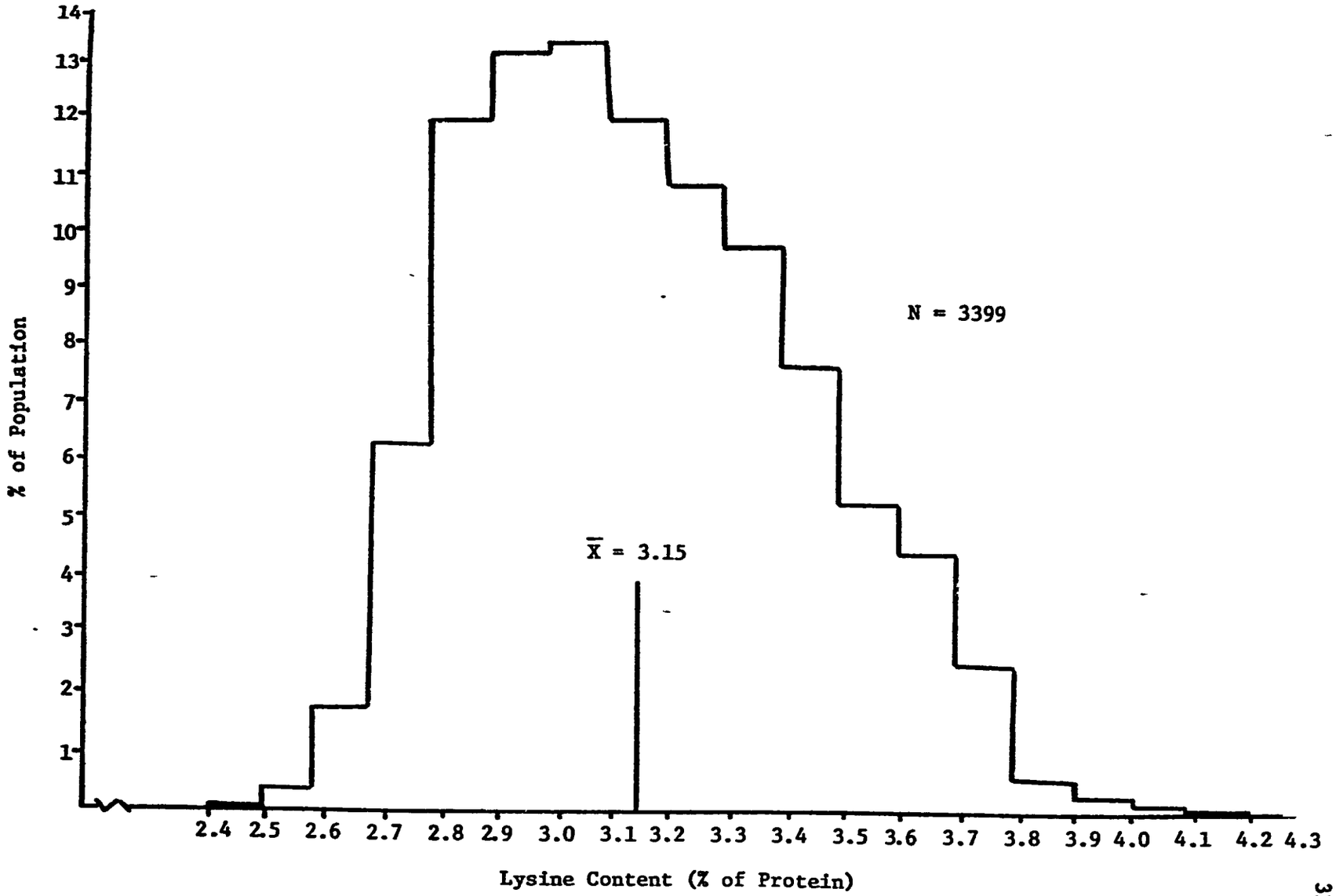

Figure 3. Frequency distribution for lysine expressed as percent of whole grain protein among 3399 durum wheats in the U.S.D.A. World Collection.

Table 2. Simple correlation coefficients (r) for percent protein, lysine percent of sample, and lysine percent of protein for durum wheats of the U.S.D.A. World Collection.

	Lysine (% of sample)	Lysine (% of protein)
% protein	0.96**	-0.82**
Lysine (% of sample)		-0.63**

**Significant at the .01 level.

Table 3. Analysis of variance for the regression of lysine percent of sample on percent protein using the quadratic model.[1/]

Source of variation	Degrees of freedom	Sum of Squares	Mean Squares	F value
Attributable to regression	2	12.37	6.18	19693.5**
Deviation from regression	3396	1.07	0.00031	
Total (corrected for the mean)	3398	13.43		

**Significant at the .01 level.

[1/]The coefficient of determination (r^2) using the quadratic model equals 0.92079.

Table 4. Regression coefficients, standard errors of the regression coefficients and computed T values for the regression of lysine percent of sample on percent of protein for the quadratic model.[1/]

Independent variable	Regression Coefficient	S.E. of regression coefficient	Computed T value
% protein	$b_1 = 0.0095$	0.00096	9.83862**
(% protein)^2	$b_2 = 0.00043$	0.000035	12.10781**

**Significant at the .01 level.

[1/]Intercept = a = 0.19664.

The linear regression of lysine percent of sample on percent protein appears to be also significant with only a very slightly lower coefficient of determination (0.91720). The slight curvilinear regression of lysine percent of sample on percent protein is shown in Figure 4.

The quadratic and the cubic models were comparable with respect to providing the best fit for the regression of lysine percent of protein on percent protein. For this reason the quadratic model was chosen to determine the relationship of these variables. The relevant analysis of variance is shown in Table 5. Regression coefficients, standard errors of the regression coefficients, and the computed "T" values are given in Table 6. About 75% of the total variation in lysine percent of protein is attributable to variation in protein content as indicated by the coefficient of determination (r^2 = .7462). As shown in Figure 5, the regression of lysine expressed as percent of protein on percent protein is curvilinear and strongly negative. This negative relationship appears to hold only among wheats with protein values less than 15%. For wheats with more than 15% protein there is little or no apparent effect of protein content on lysine per unit protein.

Lysine percent of protein values were adjusted to the mean protein level (12.75%) to remove the large variability (75%) associated with protein content. The frequency distribution of the adjusted lysine values is shown in Figure 6. Although the mean of the adjusted and unadjusted lysine percent of protein values is the same, their frequency distributions are different. The frequency distribution of the unadjusted lysine per unit protein closely resembled that of protein while the adjusted values appeared to be normally distributed following

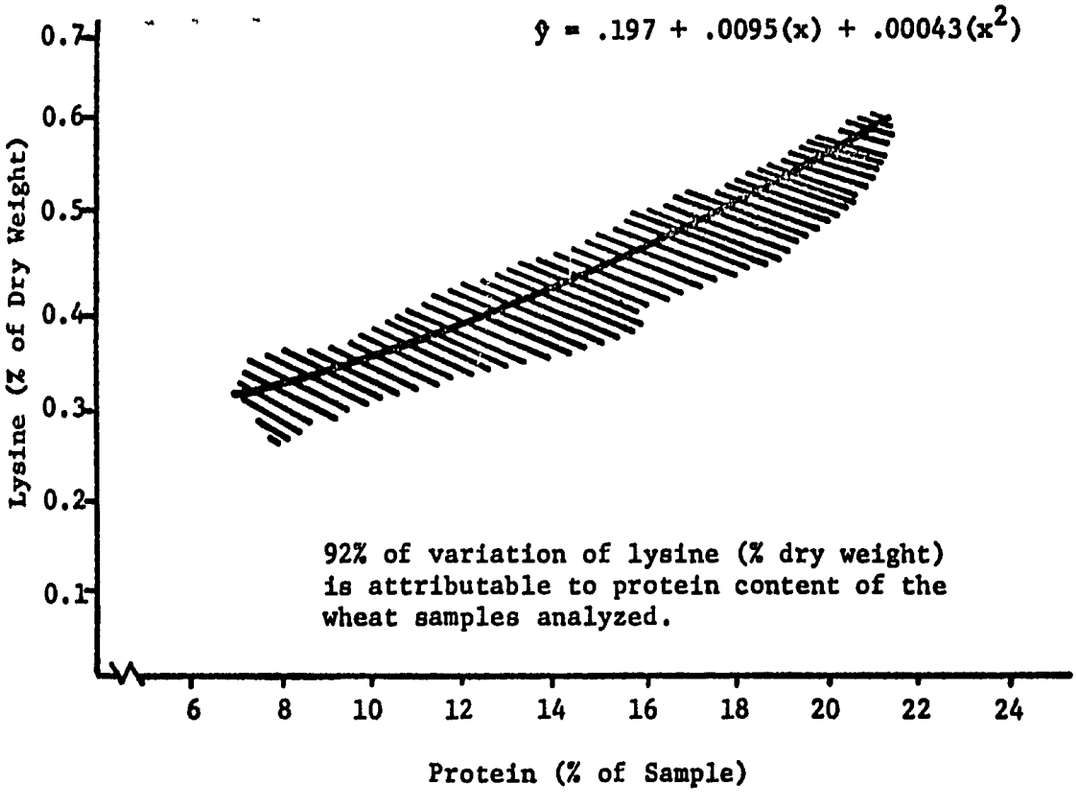

Figure 4. Curvilinear regression (quadratic model) of lysine percent of dry weight on protein and the range of dispersal of lysine values about the regression line computed from the analysis of 3399 durum wheats from the U.S.D.A. World Collection.

Table 5. Analysis of variance for the regression of lysine expressed as a percent of protein on percent protein using the quadratic model.[1/]

Source of variation	Degrees of freedom	Sum of Squares	Mean Squares	F value
Attributable to regression	2	190.65	95.32	4991.3**
Deviation from regression	3396	64.85	0.02	
Total (corrected for the mean)	3398	255.50		

**Significant at the .01 level.

[1/]The coefficient of determination (r^2) using the quadratic model = 0.74618.

Table 6. Regression coefficients, standard errors of the regression of lysine percent of protein on percent protein for the quadratic model.[1/]

Independent variable	Regression coefficient	S.E. of regression coefficient	Computed T value
% protein	b_1 = -0.3137	0.0075	-41.76**
(% protein)^2	b_2 = 0.0087	0.00028	31.49**

**Significant at the .01 level.

[1/]Intercept = a = 5.66.

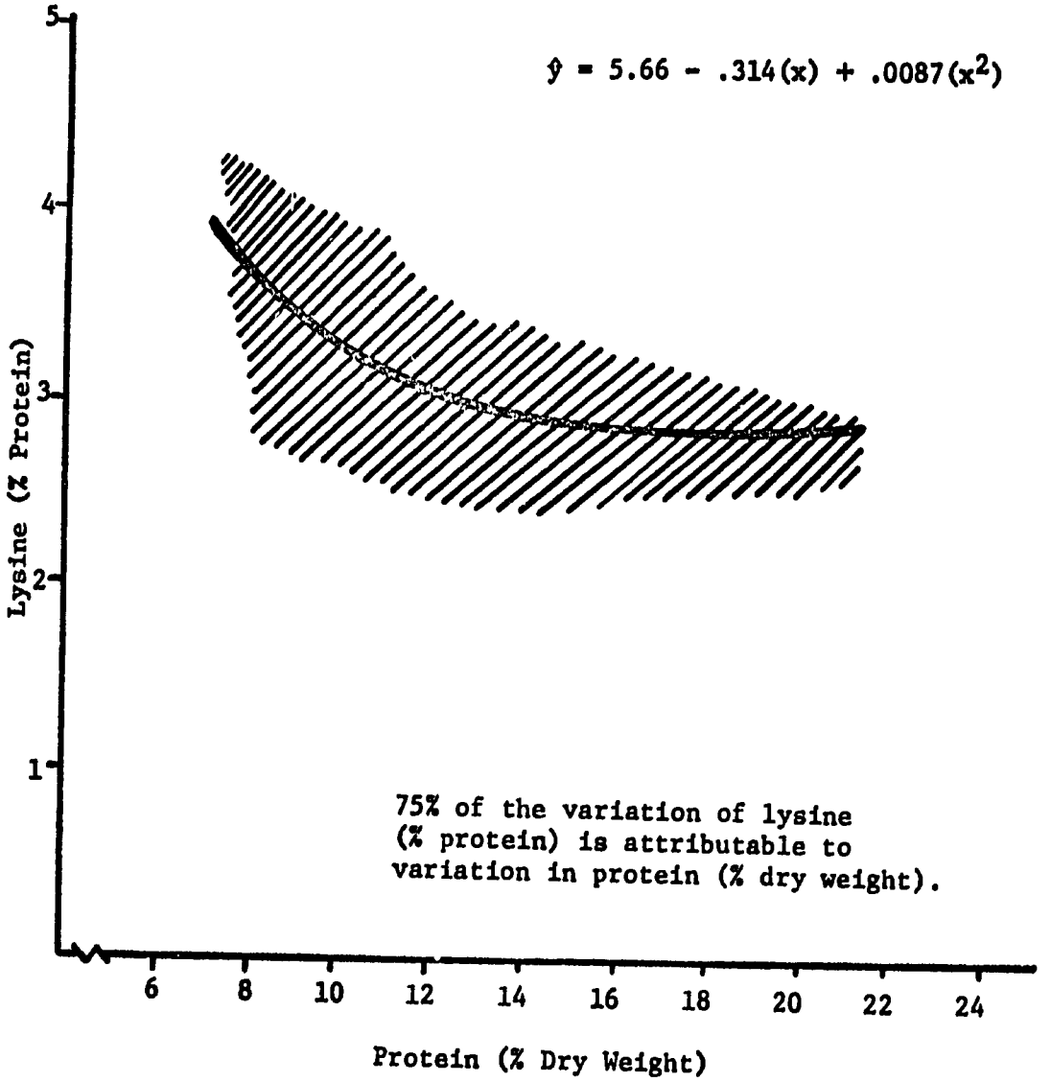

Figure 5. Curvilinear regression (quadratic model) of lysine percent of protein on protein and the range of dispersal of lysine values about the regression line computed from the analysis of 3399 durum wheats from the U.S.D.A. World Collection.

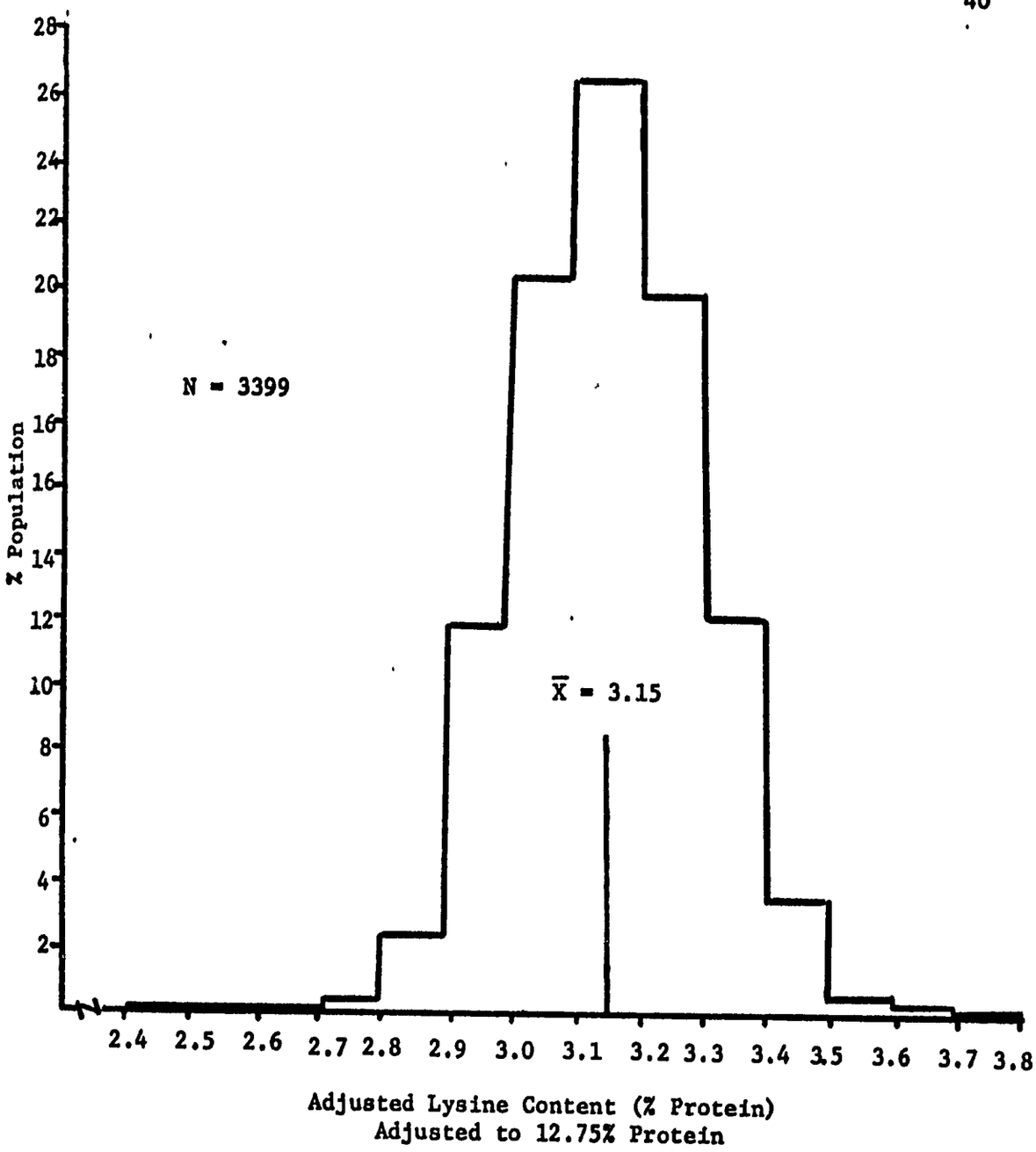

Figure 6. Frequency distribution for lysine per unit protein adjusted to 12.75% protein among 3399 durum wheats in the U.S.D.A. World Collection.

a pattern which is independent of protein content. This is a direct reflection of the removal of the variability in lysine values due to variation in protein content which thus provides a more valid basis of comparison of lysine values between wheats differing in their protein contents.

The average error variance (S^2_{adj}) and the standard error of an adjusted lysine value (S_{adj}) for the 3399 World Collection durum wheats are 0.01947 and 0.1395, respectively. The standard error of a difference between two adjusted values which was computed as $S_D = \sqrt{2S^2_{adj}}$, is 0.1973%. Using this value, the 95% confidence interval for the adjusted lysine values about the mean lysine per unit protein is 3.15 ±.39. An adjusted lysine value equal to or greater than 3.54 can therefore be regarded as significantly higher than the mean lysine (% of protein) content of durum wheats.

The 3399 durum wheats analyzed from the World Collection were ranked in descending order of protein and lysine values. The 40 highest and 10 lowest wheats for these traits are listed in Appendices 1, 2, 3, and 4, respectively. Deviations of measured lysine per unit protein from lysine per unit protein predicted by the curvilinear regression equation are also given in these tables.

Performance of Selected World Collection Durum Wheats

Data are available from only 4 sites in Ethiopia and from Fort Collins, Colorado. Several of the wheats grown at the various locations in Ethiopia failed to produce seeds. They were either day length sensitive or exhibited winter growth habit. A large number of the wheats that were harvested from these locations produced shrunken

kernels probably due to the drought stress that prevailed in most of these wheat growing areas during the growth period. Two entries, P.I. 220689P (Afghanistan source) and P.I. 262656P (Russian source), showed winter growth habit at Fort Collins, Colorado.

Protein and lysine values for wheat grown at the various locations in Ethiopia and U. S. A. are listed in Tables A8 - A12. Means, standard deviations, and range values for protein and lysine content of the wheats grown at the various sites and which produced seed are given in Table 7. Protein values were highest for wheats grown at Awasa, Alemaya, and Debre Zeit. The wheats grown at Holletta were generally low in protein content and showed an average protein value lower than the mean protein level of the World Collection of durum wheats. Similar results were obtained for the lysine (% of sample) content of the wheats grown in the various localities. Average lysine percent of protein values did not differ significantly from the mean lysine value for the World Collection durum wheats.

Following the above criteria for selecting high protein and lysine lines, it was possible to identify only one entry, C.I. 7796 (Ethiopian source), which showed consistently good protein performance over all locations. Two other entries, P.I. 192711P and P.I. 185734P, produced high protein at most of these locations. Protein and lysine values for the wheats that showed consistently good performance over the environments sampled among 200 selected World Collection durum wheats are listed in Table 8. Protein and lysine values for two check varieties, Ward and Leeds, are also included. The check varieties are relatively low in their lysine content but showed generally high protein content.

Table 7. Means, standard deviations, and range values for percent protein, lysine percent of sample, and lysine percent of protein for selected World Collection durums grown at sites in Ethiopia and U.S.A. in 1973.

Location	Number of entries[1]	Mean			Standard deviation			Range		
		% Protein[3]	% Lysine[3]	Adjusted lysine/protein[4]	Protein	Lysine	Adjusted lysine/protein	Protein	Lysine	Adjusted lysine/protein
Alemaya	182	20.43	0.51	2.94	1.60	0.03	0.13	15.2 to 24.3	0.42 to 0.61	2.63 to 3.41
Awasa	95	21.47	0.56	3.05	2.03	0.05	0.11	17.2 to 27.1	0.46 to 0.73	2.85 to 3.44
Debre Zeit	140	18.07	0.46	2.85	1.48	0.03	0.07	13.3 to 21.5	0.37 to 0.55	2.53 to 3.03
Holletta	184	12.70	0.37	2.93	1.99	0.05	0.13	8.9 to 19.9	0.29 to 0.53	2.60 to 3.46
Fort Collins	198	15.40	0.43	2.91	2.00	0.05	0.09	10.7 to 21.0	0.29 to 0.55	2.59 to 3.16
Mesa[2]	198	14.16	0.44	3.38	2.62	0.08	0.10	7.7 to 21.3	0.31 to 0.62	2.81 to 3.78

[1] Entries that were able to produce seed.
[2] Grown under irrigation in different years.
[3] Dry weight basis.
[4] Adjusted to 13.5% protein using curvilinear equation.

Table 8. Protein and lysine values of durum wheats that showed consistently good performance over environments among 200 selected lines from World Collection durum wheats grown at various locations in Ethiopia and U.S.A.

Location	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine[1/]	Lysine/ protein	Adjusted lysine/protein[2/]	Seed characteristic and other remarks
Alemaya	7796	Ethiopia	22.00	0.55	2.52	2.98	Moderately plump
	192711P	Portugal	19.90	0.50	2.52	2.87	Plump
	185734P	Portugal	21.20	0.53	2.52	2.94	Plump
	Ward	U.S.A.	19.00	0.47	2.47	2.77	Plump
	Leeds	U.S.A.	19.00	0.47	2.47	2.77	Plump
Awasa	7796	Ethiopia	19.80	0.51	2.61	2.95	Plump
	192711P	Portugal	-	-	-	-	Missing
	185734P	Portugal	22.90	0.56	2.47	2.98	Plump
	Ward	U.S.A.	17.20	0.46	2.70	2.90	Shrivelled
	Leeds	U.S.A.	-	-	-	-	Missing
Debre Zeit	7796	Ethiopia	18.60	0.48	2.61	2.89	Plump
	192711P	Portugal	18.70	0.47	2.52	2.80	Plump
	185734P	Portugal	19.00	0.46	2.42	2.72	Plump
	Ward	U.S.A.	18.00	0.45	2.52	2.76	Shrivelled
	Leeds	U.S.A.	17.40	0.43	2.52	2.73	Plump
Holletta	7796	Ethiopia	13.90	0.38	2.79	2.81	Plump
	192711P	Portugal	12.60	0.37	2.98	2.93	Plump
	185734P	Portugal	12.90	0.36	2.79	2.76	Plump
	Ward	U.S.A.	-	-	-	-	Missing
	Leeds	U.S.A.	-	-	-	-	Missing

Table 8. (Continued)

Location	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine[1/]	Lysine/ protein	Adjusted lysine/protein[2/]	Seed characteristic and other remarks
Fort Collins	7796	Ethiopia	18.60	0.49	2.65	2.93	Plump
	192711P	Portugal	13.80	0.39	2.84	2.85	Plump
	185734P	Portugal	16.20	0.46	2.84	2.98	Plump
	Ward	U.S.A.	16.40	0.45	2.75	2.70	Moderately plump
	Leeds	U.S.A.	16.80	0.45	2.70	2.88	Moderately plump
Mesa	7796	Ethiopia	10.00	0.37	3.70	3.51	Plump
	192711P	Portugal	13.40	0.41	3.09	3.10	Plump
	185734P	Portugal	16.70	0.50	3.05	3.23	Plump
	Ward	U.S.A.	-	-	-	-	Not grown
	Leeds	U.S.A.	-	-	-	-	Not grown
Havelock	7796	Ethiopia	26.30	0.66	2.52	3.22	Shrivelled
	192711P	Portugal	22.40	0.57	2.56	3.05	Shrivelled
	185734P	Portugal	-	-	-	-	Missing
	Ward	U.S.A.	-	-	-	-	Missing
	Leeds	U.S.A.	-	-	-	-	Missing

[1/] Dry weight basis.

[2/] Adjusted to 13.5% protein using curvilinear equation.

These varieties also appear to have poor adaptability to the growing conditions at Awasa, Ethiopia.

Analyses of variance for the regression of protein and lysine contents of C.I. 7796 on environment index are given in Tables 9 to 14. The stability parameters used to describe the performance of this variety over environments appear in Table 15.

Yuma Harvest Results

Growth and development of the wheat planted at Yuma, Arizona were excellent under the irrigated and disease and pest-free conditions in that area. The apparent effect of the chemical male gametocide (reduced plant height, widely open glumes, and yellowing of plot) was observed shortly after spraying took place in early April, 1974.

The plots were harvested with a small-plot combine in the middle of May. The plot sprayed with the chemical male gametocide appeared to produce less amount of seed than the untreated male-parent plot. It was not possible, however, to precisely determine the amount of male-sterility and/or hybridization that had taken place (heads were not bagged). It is, however, assumed that some degree of hybridization occurred, on the basis of the substantial amount of seed produced.

From the sub-experiment involving RH-532 conducted at Lincoln, Nebraska, the following results were obtained. Application of the chemical reduced plant height on the average by 29%. The best result in the induction of male-sterility as well as improving female receptivity was obtained from the plots treated with 6000 ppm of the chemical. Self-fertility was reduced by 87.20% while over 33% (could amount to about 38% considering natural hybridization) hybridization took place.

Table 9. Analysis of variance for the regression of protein content of C.I. 7796 on environment index involving 200 World Collection durum wheats grown at 4 sites in Ethiopia in 1973.[1/]

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F value
Due to regression	1	11.89	11.89	1.03 N.S.
Deviation from regression	2	23.15	11.58	
Total (corrected for the mean)	3	35.04		

[1/] Environment index computed either as the mean yield of all cultivars in a particular environment (Yates-Cochran method) or as a coded deviation of each environment from the grand mean of all environments (Eberhart-Russell method).

N.S. Not significant at the .05 level.

Table 10. Analysis of variance for the regression of lysine (% of sample) content of C.I. 7796 on environment index involving 200 World Collection durum wheats grown at 4 sites in Ethiopia in 1973.[1/]

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F value
Due to regression	1	.00195	.00195	.28 N.S.
Deviation from regression	2	.0138	.0069	
Total (corrected for the mean)	3	.0158		

[1/] Environment index computed either as the mean yield of all cultivars in a particular environment (Yates-Cochran method) or as a coded deviation of each environment from the grand mean of all environments (Eberhart-Russell method).

N.S. Not significant at the .05 level.

Table 11. Analysis of variance for the regression of adjusted lysine (% of protein) content of C.I. 7796 on environment index involving 200 World Collection durum wheats grown at 4 sites in Ethiopia in 1973.[1/]

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F value
Due to regression	1	.00159	.00159	.21 N.S.
Deviation from regression	2	.01528	.0076	
Total (corrected for the mean)	3	.01688		

[1/] Environment index computed either as the mean yield of all cultivars in a particular environment (Yates-Cochran method) or as a coded deviation of each environment from the grand mean of all environments (Eberhart-Russell method).

N.S. Not significant at the .05 level.

Table 12. Analysis of variance for the regression of protein content of C.I. 7796 on environment index involving 200 World Collection durum wheats grown at 5 sites in Ethiopia and U.S.A. in 1973.[1/]

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F value
Due to regression	1	11.100	11.100	1.39 N.S.
Deviation from regression	3	23.988	7.996	
Total (corrected for the mean)	4	35.088		

[1/] Environment index computed either as the mean yield of all cultivars in a particular environment (Yates-Cochran method) or as a coded deviation of each environment from the grand mean of all environments (Eberhart-Russell method).

N.S. Not significant at the .05 level.

Table 13. Analysis of variance for the regression of lysine (% of sample) content of C.I. 7796 on environment index involving 200 World Collection durum wheats grown at 5 sites in Ethiopia and U.S.A. in 1973.[1/]

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F value
Due to regression	1	.0020	.0020	.43 N.S.
Deviation from regression	3	.0139	.0046	
Total (corrected for the mean)	4	.0159		

[1/] Environment index computed either as the mean yield of all cultivars in a particular environment (Yates-Cochran method) or as a coded deviation of each environment from the grand mean of all environments (Eberhart-Russell method).

N.S. Not significant at the .05 level.

Table 14. Analysis of variance for the regression of lysine (% of protein) content of C.I. 7796 on environment index involving 200 World Collection durum wheats grown at 5 sites in Ethiopia and U.S.A. in 1973.[1/]

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F value
Due to regression	1	.0011	.0011	.20 N.S.
Deviation from regression	3	.0162	.0054	
Total (corrected for the mean)	4	.0173		

[1/] Environment index computed either as the mean yield of all cultivars in a particular environment (Yates-Cochran method) or as a coded deviation of each environment from the grand mean of all environments (Eberhart-Russell method).

N.S. Not significant at the .05 level.

Table 15. Stability parameters for protein and lysine content of C.I. 7796 grown at sites in Ethiopia and U.S.A. using either the Eberhart-Russell procedure or the Yates-Cochran procedure.

	Mean[1/]		Regression coefficient		S.E. of regression coefficient		Deviation mean square		Computed T value	
	4 Sites[2/]	5 Sites[3/]	4 Sites	5 Sites	4 Sites	5 Sites	4 Sites	5 Sites	4 Sites	5 Sites
% Protein	18.58	18.58	.539	.503	.532	.427	11.575	7.996	1.01 N.S.	1.18 N.S.
% Lysine	0.48	0.48	.291	.270	.545	.413	.007	.005	.53 N.S.	.65 N.S.
Adjusted lysine/ protein	2.91	2.91	.039	.028	.084	.075	.008	.005	.46 N.S.	.37 N.S.

[1/] N = 200

[2/] Grown at 4 wheat growing sites in Ethiopia in 1973.

[3/] Grown at 5 wheat growing sites in Ethiopia and Fort Collins, Colorado in 1973.

N.S. Not significant at the .05 level.

The lower application levels, 2000 and 4000 ppm, resulted in 77% and 79% reductions in self-fertility and 22% and 23% hybridization, respectively (these differences were not significant statistically). Since RH-532 development is an improvement over RH-531, especially with respect to minimal interference with female receptivity, it is assumed that utilization of this chemical in future experiments would result in a more efficient enforcement of hybridization.

DISCUSSION

World Collection Durum Wheats

Variability of Grain Protein and Lysine

A wide range of values for protein content of the U.S.D.A. World Collection durum wheats was measured. The means, standard deviations, and range values for protein and lysine closely resemble those obtained for the World Collection common wheats (57). The frequency distributions of the protein and lysine values observed for these two wheat species are also quite similar. In the much larger hexaploid wheat population, however, protein and lysine/protein values approximated normal distribution while this was not true in the case of the World Collection durums. Means and range values for protein and lysine reported for the relatively small durum wheat population are slightly lower than those obtained for the World Collection of hexaploid wheats (31, 56).

The wide range of protein values suggests that tremendous variability in protein content exists among durum wheats of the World Collection. Since the grain of the World Collection wheats was produced under similar environmental conditions at Mesa, Arizona, we may assume that a significant portion of this variability is genetic in nature.

Comparison of the variability in protein content of these wheats with the protein content of the hexaploid sector of the World Collection (57) would indicate that durum wheats contain as much genetic variability for this trait as common wheats. About 136 of the World

Collection durum wheats exhibit protein contents exceeding 18.47%, i.e., two standard deviations above the mean protein percent. This group of varieties exhibiting high protein content constitutes 4% of the total population and compares favorably with what has been reported for the World Collection common wheats (57). Durum wheats with protein content falling within this range of high level values would represent the best potential source of genes for high protein.

Very few of the durum wheats in the World Collection show lysine per unit protein content that is significantly greater than the mean lysine/protein value. Most varieties are within the 3.15 ± .39 limit and do not, therefore, differ in this respect from ordinary durum wheat. There are 15 entries in the World Collection durum wheats (Table A3) with adjusted lysine/protein above 3.54%. Only three of these wheats are superior in protein content to ordinary durum wheat. The remaining 12 varieties, five of which are contributions from Ethiopia, exhibit protein values significantly lower than the mean percent protein.

The variability in lysine/protein values appears to be limited. Further, it has been reported (27) that most varieties with high lysine values based on analysis of samples from World Collection wheats grown in Arizona were not genetically different for high lysine potential when they were regrown at different sites in the United States. In view of these factors it is difficult to tentatively identify potentially high lysine/protein wheats.

Lysine - Protein Relationship

The relationship between protein and lysine, either expressed as percent of protein or as percent of sample, is in agreement with other

findings (27, 31, 57). The magnitude of their correlations, however, is somewhat higher in durum wheats than in the hexaploid wheats and other species (57).

There is a sharp similarity with respect to the negative curvilinearity of the lysine/protein and protein content relationship between the durums and the hexaploids in the World Collection (57). When lysine/protein values are plotted against protein, the negative relationship of these factors becomes less pronounced as protein increases, and virtually disappears above 15% protein. The level beyond which protein content is reported to have no influence on lysine/protein is somewhat lower for a much smaller population of common wheats studied by Lawrence et. al. (31).

About 75% of the lysine variation is associated with protein variation. This is a much stronger association of lysine/protein and protein than that reported for World Collection common wheats. Since this relationship largely disappears above 15% protein, the validity of adjusted lysine/protein values on the basis of the curvilinear regression of lysine on protein becomes questionable for protein values above 15%.

In general, the apparent lack of protein influence on content of lysine/protein beyond a certain protein level, i.e., 15%, appears to be established for both common wheat and durums. This can be due to a relatively stable albumin-globulin : gluten ratio that may exist for wheats with more than 15% protein (57). It would therefore be possible to select for high protein content without adversely affecting the amino acid composition.

The relationship of lysine percent of sample to protein content is strongly positive and linear (Figure 4). As much as 92% of the variation in lysine percent of sample is due to variation in protein content. As protein increases from 7.3 to 21.3 percent lysine also increases from 0.29 to 0.59 percent on the basis of the quadratic regression equation. Lysine expressed as percent of sample is, therefore, a direct measure of protein content. Improvement in lysine of grain sample should be possible by selecting for higher protein content.

Effect of Environment on Protein and Lysine

Environment exerts a large influence on protein and lysine values of wheat (27, 31, 57) and thus causes genotypes to vary relative to one another in different locations and seasons. Genetic expression of a trait such as protein content must, therefore, be measured with reference to a set of environmental conditions which, in practice, are usually identified with locations and years. The joint action of genotype and environment may be expressed in a linear fashion so that the phenotypic expression of a trait considered in this study may be represented as (2)

$$P_{ijk} = \mu + g_i + l_j + y_k + (gl)_{ij} + (gy)_{ik} + (yl)_{jk} + (gly)_{ijk} + e_{ijk}.$$

P_{ijk} is the phenotypic measurement made on the ith genotype at the jth location in the kth year; μ and g_i are the population mean and the effect of the ith genotype; l_j and y_k are the direct effects of the jth location and the kth year, respectively; and e_{ijk} is a composite error term of the remaining effects (the micro-environmental effect at a location, sampling error, and errors of measurement). The interaction effects are represented by $(gl)_{ij}$, $(gy)_{ik}$, $(yl)_{jk}$, and $(gly)_{ijk}$.

Location and year effects may not be important since the wheats analyzed were grown at Mesa, Arizona where the year to year variation under irrigated conditions may be relatively small (57). As already demonstrated by the various researchers (27, 57), however, genotype x environment interactions will be expected to contribute substantially to the amount of variation in protein and lysine values when these wheats are grown over an array of environments.

Micro-environmental effect may also be important from the standpoint of inter-genotypic competition that may exist among wheats with differing backgrounds. The production environment in Mesa, Arizona (relatively high fertilizer application level and irrigation) also may have adverse effect on the yields of the World Collection wheats most of which have weak straw and lodge easily (57). This in turn would influence the variation in the protein content, with the lower yielding wheats tending to be higher. Some of the wheats that were high in protein content may, therefore, fail to perform the same way when grown in other environments.

Identification of High Protein and Lysine Sources

The strong influence of environment and genotype x environment interaction effects on protein and lysine levels does not permit heavy reliance upon the high protein and lysine values appearing in Appendix Tables 1 to 3. It is, however, possible to tentatively identify wheats that are likely to be genetically superior in protein and lysine content. Growing these wheats at several locations over a period of years can firmly establish their genetic uniqueness for high protein and high lysine. The results of Stroike and Johnson (51) have shown that wheats that are known to possess high protein genes were consistently superior

in their protein contents to ordinary wheats over a wide array of environments. Such superior performance in a range of environments for which the wheats are adapted will serve as a useful criterion for the identification of varieties representing the best potential source of genes for high protein and lysine.

Wheats with lysine values that are significantly higher than the mean lysine value of the World Collection of durum wheats are the most likely sources of genes for high lysine. These are wheats that show a positive deviation of 0.29 or more in their lysine (% protein) from lysine percent of protein predicted from the curvilinear regression equation. These wheats also have the highest adjusted lysine values. The lysine content of wheats can, therefore, be compared using lysine values corrected on the basis of the linear regression of lysine on protein.

Wheats that are consistently superior in their adjusted lysine values over environments represent the best sources of high lysine genes. In view of the low magnitude of the variability that exists for this trait among the World Collection wheats, however, it may be difficult to find varieties that show consistently higher lysine content than ordinary wheats over environments. The problem is further compounded by the strong influence of environment and genotype x environment effects on lysine level.

More than 99% of the World Collection durums show lysine per unit protein values that are not significantly different from the mean lysine (% protein). In identifying wheats that are genetically superior in protein and lysine values over environments the breeder will have to select primarily on the basis of high protein content against a normal

lysine level background. In selecting for a specific region, lines that show higher lysine and protein values than ordinary wheat in a specific environment may be identified as high lysine and protein sources with reference to that particular environment.

Performance of Selected Durums

A large number of the wheats harvested from the various locations in Ethiopia produced defective kernels. This was particularly true for Awasa where most of the wheat grains were shrivelled and relatively small in size. The relatively high mean protein values obtained from these regions are partly attributed to the shrunken kernels. This defect is believed to have been caused by the drought stress that has prevailed in the wheat growing regions of Ethiopia.

The wheats harvested from Holletta were generally low in protein. Part of this appears to have been influenced by disease. Comparison of protein contents of the few stem rust (*P. graminis tritici*) resistant entries with the protein content of the susceptible entries provides some evidence that protein level may have been influenced by the disease. Varieties P.I. 195717P, C.I. 7523, C.I. 3068, and C.I. 8455 which showed very high resistance to rust, also showed relatively high protein values ranging from 12.8 to 15.7%. The varieties which showed high degree of rust susceptibility were at the same time low in protein content ranging from 10.3% to only 11.7%. Since this relationship did not hold at the other locations and the majority of the varieties were affected by rust, it may be that part of the reason for low protein values is the rust infection. The validity of this comparison is, however, questionable since *Septoria tritici* also occurred and, as it could also influence

protein content, perhaps counterbalance the rust effect (the rust susceptible varieties tend to be more resistant to the blight).

Environment definitely influences protein and lysine levels. The magnitudes of this influence can be demonstrated by comparing the protein and lysine values for a number of varieties grown over the various locations. About 14 varieties had lysine per unit protein values that were significantly higher than the World Collection population mean on the basis of samples from Yuma-grown wheats. When these varieties were regrown at sites in Ethiopia and the U.S.A. their lysine values did not differ significantly from the mean lysine value for ordinary durum wheats. They did, however, show a general tendency to approximate the mean, relative to most of the other entries.

Another important influence of environment on lysine per unit protein occurred among varieties whose lysine values were relatively high under Yuma conditions but were considerably lower than the mean lysine value when regrown at the various other locations. The variety P.I. 185726P, for instance, had a lysine per unit protein content of 3.25% but this value dropped to 2.6% under Colorado growth conditions.

The effects of environment on protein content were pronounced over most of the locations, especially with reference to Yuma versus the other locations. A great number of the varieties that were low in their protein content under Yuma conditions, for instance, produced much higher protein contents in a number of the other locations at which they were grown. C.I. 7528, for example, had protein values which varied from 7.7% to 21.6% under Yuma and Alemaya conditions, respectively.

The effects of genotype x environment interactions have also been noted (3, 15, 16, 57). In this study these interaction effects can be demonstrated by comparing the protein content of two varieties C.I. 8493 and P.I. 185726P. These two entries had protein contents of 15.3% and 20.9%, respectively, when grown at Yuma. The relationship was reversed (21.2% and 16.0%, respectively) when the two varieties were regrown at Debre Zeit, Ethiopia. The effects of genotype x environment interactions among varieties grown at the various locations in Ethiopia appear to be less pronounced. The general tendency of these varieties to be unusually high in protein content, which value was partly influenced by kernel shrivelling, does not permit a valid assessment of the magnitude of these interaction effects on protein content. Moreover, since year effects have not been considered in this study it is impossible to fully explore the effect of genotype x environment on protein and lysine (10).

Genotype x environment interaction effects on lysine per unit protein are limited in magnitude and do not occur to the same extent among the varieties as they do in the case of protein. This can be illustrated by comparing lysine per unit protein content of entries P.I. 191127P and 191145P. These varieties had lysine per unit protein values of 2.99% and 3.10%, respectively, when grown at Alemaya. This relationship changed to 3.16% for P.I. 191127P and 2.90% for 191145P when the varieties were grown at Fort Collins. Genotype x environment effects of larger magnitude have been reported (57). The generally low magnitude of these interactions in this study may be due to the fact that the varieties were initially selected on the basis of high

lysine and normal protein levels. Since these values tend to approximate the normal lysine level, the difference among varieties would be expected to be too small for important genotype x environment interaction to occur.

The variability that existed for lysine per unit protein among the varieties was of limited magnitude. None of these varieties showed lysine values exceeding the cut-off point for high lysine content, but approached normal lysine level. The criterion for identifying wheats with high nutritive value was, therefore, based on high protein and normal lysine level.

The number of entries that could be identified as high protein and normal lysine lines is limited. This is because several of the high protein values were also influenced by shrunken kernels. Moreover, values for several entries were missing at some locations and this resulted in the exclusion of varieties that otherwise tended to do well in a specific environment. A few examples may serve to demonstrate this. The entry C.I. 177950P (Turkish source) had shown 23.5% protein and 2.9% lysine at Alemaya. Similarly, high protein and lysine values were obtained for this variety at Yuma and Debre Zeit. At the two other locations in Ethiopia, however, this entry either failed to produce seed (Awasa) or was very low in its protein content (Holletta). Similar situations were observed also for entries P.I. 195099P (Ethiopian source), P.I. 199995 (Ethiopian source), and P.I. 191640P (Portuguese source) which had shown the highest protein values at Debre Zeit, Awasa, and Holletta, respectively.

The stability parameters used to describe the performance of C.I. 7796 indicate that the protein and lysine content of this variety has

no relationship with the environment index, using either the Yates-Cochran or Eberhart-Russell procedure (59, 12). This was true whether the index involved four or five sites as in Ethiopia or Ethiopia and U.S.A., respectively. Whether this variety can be described as a stable variety is disputed by the differing interpretations provided by these authors. The interpretations of the stability parameters for C.I. 7796 obtained in this study following the Eberhart-Russell procedure do not conform to the description of a stable variety since the performance of this variety while stable over environments is not predictable because of the relatively large deviation mean square values.

The performance of C.I. 7796 at the various locations fits very well the description of a stable variety as determined by the Yates-Cochran procedure. It also fits the description of a variety with broad adaptability as described by Finlay (13). The reliability of the stability parameters is possibly influenced by the limited number of locations and the fact that the experiment was not repeated over years. Since this study is conducted with the aim of finding high protein and lysine lines for the wheat growing regions of Ethiopia, it is assumed that the number and distribution of the experimental sites adequately cover these areas. The additional predictive value provided by the Eberhart-Russell model, the deviation mean square, thus may not be necessary.

The results from the sub-experiment with RH-532 indicate a somewhat lower effect of the chemical in inducing self-sterility and/or hybridization in wheat than what has been found in other studies (personal communications with Dr. V. A. Johnson, the writer's advisor). RH-532 is reportedly also more potent and usable in lower concentrations

than RH-531 (usual rate is 4000 ppm for the latter). With 4000 ppm rate of application, RH-532 produced 79% male sterility and, relative to RH-531[1/], this effect appears to be low (at higher and lower concentration, however, RH-532 may be more effective).

One important asset of RH-532 is the fact that it produced little effect on female receptivity (more so at higher concentrations) whereas RH-531 tends to even cause female sterility.

The optimum level of application of RH-532 could not be determined from this study since it is not known what the effects of this chemical on wheat would be at concentrations higher than 6000 ppm.

Conclusion and Recommendations

There is a wide range of variability in protein level among durum wheats. A large portion of this variability, however, appears to be due to environmental and genotype x environment effects as indicated by the results from this study. Although no definite conclusions can be drawn with regard to the genetic uniqueness of most of the varieties considered in this study, it was possible to identify a few entries that were genetically superior to ordinary wheat in their protein content. The 200 selected entries considered in this study did not show genetic potential for high lysine content, but appear to be equal on the whole to ordinary durum wheats.

The entry C.I. 7796, which is Ethiopian in origin, is identified as a high protein - normal lysine level line with a broad range of adaptability (suspected to be drought resistant also). It is recommended

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[1/] Unpublished information, University of Nebraska, Lincoln.

that this variety be used as immediate parent for the genetic improvement of the nutritional value of Ethiopian wheat. It is also recommended that this variety be tested for yield and various other characteristics, including resistance to disease (especially to stem rust) for possible future release as a high protein line.

A back-crossing program should be followed, employing chemical male gametocides, using the 3 high protein (possibly also drought resistant) lines as donor lines and the same composite population which was used as female parent. The program can be initiated in Ethiopia by planting seeds harvested from the female-parent rows (now largely a hybrid population) along with the selected pollen donor lines following the same procedure as at Yuma. Screening for yield and other characteristics should be conducted following a series of such back-crosses (five or six may be sufficient).

A fairly rapid improvement of the nutritional quality and agronomic characteristics of the indigenous wheats can be effected through a mass selection program following the incorporation of the genes for the desired levels of protein and lysine. Lines with the best nutritional potential would be identified according to the following procedure. For the initial screening, total dye-binding capacity (DBC) will be determined through the Dye-Binding Method to identify high protein and/or lysine lines. Lines exhibiting DBC values lower than the donor parents would be discarded. The Kjeldhal Method would then be used for protein content for the smaller population. A high DBC and a high (or equal to DBC) Kjeldhal would indicate low lysine. However, a high DBC and a low Kjeldhal would indicate high lysine. This will differentiate

between samples which are high in protein or in lysine. The DBC of a sample containing 65 mg protein (based on Kjeldhal) would identify lines with the best lysine potential since DBC is correlated ($r = 0.80$) with lysine. Eventually lines which consistently indicate high lysine potential should be verified using a standard analytical procedure such as ion-exchange chromatography. The population thus formed would then be put on yield trial as well as on observation for disease resistance against an unimproved control population for further screening.

This approach, which is conservative, has a number of advantages. First some degree of progress through release of improved varieties for commercial production can be achieved in a relatively short period of time. Second, as an initial step in the overall breeding program, it will save much effort and time allowing provision for parallel breeding program involving selection of superior pure lines as well as further hybridization.

One most important asset of the breeding program proposed in this study is that, as a mass selection procedure involving the indigenous population, it insures effective utilization of the superior germ plasm without any threat of losing the already existing, hitherto unexplored, one represented by the indigenous population. The feasibility of this approach which is expected to lead to a thorough exploration and maximum utilization of the germ plasm available in Ethiopia, as well as in the U.S.D.A. Collection of Wheat, has been accentuated greatly by the fact that a substantial number of the high protein and high lysine lines found in the World Collection are contributions from Ethiopia. Any breeding approach leading to the substitution of the natural

composite of types growing in Ethiopia by a limited number of pure line varieties, whether these are introduced or indigenous, without even defining the available resources is, therefore, a risky undertaking which involves the threat of losing a highly valuable source of germ plasm.

The production of wheat may, however, be extended into the low land areas of the country where wheat has never been grown to any reasonably large scale. In such areas (elevation below 1500 meters) it would be possible under irrigation to produce wheats adaptable to the area without any need of conservation of local types. Probably the most important limitation associated with production of wheat in these areas is the serious disease problem, particularly rust, which probably would occur especially under large contiguous acreage of the crop.

The use of chemical male gametocide may have several advantages over the conventional hand-crossing technique. It promotes hybridization on a continual basis with minimal cost and effort. It also is relatively easy to manipulate. This could lead to emergence of new unusual genetic combinations that would be unlikely to surface under a controlled manual hybridization system.[1/] It is, therefore, recommended that a series of experiments be conducted on a continual basis to determine the effects and optimum rate of application of new chemical gametocides (including RH-532) in Ethiopia.

[1/] Project Review (Utilization), Improvement of the Nutritional Quality of Wheat, Contract No. AID/CSD-1208, May 7, 1973. University of Nebraska (page 21).

SUMMARY

The agronomic and quality data from the *T. durum* segment of the World Wheat Collection available at the University of Nebraska Wheat Quality Laboratory were analyzed to determine the amount of variability that existed for protein and lysine among the various entries.

A wide range of values for protein content of the U.S.D.A. World Collection durum wheats was observed. Protein varied from 7.3% to 21.3% with a mean and standard deviation of 12.75% and 2.86, respectively. Lysine (% of sample) had a range of 0.26% to 0.60%, a mean of 0.39% and standard deviation equal to 0.06. Lysine expressed as percent of protein showed a range of 2.43% to 4.29% with a mean and standard deviation equal to 3.15% and 0.27, respectively. These protein and lysine values closely resemble the values for common wheats. Protein and lysine variability and the relationship of protein and lysine in these two species also are similar.

Selected varieties that exhibited unusual properties of protein and lysine were grown at sites in Ethiopia and U.S.A. Seeds harvested from the varieties at each of these sites were returned to Lincoln and analyzed for protein and lysine at the Wheat Quality Laboratory to determine whether they are genetically superior to ordinary durum varieties and to assess their potential value for genetic improvement of wheats indigenous to Ethiopia.

Varieties that exhibited high protein and normal lysine levels over environments were identified as high protein lines. On the basis of

this criterion, with shrunken seed samples disregarded, only one variety, C.I. 7796 (Ethiopian source), showed excellent performance over all environments. Two varieties, P.I. 192711P and 185734P (both from Portugal), showed good performance over most environments but appear to perform poorly at Awasa (did not produce seed) and Debre Zeit (low lysine/protein value), respectively.

The stability of C.I. 7796 in different environments was tested by using both the Yates-Cochran and Eberhart-Russell procedures. The performance of this variety fits very well the description of a stable variety, as originally proposed by Yates and Cochran, and/or a variety with broad adaptability (Finlay and Wilkinson). It is proposed that this variety, which also is suspected of being drought resistant, be used as an immediate parent for the improvement of the nutritional value of Ethiopian durums. Following further investigation on its rust resistance, yield and other agronomic characteristics the variety might also be multiplied as a high protein line.

A regionalized series of experiments on protein with the wheats that have shown superior performance over most environments in Ethiopia is proposed. It is also recommended that entries that exhibited unusually high protein values but were disregarded because of kernel shrunkenness be included in these experiments.

An experiment was initiated at Yuma, Arizona in 1973 employing a breeding technique considered appropriate for effective utilization of the superior germ plasm in Ethiopia. This approach which involves the use of chemical male gametocide to enforce genetic recombination, will be utilized to incorporate genes for high quality and other desirable characteristics into wheats indigenous to Ethiopia.

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APPENDIX

Table A1. Protein and lysine values for durum wheats in the World Collection with the highest and lowest protein values.

C.I. or P.I. No.	% Protein[1/]	% Lysine[1/]	Lysine/ protein	Adjusted lysine/protein[2/]	Deviation lysine/protein[3/]
177950P	21.30	0.55	2.59	2.81	-0.34
185721P	21.10	0.62	2.95	3.18	0.03
185726P	20.90	0.62	3.01	3.25	0.11
177949P	20.70	0.56	2.72	2.97	-0.18
184541P	20.60	0.60	2.91	3.17	0.02
166728P	20.10	0.54	2.72	3.00	-0.15
185736P	20.10	0.58	2.91	3.19	0.04
192485P	20.00	0.51	2.59	2.87	-0.28
185729P	20.00	0.52	2.61	2.89	-0.26
185728P	19.90	0.58	2.91	3.19	0.05
185610P	19.90	0.58	2.96	3.24	0.10
184527P	19.90	0.59	3.01	3.29	0.15
185740P	19.90	0.57	2.87	3.15	0.01
134936P	19.80	0.52	2.65	2.94	-0.21
191528P	19.80	0.60	3.04	3.33	0.18
295036P	19.80	0.51	2.61	2.90	-0.25
184174P	19.80	0.54	2.76	3.05	-0.10
204011P	19.80	0.56	2.87	3.16	0.01
184540P	19.80	0.59	3.00	3.29	0.14
134935P	19.70	0.54	2.74	3.03	-0.12
185749P	19.70	0.56	2.86	3.15	0.00
191089P	19.70	0.60	3.09	3.38	0.23
185731P	19.70	0.54	2.76	3.05	-0.10
185196P	19.70	0.55	2.82	3.11	-0.04
185765P	19.70	0.56	2.86	3.15	0.00
184535P	19.70	0.57	2.93	3.22	0.07
185738P	19.60	0.56	2.87	3.16	0.01

Table A1. (Continued)

C.I. or P.I. No.	% Protein[1]	% Lysine[1]	Lysine/ protein	Adjusted lysine/protein[2]	Deviation lysine/protein[3]
192733P	19.60	0.56	2.89	3.18	0.03
204038P	19.60	0.58	3.00	3.29	0.14
177947P	19.60	0.50	2.57	2.86	-0.29
191608P	19.60	0.52	2.69	2.98	-0.17
295042P	19.60	0.52	2.70	2.99	-0.16
192736P	19.60	0.54	2.75	3.04	-0.11
165117P	19.60	0.54	2.80	3.09	-0.06
165154P	19.60	0.56	2.87	3.16	0.01
166817P	19.60	0.56	2.88	3.17	0.02
185724P	19.60	0.56	2.89	3.18	0.03
166816P	19.50	0.54	2.81	3.11	-0.04
184534P	19.50	0.55	2.82	3.12	-0.03
185764P	19.50	0.56	2.89	3.19	0.04
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
177919P	8.80	0.29	3.36	2.93	-0.22
7189	8.80	0.33	3.77	3.34	0.19
7438	8.80	0.29	3.33	2.90	-0.25
7392	8.80	0.29	3.37	2.94	-0.21
7551	8.80	0.29	3.38	2.95	-0.20
176284P	8.80	0.29	3.39	3.58	-0.19
176293P	8.80	0.30	3.41	2.98	-0.17

Table A1. (Continued)

C.I. or P.I. No.	% Protein[1]	% Lysine[1]	Lysine/ protein	Adjusted lysine/protein[2]	Deviation lysine/protein[3]
7297	8.80	0.30	3.43	3.00	-0.15
7390	8.80	0.30	3.46	3.03	-0.12
9247	8.80	0.30	3.47	3.04	-0.11

[1] Dry weight basis.

[2] Adjusted to 12.75% protein using the quadratic regression equation.

[3] Deviation of observed lysine percent of protein from lysine percent of protein predicted from curvilinear (quadratic) equation.

Table A2. Protein and lysine values for durum wheats in the World Collection with the highest and lowest lysine percent of sample values.

C.I. or P.I. No.	% Protein 1/	% Lysine 1/	Lysine/ protein	Adjusted lysine/protein 2/	Deviation lysine/protein 3/
185726P	20.90	0.62	3.01	2.90	0.11
185721P	21.10	0.62	2.95	2.92	0.03
184541P	20.60	0.60	2.91	2.89	0.02
191089P	19.70	0.60	3.09	2.86	0.23
191528P	19.80	0.60	3.04	2.86	0.18
166838P	19.00	0.60	3.17	2.84	0.33
166837P	18.90	0.59	3.12	2.84	0.28
184527P	19.90	0.59	3.01	2.86	0.15
184540P	19.80	0.59	3.00	2.86	0.14
191127P	17.90	0.59	3.30	2.83	0.47
185610P	19.90	0.58	2.96	2.86	0.10
185728P	19.90	0.58	2.91	2.86	0.05
185736P	20.10	0.58	2.91	2.87	0.04
166729P	19.20	0.58	3.03	2.85	0.18
165113P	18.40	0.58	3.18	2.84	0.34
204038P	19.60	0.58	3.00	2.86	0.14
204015P	18.70	0.58	3.12	2.84	0.28
165119P	18.50	0.57	3.12	2.84	0.28
185740P	19.90	0.57	2.87	2.86	0.01
184535P	19.70	0.57	2.93	2.86	0.07
297852P	18.90	0.57	3.03	2.84	0.19
297855P	19.20	0.57	3.01	2.85	0.16
185609P	18.90	0.56	3.00	2.84	0.16
185738P	19.60	0.56	2.87	2.86	0.01
177949P	20.70	0.56	2.72	2.90	-0.18

Table A2. (Continued)

C.I. or P.I. No.	% Protein[1/]	% Lysine[1/]	Lysine/ protein	Adjusted lysine/protein[2/]	Deviation lysine/protein[3/]
185765P	19.70	0.56	2.86	2.86	0.00
185764P	19.50	0.56	2.89	2.85	0.04
185724P	19.60	0.56	2.89	2.86	0.03
185749P	19.70	0.56	2.86	2.86	0.00
190986P	19.30	0.56	2.95	2.85	0.10
166817P	19.60	0.56	2.88	2.86	0.02
165116P	19.20	0.56	2.92	2.85	0.07
165154P	19.60	0.56	2.87	2.86	0.01
192683P	18.00	0.56	3.15	2.83	0.32
204011P	19.80	0.56	2.87	2.86	0.01
192735P	19.30	0.56	2.92	2.85	0.07
192733P	19.60	0.56	2.89	2.86	0.03
192517P	18.40	0.56	3.04	2.84	0.20
192516P	18.00	0.55	3.08	2.83	0.25
192512P	18.60	0.55	3.00	2.84	0.16
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
7529	8.00	0.28	3.61	3.71	-0.10
7852*	8.50	0.28	3.35	3.63	-0.28
7472	8.40	0.28	3.43	3.64	-0.21
176285P	8.00	0.28	3.60	3.71	-0.11
176292P	8.10	0.28	3.52	3.69	-0.17
176289P	8.50	0.28	3.40	3.63	-0.23
176296P	8.00	0.27	3.40	3.71	-0.31

Table A2. (Continued)

C.I. or P.I. No.	% Protein[1/]	% Lysine[1/]	Lysine/ protein	Adjusted lysine/protein[2/]	Deviation lysine/protein[3/]
164510P	7.80	0.27	3.51	3.75	-0.24
164512P	7.50	0.26	3.47	3.80	-0.33
167562P	9.20	0.25	2.80	3.51	-0.71

*Contribution from Ethiopia.

[1/] Dry weight basis.

[2/] Adjusted to 12.75% protein using the quadratic regression equation.

[3/] Deviation of observed lysine percent of protein from lysine percent of protein predicted from curvilinear (quadratic) equation.

Table A3. Protein and lysine values for durum wheats in the World Collection with the highest and lowest adjusted lysine percent of protein values.

C.I. or P.I. No.	% Protein[1/]	% Lysine[1/]	Lysine/ protein	Adjusted lysine/protein[2/]	Deviation lysine/protein[3/]
193867P*	12.10	0.45	3.77	3.78	0.63
192129P	9.50	0.37	3.99	3.67	0.52
7528	7.70	0.33	4.29	3.67	0.53
192442P	14.70	0.50	3.41	3.63	0.48
212835P	14.90	0.50	3.40	3.63	0.48
7267	12.30	0.44	3.59	3.62	0.47
191127P	17.90	0.59	3.30	3.61	0.47
297838P*	10.50	0.39	3.79	3.61	0.46
192120P	10.80	0.40	3.74	3.60	0.45
192086P	8.00	0.33	4.15	3.59	0.44
8635 *	11.40	0.41	3.65	3.58	0.43
195089P*	9.90	0.38	3.84	3.58	0.43
192619P	10.20	0.38	3.79	3.57	0.42
196907P*	10.50	0.39	3.74	3.56	0.41
191145P	15.50	0.51	3.29	3.55	0.40
192107P	10.50	0.38	3.71	3.53	0.38
193863P	11.50	0.41	3.59	3.53	0.38
196090P	16.30	0.52	3.24	3.53	0.38
220704P	7.70	0.31	4.14	3.52	0.38
192201P	12.70	0.43	3.45	3.52	0.37
7517	10.40	0.38	3.71	3.52	0.37
185300P	16.30	0.52	3.22	3.51	0.36
191827P	10.80	0.39	3.65	3.51	0.36
220689P	14.40	0.47	3.30	3.50	0.35

Table A3. (Continued)

C.I. or P.I. No.	% Protein[1/]	% Lysine[1/]	Lysine/ protein	Adjusted lysine/protein[2/]	Deviation lysine/protein[3/]
196098P	17.10	0.54	3.19	3.50	0.35
196097P	16.80	0.53	3.20	3.50	0.35
166854P	15.00	0.49	3.27	3.50	0.36
165113P	18.40	0.58	3.18	3.49	0.34
196102P	17.00	0.54	3.19	3.49	0.35
192618P	8.80	0.34	3.92	3.49	0.34
197473P	11.10	0.39	3.59	3.49	0.34
193887P*	10.50	0.38	3.67	3.49	0.34
195081P*	12.20	0.42	3.47	3.49	0.34
192119P	9.20	0.35	3.86	3.49	0.35
192130P	12.00	0.41	3.49	3.49	0.34
191051P	16.30	0.52	3.20	3.49	0.34
185608P	13.80	0.46	3.33	3.49	0.34
8123 *	10.30	0.38	3.70	3.49	0.34
7391	10.00	0.37	3.74	3.49	0.34
265005P	9.10	0.35	3.87	3.49	0.34
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
170997P	10.90	0.31	2.91	2.78	-0.37
172562P	9.30	0.29	3.12	2.77	-0.38
167443P	12.80	0.34	2.67	2.75	-0.40
167512P	9.70	0.29	3.03	2.74	-0.41

Table A3. (Continued)

C.I. or P.I. No.	% Protein[1/]	% Lysine[1/]	Lysine/ protein	Adjusted lysine/protein[2/]	Deviation lysine/protein[3/]
166893P	14.60	0.36	2.52	2.73	-0.42
280462P	13.40	0.34	2.60	2.73	-0.42
167579P	10.50	0.30	2.89	2.71	-0.44
166560P	11.30	0.31	2.79	2.71	-0.44
11496	13.50	0.32	2.43	2.56	-0.58
167562P	9.20	0.25	2.80	2.43	-0.71

*Contribution from Ethiopia.

[1/] Dry weight basis.

[2/] Adjusted to 12.75% protein using the quadratic regression equation.

[3/] Deviation of observed lysine percent of protein from lysine percent of protein predicted from curvilinear (quadratic) equation.

Table A4. Protein and lysine values for 200 lines selected from the World Collection durums totalling 3399 on the basis of protein values and unadjusted lysine per unit protein.

No.	C.I. or P.I. No.	Source	% Protein 1/	% Lysine 1/	Lysine/ protein	Adjusted lysine/protein 2/	Deviation lysine/protein 3/
1	7528	Egypt	7.7	0.33	4.29	3.67*	0.53
2	192086P	Portugal	8.0	0.33	4.15	3.59*	0.44
3	192129P	Portugal	9.5	0.37	3.99	3.67*	0.52
4	192618P	Portugal	8.8	0.34	3.66	3.49	0.34
5	268456P	Afghanistan	8.7	0.33	3.89	3.45	0.30
6	6880	Tunisia	8.2	0.31	3.88	3.35	0.20
7	265005P	Yugoslavia	9.1	0.35	3.87	3.49	0.34
8	192119P	Portugal	9.2	0.35	3.86	3.49	3.50
9	137744P	Iran	8.1	0.31	3.84	3.29	0.15
10	195089P	Ethiopia	9.9	0.38	3.84	3.58*	0.43
11	220129P	Afghanistan	8.7	0.33	3.83	3.39	0.24
12	3068	Ethiopia	8.8	0.33	3.82	3.39	0.24
13	297838P	Ethiopia	10.5	0.39	3.79	3.61*	0.46
14	8066	Ethiopia	9.1	0.34	3.78	3.40	0.25
15	193867P	Ethiopia	12.1	0.45	3.77	3.78*	0.63
16	7293	Egypt	9.0	0.33	3.76	3.36	0.21
17	192120P	Portugal	10.8	0.40	3.74	3.60*	0.45
18	196907P	Ethiopia	10.5	0.39	3.74	3.56*	0.41
19	195059P	Ethiopia	9.5	0.35	3.73	3.41	0.26
20	7325	India	8.8	0.32	3.72	3.29	0.14
21	7517	Egypt	10.4	0.38	3.71	3.52	0.37
22	192107P	Portugal	10.5	0.38	3.71	3.53	0.38
23	7796	Ethiopia	10.0	0.37	3.70	3.45	0.30
24	8123	Ethiopia	10.3	0.38	3.70	3.49	0.34
25	4561	India	10.0	0.36	3.67	3.42	0.27
26	193887P	Ethiopia	10.5	0.38	3.67	3.49	0.34

Table A4. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine[1/]	Lysine/ protein	Adjusted lysine/protein[2/]	Deviation lysine/protein[3/]
27	8635	Ethiopia	11.4	0.41	3.65	3.58*	0.43
28	191827P	Portugal	10.8	0.39	3.65	3.51	0.36
29	3150	Tunisia	10.0	0.36	3.64	3.39	0.24
30	7506	Egypt	10.1	0.36	3.64	3.41	0.26
31	7267	Egypt	12.3	0.44	3.59	3.62*	0.47
32	193888P	Ethiopia	12.1	0.42	3.47	3.48	0.33
33	195081P	Ethiopia	12.2	0.42	3.47	3.49	0.34
34	191850P	Portugal	12.0	0.41	3.46	3.46	0.31
35	191982P	Portugal	12.0	0.41	3.45	3.45	0.30
36	192201P	Portugal	12.7	0.43	3.45	3.52	0.37
37	192442P	Portugal	14.7	0.50	3.41	3.63*	0.48
38	212835P	Iran	14.9	0.50	3.40	3.63*	0.48
39	195095P	Ethiopia	12.4	0.42	3.39	3.43	0.28
40	195717P	Ethiopia	12.6	0.42	3.39	3.45	0.30
41	191836P	Portugal	12.2	0.41	3.38	3.40	0.25
42	7523	Egypt	12.6	0.42	3.37	3.43	0.28
43	192197P	Portugal	12.8	0.42	3.31	3.39	0.24
44	192620P	Portugal	12.7	0.42	3.36	3.43	0.28
45	195099P	Ethiopia	12.4	0.41	3.35	3.39	0.24
46	191848P	Portugal	12.6	0.42	3.34	3.40	0.25
47	194037P	Ethiopia	12.8	0.42	3.31	3.39	0.24
48	191127P	Spain	17.9	0.59	3.30	3.61*	0.47
49	220689P	Afghanistan	14.4	0.47	3.30	3.50	0.35
50	191145P	Spain	15.5	0.51**	3.29	3.55*	0.40
51	166854P	Turkey	15.0	0.49	3.27	3.50	0.36
52	191632P	Portugal	13.5	0.44	3.27	3.40	0.26
53	193871P	Ethiopia	13.1	0.42	3.27	3.37	0.22
54	195096P	Ethiopia	12.6	0.41	3.27	3.33	0.18

Table A4. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine[1/]	Lysine/ protein	Adjusted lysine/protein[2/]	Deviation lysine/protein[3/]
55	195724P	Ethiopia	13.8	0.45	3.27	3.43	0.28
56	194031P	Ethiopia	13.8	0.45	3.26	3.42	0.27
57	272537P	Hungary	14.0	0.45	3.26	3.43	0.28
58	193862P	Ethiopia	13.6	0.44	3.25	3.39	0.24
59	193869P	Ethiopia	12.4	0.40	3.25	3.29	0.14
60	8161	Peru	14.2	0.46	3.24	3.43	0.28
61	151205P	Ethiopia	12.6	0.40	3.24	3.30	0.15
62	191970P	Portugal	14.8	0.48	3.24	3.46	0.31
63	192006P	Portugal	15.0	0.48	3.23	3.46	0.32
64	185300P	Argentina	16.3	0.52**	3.22	3.51	0.36
65	191819P	Portugal	15.7	0.50	3.21	3.48	0.33
66	194830P	Ethiopia	13.5	0.43	3.21	3.34	0.20
67	195711P	Ethiopia	13.6	0.43	3.21	3.35	0.20
68	196091P	Ethiopia	14.9	0.47	3.21	3.44	0.29
69	210911P	Pakistan	12.0	0.38	3.21	3.21	0.06
70	7855	Ethiopia	13.5	0.43	3.20	3.33	0.19
71	196097P	Ethiopia	16.8	0.53**	3.20	3.50	0.35
72	113396P	Egypt	14.5	0.46	3.19	3.40	0.25
73	134930P	Portugal	13.2	0.42	3.19	3.30	0.15
74	177951P	Turkey	13.6	0.43	3.19	3.33	0.18
75	184537P	Portugal	14.8	0.47	3.19	3.41	0.26
76	191239P	Spain	13.2	0.42	3.19	3.30	0.15
77	195710P	Ethiopia	14.0	0.44	3.19	3.36	0.21
78	196098P	Ethiopia	17.1	0.54**	3.19	3.50	0.35
79	196102P	Ethiopia	17.0	0.54**	3.19	3.49	0.35
80	165113P	Turkey	18.4	0.58**	3.18	3.49	0.34
81	185753P	Portugal	16.6	0.52**	3.18	3.48	0.33
82	192743P	Portugal	16.1	0.51**	3.18	3.46	0.31

Table A4. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine[1/]	Lysine/ protein	Adjusted lysine/protein[2/]	Deviation lysine/protein[3/]
83	192839P	Portugal	15.3	0.48	3.18	3.43	0.28
84	166838P	Turkey	19.0**	0.60**	3.17	3.48	0.33
85	7778	Ethiopia	16.0	0.50	3.16	3.44	0.29
86	8455	U.A.R.	14.5	0.45	3.16	3.35	0.20
87	145720P	Arabia	14.0	0.44	3.16	3.33	0.18
88	196089P	Ethiopia	17.3	0.54**	3.16	3.47	0.32
89	196103P	Ethiopia	17.4	0.55**	3.16	3.47	0.32
90	196908P	Ethiopia	15.7	0.49	3.16	3.43	0.28
91	220426P	Egypt	14.3	0.45	3.16	3.43	0.28
92	225310P	Iran	15.6	0.49	3.16	3.42	0.27
93	191182P	Spain	14.0	0.44	3.15	3.32	0.17
94	192683P	Portugal	18.0	0.56**	3.15	3.46	0.32
95	234861P	Ethiopia	14.9	0.46	3.15	3.38	0.23
96	273997P	Ethiopia	14.8	0.46	3.15	3.37	0.22
97	7770	Ethiopia	14.4	0.45	3.14	3.34	0.19
98	113398P	Egypt	14.1	0.44	3.14	3.32	0.17
99	196092P	Ethiopia	16.3	0.51**	3.14	3.43	0.28
100	244342P	Ethiopia	14.2	0.44	3.14	3.33	0.18
101	119326P	Turkey	13.1	0.41	3.13	3.24	0.09
102	191412P	Morocco	13.5	0.42	3.13	3.26	0.12
103	191971P	Portugal	13.5	0.42	3.13	3.26	0.12
104	192461P	Portugal	13.4	0.42	3.13	3.26	0.11
105	192742P	Portugal	16.0	0.50	3.13	3.41	0.26
106	195100P	Ethiopia	15.6	0.48	3.13	3.39	0.24
107	195106P	Ethiopia	14.1	0.44	3.13	3.31	0.16
108	195698P	Ethiopia	14.3	0.44	3.13	3.32	0.17
109	273996P	Ethiopia	15.6	0.48	3.13	3.39	0.24
110	7234	Russia	14.0	0.43	3.12	3.29	0.14

Table A4. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine[1/]	Lysine/ protein	Adjusted lysine/protein[2/]	Deviation lysine/protein[3/]
111	7239	Russia	13.5	0 42	3.12	3.25	0.11
112	165119P	Turkey	18.5**	0.57**	3.12	3.43	0.28
113	166837P	Turkey	18.9**	0.59**	3.12	3.43	0.28
114	191629P	Portugal	14.6	0.45	3.12	3.33	0.18
115	196096P	Ethiopia	16.7	0.52**	3.12	3.42	0.27
116	204015P	Portugal	18.7**	0.58**	3.12	3.43	0.28
117	226573P	Ethiopia	14.1	0.44	3.12	3.30	0.15
118	195701P	Ethiopia	14.8	0.53**	3.12	3.34	0.19
119	297841P	Ethiopia	15.8	0.49	3.12	3.39	0.24
120	194028P	Ethiopia	14.6	0.45	3.11	3.32	0.17
121	194035P	Ethiopia	14.9	0.46	3.11	3.34	0.19
122	195729P	Ethiopia	16.2	0.50	3.11	3.39	0.25
123	196093P	Ethiopia	16.5	0.51**	3.11	3.40	0.26
124	166977P	Turkey	13.9	0.43	3.10	3.27	0.12
125	191010P	Spain	14.8	0.45	3.10	3.32	0.17
126	191958P	Portugal	14.1	0.43	3.10	3.28	0.13
127	192019P	Portugal	13.7	0.42	3.10	3.25	0.10
128	192841P	Portugal	13.8	0.42	3.10	3.26	0.11
129	210946P	Cyprus	13.7	0.42	3.10	3.25	0.10
130	7235	Russia	14.1	0.43	3.09	3.27	0.12
131	8493	Russia	15.3	0.47	3.09	3.34	0.19
132	094733P	Ethiopia	13.9	0.43	3.09	3.26	0.11
133	191021P	Spain	13.6	0.42	3.09	3.23	0.08
134	191087P	Spain	14.0	0.43	3.09	3.26	0.11
135	191089P	Spain	19.7**	0.60**	3.09	3.38	0.23
136	191186P	Spain	14.5	0.44	3.09	3.30	0.15
137	191832P	Portugal	14.8	0.45	3.09	3.31	0.16
138	191952P	Portugal	15.1	0.46	3.09	3.33	0.18

Table A4. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine[1/]	Lysine/ protein	Adjusted lysine/protein[2/]	Deviation lysine/protein[3/]
139	192036P	Portugal	13.6	0.42	3.09	3.23	0.08
140	192606P	Portugal	14.3	0.44	3.09	3.28	-0.13
141	192711P	Portugal	13.4	0.41	3.09	3.22	0.07
142	192741P	Portugal	16.5	0.51**	3.09	3.38	0.24
143	262656P	Russia	15.1	0.46	3.09	3.33	0.18
144	297837P	Ethiopia	16.0	0.49	3.09	3.37	0.22
145	297849P	Ethiopia	15.4	0.47	3.09	3.34	0.20
146	191400P	Spain	15.0	0.46	3.08		
147	192516P	Portugal	18.0	0.55**	3.08	3.39	0.24
148	194034P	Ethiopia	14.4	0.44	3.08	3.28	0.13
149	195728P	Ethiopia	15.0	0.46	3.08	3.31	0.17
150	199995P	Ethiopia	15.3	0.47	3.08	3.33	0.18
151	204021P	Portugal	14.4	0.44	3.08	3.28	0.13
152	204040P	Portugal	15.9	0.49	3.08	3.35	0.21
153	204054P	Portugal	16.8	0.51**	3.08	3.38	0.23
154	274003P	Ethiopia	14.6	0.45	3.08	3.29	0.14
155	8000	Ethiopia	15.2	0.46	3.07	3.31	0.17
156	191370P	Italy	16.5	0.50	3.07	3.36	0.22
157	191471P	Italy	14.3	0.43	3.07	3.26	0.11
158	191616P	Portugal	15.0	0.46	3.07	3.30	0.16
159	191635P	Portugal	14.1	0.43	3.07	3.25	0.10
160	191805P	Portugal	16.5	0.50	3.07	3.36	0.22
161	191955P	Portugal	15.7	0.48	3.07	3.34	0.19
162	192505P	Portugal	15.9	0.48	3.07	3.34	0.20
163	196087P	Ethiopia	17.1	0.52**	3.07	3.38	0.23
164	196095P	Ethiopia	17.8	0.54**	3.07	3.38	0.24
165	204043P	Portugal	15.4	0.47	3.07	3.32	0.17
166	177964P	Turkey	16.1	0.49	3.06	3.34	0.19

Table A4. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine[1/]	Lysine/ protein	Adjusted lysine/protein[2/]	Deviation lysine/protein[3/]
167	185723P	Portugal	15.5	0.47	3.06	3.32	0.17
168	191812P	Portugal	16.1	0.49	3.06	3.34	0.19
169	191816P	Portugal	17.6	0.53**	3.06	3.37	0.22
170	192609P	Portugal	14.8	0.45	3.06	3.28	0.13
171	193890P	Ethiopia	14.4	0.44	3.06	3.26	0.11
172	195696P	Ethiopia	15.9	0.48	3.06	3.33	0.19
173	195726P	Ethiopia	16.1	0.49	3.06	3.34	0.19
174	254012P	Unknown	14.3	0.43	3.06	3.25	0.10
175	185412P	Portugal	15.6	0.47	3.05	3.09	-0.06
176	185734P	Portugal	16.7	0.50	3.05	3.35	0.20
177	191788P	Portugal	16.7	0.50	3.05	3.35	0.20
178	192168P	Portugal	14.7	0.44	3.05	3.27	0.12
179	195705P	Ethiopia	15.0	0.45	3.05	3.28	0.14
180	196906P	Ethiopia	18.0	0.54**	3.05	3.36	0.22
181	297852P	Ethiopia	18.9**	0.57**	3.03	3.34	0.19
182	185726P	Portugal	20.9**	0.62**	3.01	3.25	0.11
183	185721P	Portugal	21.1**	0.62**	2.95	3.18	0.03
184	177950P	Turkey	21.3**	0.55**	2.59	2.81	-0.34
185	7150	Russia	8.9	0.33	3.80	3.39	0.24
186	195719P	Ethiopia	13.7	0.44	3.28	3.43	0.28
187	191941P	Portugal	12.6	0.41	3.25	3.31	0.16
188	191988P	Portugal	13.5	0.43	3.25	3.38	0.24
189	196090P	Ethiopia	16.3	0.52**	3.24	3.53	0.38
190	265007P	Yugoslavia	13.9	0.44	3.23	3.40	0.25
191	274681P	Poland	13.7	0.44	3.23	3.38	0.23
192	191640P	Portugal	14.1	0.42	3.04	3.22	0.07
193	192510P	Portugal	15.7	0.47	3.04	3.31	0.16
194	264951P	Italy	16.9	0.51	3.04	3.34	0.19

Table A4. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine[1/]	Lysine/ protein	Adjusted lysine/protein[2/]	Deviation lysine/protein[3/]
195	192504P	Portugal	15.1	0.45	3.03	3.27	0.12
196	192734P	Portugal	16.1	0.48	3.03	3.31	0.16
197	150380P	Tunisia	15.5	0.46	3.02	3.28	0.13
198	185191P	Portugal	16.0	0.48	3.02	3.30	0.15
199	Ward	U.S.A.					
200	Leeds	U.S.A.	15.9	0.42	2.67	2.94	-0.20

*Significantly higher (.05 level of significance) than the mean adjusted lysine (% of protein) value for World Collection durum wheats totalling 3399.

**Two standard deviations higher than the mean protein/lysine (% of sample) value for World Collection durum wheats totalling 3399.

1/ Dry weight basis.

2/ Adjusted to 12.75% protein using the quadratic regression equation.

3/ Deviation of observed lysine percent of protein from lysine percent of protein predicted from curvilinear (quadratic) regression equation.

Table A5. Protein and lysine values for 71 Ethiopian spring durum wheats among 200 entries selected from World Collection durums totalling 3399.

C.I. or P.I. No.	% Protein 1/	Lysine % of sample 1/	Lysine % of protein	Adjusted lysine/protein 2/	Deviation protein % 3/	Deviation lysine % of sample 4/	Deviation lysine/protein 5/
195089P	9.9	0.38	3.84	3.58*	-2.85	-0.01	0.43
3068	8.8	0.33	3.82	3.39	-3.95	-0.06	0.24
297838P	10.5	0.39	3.79	3.61*	-2.25	0.00	0.46
8066	9.1	0.34	3.78	3.40	-3.65	-0.05	0.25
193867P	12.1	0.45	3.77	3.78*	-0.65	0.06	0.63
196907P	10.5	0.39	3.74	3.56*	-2.25	0.00	0.41
195059P	9.5	0.35	3.74	3.41	-3.25	-0.04	0.26
7796	10.0	0.37	3.70	3.45	-2.75	-0.02	0.30
8123	10.3	0.38	3.70	3.49	-2.45	-0.01	0.34
193887P	10.5	0.38	3.67	3.49	-2.25	-0.01	0.34
8635	11.4	0.41	3.65	3.58*	-1.35	0.02	0.43
193888P	12.1	0.42	3.47	3.48	-0.65	0.03	0.33
195081P	12.2	0.42	3.47	3.49	-5.55	0.03	0.34
195095P	12.4	0.42	3.39	3.43	-0.35	0.03	0.28
195717P	12.6	0.42	3.39	3.45	-0.15	0.03	0.30
195099P	12.4	0.41	3.35	3.39	-0.35	0.02	0.24
194037P	12.8	0.42	3.31	3.39	0.05	0.03	0.24
193871P	13.1	0.42	3.27	3.37	0.35	0.03	0.22
195096P	12.6	0.38	3.27	3.33	-0.15	-0.01	0.18
195724P	13.8	0.45	3.27	3.43	1.05	0.06	0.28
194031P	13.8	0.45	3.26	3.42	1.05	0.06	0.27
193862P	13.6	0.44	3.25	3.39	0.85	0.05	0.24
193869P	12.4	0.40	3.25	3.29	-0.35	0.01	0.14
151205P	12.6	0.40	3.24	3.30	-0.15	0.01	0.15
194030P	13.5	0.43	3.21	3.34	0.75	0.04	0.20
195711P	13.6	0.43	3.21	3.35	0.85	0.04	0.20
196091P	14.9	0.47	3.21	3.44	2.15	0.08	0.29

Table A5. (Continued)

C.I. or P.I. No.	% Protein[1/]	Lysine % of sample[1/]	Lysine % of protein	Adjusted lysine/protein[2/]	Deviation protein %[3/]	Deviation lysine % of sample[4/]	Deviation lysine/protein[5/]
7855	13.5	0.43	3.20	3.33	0.75	0.04	0.19
196097P	16.8	0.53**	3.20	3.50	4.05	0.14	0.35
195710P	14.0	0.44	3.19	3.36	1.25	0.05	0.21
196098P	17.1	0.54**	3.19	3.50	4.35	0.15	0.35
196102P	17.0	0.54**	3.19	3.49	4.25	0.15	0.35
7778	16.0	0.50	3.16	3.44	3.25	0.11	0.29
196089P	17.3	0.54**	3.16	3.47	4.55	0.15	0.32
196103P	17.4	0.55**	3.16	3.47	4.65	0.16	0.32
196908P	15.7	0.49	3.16	3.43	2.95	0.10	0.28
234861P	14.9	0.46	3.15	3.38	2.15	0.07	0.23
273997P	14.8	0.46	3.15	3.37	2.05	0.07	0.22
7770	14.4	0.45	3.14	3.34	1.65	0.06	0.19
196092P	16.3	0.51**	3.14	3.43	3.55	0.12	0.28
244342P	14.2	0.44	3.14	3.33	1.45	0.05	0.18
195100P	15.6	0.48	3.13	3.39	2.85	0.09	0.24
195106P	14.1	0.44	3.13	3.31	1.35	0.05	0.16
195698P	14.3	0.44	3.13	3.32	1.55	0.05	0.17
273996P	15.6	0.48	3.13	3.39	2.85	0.09	0.24
196096P	16.7	0.52	3.12	3.42	3.95	0.13	0.27
226573P	14.1	0.44	3.12	3.30	1.35	0.05	0.15
195701P	14.8	0.46	3.12	3.34	2.05	0.07	0.19
297841P	15.8	0.49	3.12	3.39	3.05	0.10	0.24
194028P	14.6	0.45	3.11	3.32	1.85	0.06	0.17
194035P	14.9	0.46	3.11	3.34	2.15	0.07	0.19
195729P	16.2	0.50	3.11	3.39	3.45	0.11	0.25
196093P	16.5	0.51**	3.11	3.40	3.75	0.12	0.26
094733P	13.9	0.43	3.09	3.26	1.15	0.04	0.11
297838P	16.0	0.49	3.09	3.37	3.25	0.10	0.22
297849P	15.4	0.47	3.09	3.34	2.65	0.08	0.20

Table A5. (Continued)

C.I. or P.I. No.	% Protein[1/]	Lysine % of sample[1/]	Lysine % of protein	Adjusted lysine/protein[2/]	Deviation protein %[3/]	Deviation lysine % of sample[4/]	Deviation lysine/protein[5/]
194034P	14.4	0.44	3.08	3.28	1.65	0.05	0.13
195728P	15.0	0.46	3.08	3.31	2.25	0.07	0.17
199995P	15.3	0.47	3.08	3.33	2.55	0.08	0.18
274003P	14.6	0.45	3.08	3.29	1.85	0.06	0.14
8000	15.2	0.46	3.07	3.31	2.45	0.07	0.17
196087P	17.1	0.52	3.07	3.38	4.35	0.13	0.23
196095P	17.8	0.54**	3.07	3.38	5.05	0.15	0.24
193890P	14.4	0.44	3.06	3.26	1.65	0.05	0.11
195696P	15.9	0.48	3.06	3.33	3.15	0.09	0.19
195726P	16.1	0.49	3.06	3.34	3.35	0.10	0.19
195705P	15.0	0.45	3.05	3.28	2.25	0.06	0.14
196906P	18.0	0.54**	3.05	3.36	5.25	0.15	0.22
297852P	18.9**	0.57**	3.03	3.34	6.15	0.18	0.19
195719P	13.7	0.44	3.28	3.43	0.95	0.05	0.28
196090P	16.3	0.52**	3.24	3.53	3.55	0.13	0.38

*Significantly higher (.05 level of significance) than the mean adjusted lysine (% protein) value for World Collection durum wheats totalling 3399.

**Two standard deviations higher than the mean protein/lysine (% sample) value for World Collection durum wheats totalling 3399.

1/ Dry weight basis.

2/ Adjusted to 12.75% protein using the quadratic regression equation.

3/ Deviation from mean % protein value, i.e., deviation from protein value for ordinary durum wheat.

Table A5. (Continued)

C.I. or P.I. No.	% Protein[1/]	Lysine % of sample[1/]	Lysine % of protein	Adjusted lysine/protein[2/]	Deviation protein %[3/]	Deviation lysine % of sample[4/]	Deviation lysine/protein[5/]

[4/] Deviation from mean lysine percent of sample, i.e., deviation from % lysine value for ordinary durum wheat.

[5/] Deviation of observed lysine percent of protein from lysine percent of protein predicted from curvilinear (quadratic) regression equation.

Table A6.1. List of spring durum wheats included in the composite population for inter-crossing with 200 selected donor lines from U.S.D.A. World Collection.

No.	Entry	Origin	Source	Known character
1	Wells	North Dakota	F73	Drought resistant
2	Wakooma	Canada	F73	Drought resistant, good quality
3	Rollette	North Dakota	F73	Early, rust resistant
4	Ward	North Dakota	F73	Good quality, rust resistant
5	D6715	North Dakota	F73	Good quality, rust resistant
6	D6721	North Dakota	F73	Early, good quality, rust resistant
7	D6722	North Dakota	F73	Good quality, rust resistant
8	D6647	North Dakota	L72	Semidwarf, rust resistant
9	DL1	North Dakota	F70-DL1	Daylength insensitive
10	DL2	North Dakota	F70-DL2	Daylength insensitive
11	Cocorit	Mexico		Daylength insensitive

Table A6.2. List of indigenous Ethiopian durum wheats included in the composite population for inter-crossing with 200 selected donor lines from U.S.D.A. World Collection.

No.	Entry	No.	Entry	No.	Entry
1	DZ01-19	24	DZ01-227	47	DZ01-601
2	DZ01-30	25	DZ01-244	48	DZ01-614
3	DZ01-31	26	DZ01-252	49	DZ01-622
4	DZ01-38	27	DZ01-267	50	DZ01-632
5	DZ01-47	28	DZ01-284	51	DZ01-634
6	DZ01-86	29	DZ01-289	52	DZ01-641
7	DZ01-91	30	DZ01-310	53	DZ04-649
8	DZ01-98	31	DZ01-317	54	DZ04-651
9	DZ01-108	32	DZ01-323	55	DZ04-655
10	DZ01-110	33	DZ01-331	56	DZ04-656
11	DZ01-111	34	DZ01-337	57	DZ04-658
12	DZ01-117	35	DZ01-488	58	DZ04-659
13	DZ01-118	36	DZ01-489	59	DZ04-667
14	DZ01-120	37	DZ01-496	60	DZ04-674
15	DZ01-121	38	DZ01-508	61	DZ04-678
16	DZ01-135	39	DZ01-511	62	DZ04-680
17	DZ01-179	40	DZ01-541	63	DZ04-684
18	DZ01-182	41	DZ01-557	64	DZ04-686
19	DZ01-190	42	DZ01-572	65	DZ04-689
20	DZ01-195	43	DZ01-579	66	DZ04-690
21	DZ01-206	44	DZ01-582	67	DZ04-691
22	DZ01-211	45	DZ01-584	68	DZ04-692
23	DZ01-212	46	DZ01-591	69	DZ04-693

Table A7. List of 53 U.S.D.A. World Collection durum wheats included in the composite population for inter-crossing with 200 selected donor lines (U.S.D.A. World Collection).

No.	C.I. or P.I. No.	Source	No.	C.I. or P.I. No.	Source
1	192129P	Portugal	28	191632P	Portugal
2	3068	Ethiopia	29	194037P	Ethiopia
3	196907P	Ethiopia	30	196097P	Ethiopia
4	192839P	Portugal	31	195711P	Ethiopia
5	185753P	Portugal	32	194030P	Ethiopia
6	192683P	Portugal	33	191819P	Portugal
7	196908P	Ethiopia	34	192006P	Portugal
8	196092P	Ethiopia	35	196102P	Ethiopia
9	195698P	Ethiopia	36	196098P	Ethiopia
10	195106P	Ethiopia	37	192504P	Portugal
11	194035P	Ethiopia	38	264951P	Italy
12	194028P	Ethiopia	39	192510P	Portugal
13	297841P	Ethiopia	40	196090P	Ethiopia
14	195701P	Ethiopia	41	196906P	Ethiopia
15	226573P	Ethiopia	42	195726P	Ethiopia
16	7235	Russia	43	195696P	Ethiopia
17	195729P	Ethiopia	44	193890P	Ethiopia
18	8493	Russia	45	177964P	Turkey
19	193888P	Ethiopia	46	196095P	Ethiopia
20	7267	Egypt	47	204021P	Portugal
21	193887P	Ethiopia	48	274003P	Ethiopia
22	7796	Ethiopia	49	204054P	Portugal
23	7517	Egypt	50	195728P	Ethiopia
24	194031P	Ethiopia	51	297849P	Ethiopia
25	195724P	Ethiopia	52	192741P	Portugal
26	195096P	Ethiopia	53	192711P	Portugal
27	193871P	Ethiopia			

Table A8. Protein and lysine values for 200 durum wheats grown at Alemaya, Ethiopia in 1973.

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
1	7528	Egypt	21.50	0.51	2.38	2.82
2	192086P	Portugal	22.60	0.61	2.70	3.20
3	192129P	Portugal	22.20	0.57	2.56	3.04
4	192618P	Portugal	20.70	0.55	2.65	3.05
5	268456P	Afghanistan	21.30	0.53	2.52	2.94
6	6880	Tunisia	20.20	0.50	2.47	2.84
7	265005P	Yugoslavia	00.00	0.00	0.00	0.00
8	192119P	Portugal	19.70	0.49	2.52	2.85
9	137744P	Iran	16.80	0.42	2.52	2.70
10	195089P	Ethiopia	21.70	0.53	2.47	2.92
11	220129P	Afghanistan	00.00	0.00	0.00	0.00
12	3068	Ethiopia	21.60	0.51	2.38	2.82
13	297838P	Ethiopia	20.30	0.51	2.52	2.89
14	8066	Ethiopia	19.90	0.52	2.61	2.96
15	193867P	Ethiopia	21.50	0.54	2.52	2.95
16	7293	Egypt	20.30	0.50	2.47	2.84
17	192170P	Portugal	19.70	0.48	2.47	2.81
18	196907P	Ethiopia	20.50	0.52	2.56	2.94
19	195059P	Ethiopia	21.50	0.55	2.56	3.00
20	7325	India	18.90	0.45	2.42	2.72
21	7517	Egypt	19.60	0.48	2.47	2.80
22	192107P	Portugal	19.80	0.48	2.42	2.77
23	7796	Ethiopia	22.00	0.55	2.52	2.98
24	8123	Ethiopia	21.00	0.52	2.52	2.93
25	4561	India	18.80	0.47	2.52	2.81

Table A8. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
26	193887P	Ethiopia	19.70	0.54	2.75	3.08
27	8635	Ethiopia	19.70	0.51	2.61	2.95
28	191827P	Portugal	18.90	0.47	2.52	2.81
29	3150	Tunisia	00.00	0.00	0.00	0.00
30	7506	Egypt	18.40	0.50	2.75	3.01
31	7267	Egypt	20.60	0.55	2.70	3.09
32	193888P	Ethiopia	20.20	0.50	2.52	2.88
33	195081P	Ethiopia	20.30	0.53	2.61	2.98
34	191850P	Portugal	23.00	0.56	2.47	2.99
35	191982P	Portugal	21.00	0.51	2.42	2.83
36	192201P	Portugal	21.30	0.53	2.52	2.94
37	192442P	Portugal	19.90	0.49	2.47	2.82
38	212835P	Iran	00.00	0.00	0.00	0.00
39	195095P	Ethiopia	20.60	0.51	2.52	2.90
40	195717P	Ethiopia	18.10	0.51	2.84	3.09
41	191836P	Portugal	19.70	0.49	2.52	2.85
42	7523	Egypt	20.20	0.55	2.75	3.11
43	192197P	Portugal	21.30	0.51	2.42	2.85
44	192620P	Portugal	22.80	0.57	2.52	3.02
45	195099P	Ethiopia	23.30	0.58	2.52	3.05
46	191848P	Portugal	22.80	0.56	2.47	2.98
47	194037P	Ethiopia	21.70	0.59	2.75	3.19
48	191127P	Spain	19.70	0.52	2.65	2.99
49	220689P	Afghanistan	00.00	0.00	0.00	0.00
50	191145P	Spain	21.10	0.53	2.52	2.93
51	166854P	Turkey	00.00	0.00	0.00	0.00
52	191632P	Portugal	20.30	0.53	2.61	2.98

Table A8. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
53	193871P	Ethiopia	20.80	0.56	2.70	3.10
54	195096P	Ethiopia	19.20	0.51	2.65	2.97
55	195724P	Ethiopia	19.10	0.56	2.93	3.24
56	194031P	Ethiopia	18.70	0.54	2.88	3.17
57	272537P	Hungary	00.00	0.00	0.00	0.00
58	193862P	Ethiopia	20.90	0.56	2.70	3.10
59	193869P	Ethiopia	20.50	0.57	2.79	3.17
60	8161	Peru	00.00	0.00	0.00	0.00
61	151205P	Ethiopia	18.90	0.55	2.93	3.22
62	191970P	Portugal	22.20	0.57	2.56	3.04
63	192006P	Portugal	20.80	0.54	2.61	3.01
64	185300P	Argentina	22.10	0.52	2.38	2.85
65	191819P	Portugal	21.50	0.58	2.70	3.14
66	194830P	Ethiopia	20.50	0.55	2.70	3.08
67	195711P	Ethiopia	20.10	0.54	2.70	3.06
68	196091P	Ethiopia	19.20	0.50	2.61	2.92
69	210911P	Pakistan	20.40	0.50	2.47	2.85
70	7855	Ethiopia	21.20	0.53	2.52	2.94
71	196097P	Ethiopia	20.00	0.53	2.65	3.01
72	113396P	Egypt	19.80	0.54	2.75	3.09
73	134930P	Portugal	19.80	0.49	2.47	2.81
74	177951P	Turkey	21.80	0.49	2.29	2.74
75	184537P	Portugal	24.30	0.57	2.38	2.97
76	191239P	Spain	20.10	0.47	2.38	2.74
77	195710P	Ethiopia	21.10	0.53	2.52	2.93
78	196098P	Ethiopia	17.90	0.50	2.79	3.03
79	196102P	Ethiopia	17.60	0.50	2.84	3.06

Table A8. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
80	165113P	Turkey	19.30	0.46	2.42	2.74
81	185753P	Portugal	20.30	0.52	2.56	2.93
82	192743P	Portugal	00.00	0.00	0.00	0.00
83	192839P	Portugal	19.90	0.50	2.52	2.87
84	166838P	Turkey	00.00	0.00	0.00	0.00
85	7778	Ethiopia	00.00	0.00	0.00	0.00
86	8455	U.A.R.	18.20	0.50	2.79	3.05
87	145720P	Arabia	22.20	0.54	2.47	2.95
88	196089P	Ethiopia	19.70	0.53	2.70	3.04
89	196103P	Ethiopia	18.40	0.51	2.79	3.06
90	196908P	Ethiopia	19.60	0.53	2.70	3.03
91	220426P	Egypt	22.70	0.57	2.52	3.02
92	225310P	Iran	00.00	0.00	0.00	0.00
93	191182P	Spain	22.60	0.52	2.33	2.83
94	192683P	Portugal	20.80	0.59	2.84	3.24
95	234861P	Ethiopia	20.30	0.53	2.65	3.03
96	273997P	Ethiopia	20.30	0.53	2.65	3.03
97	7770	Ethiopia	20.60	0.50	2.42	2.81
98	113398P	Egypt	22.10	0.54	2.47	2.94
99	196092P	Ethiopia	18.50	0.50	2.70	2.97
100	244342P	Ethiopia	19.30	0.50	2.61	2.92
101	119326P	Turkey	20.90	0.57	2.75	3.15
102	191412P	Morocco	22.10	0.53	2.42	2.89
103	191971P	Portugal	24.20	0.57	2.38	2.96
104	192461P	Portugal	21.70	0.51	2.38	2.83
105	192742P	Portugal	20.70	0.52	2.52	2.91
106	195100P	Ethiopia	20.60	0.56	2.75	3.13

Table A8. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
107	195106P	Ethiopia	15.20	0.43	2.88	2.98
108	195698P	Ethiopia	18.10	0.52	2.88	3.13
109	273996P	Ethiopia	19.40	0.52	2.70	3.02
110	7234	Russia	22.10	0.50	2.29	2.76
111	7239	Russia	20.20	0.48	2.38	2.74
112	165119P	Turkey	00.00	0.00	0.00	0.00
113	166837P	Turkey	00.00	0.00	0.00	0.00
114	191629P	Portugal	18.90	0.45	2.42	2.72
115	196096P	Ethiopia	17.60	0.49	2.79	3.02
116	204015P	Portugal	18.80	0.48	2.56	2.85
117	226573P	Ethiopia	21.40	0.56	2.65	3.09
118	195701P	Ethiopia	18.40	0.53	2.88	3.15
119	297841P	Ethiopia	16.50	0.53	3.25	3.41
120	194028P	Ethiopia	19.00	0.54	2.84	3.14
121	194035P	Ethiopia	17.30	0.50	2.93	3.14
122	195729P	Ethiopia	00.00	0.00	0.00	0.00
123	196093P	Ethiopia	18.60	0.52	2.79	3.07
124	166977P	Turkey	18.40	0.46	2.52	2.78
125	191010P	Spain	22.20	0.52	2.38	2.85
126	191958P	Portugal	24.00	0.56	2.33	2.91
127	192019P	Portugal	23.10	0.55	2.38	2.90
128	192841P	Portugal	17.30	0.49	2.88	3.09
129	210946P	Cyprus	22.00	0.53	2.42	2.89
130	7235	Russia	20.30	0.49	2.42	2.80
131	8493	Russia	22.90	0.52	2.29	2.80
132	094733P	Ethiopia	19.90	0.48	2.42	2.77
133	191021P	Spain	00.00	0.00	0.00	0.00

Table A8. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
134	191087P	Spain	00.00	0.00	0.00	0.00
135	191089P	Spain	20.40	0.50	2.47	2.85
136	191186P	Spain	20.10	0.47	2.38	2.74
137	191832P	Portugal	20.60	0.51	2.52	2.90
138	191952P	Portugal	21.10	0.50	2.38	2.79
139	192036P	Portugal	20.50	0.50	2.47	2.85
140	192606P	Portugal	20.80	0.50	2.42	2.82
141	192711P	Portugal	19.90	0.50	2.52	2.87
142	192741P	Portugal	18.20	0.46	2.56	2.82
143	262656P	Russia	21.30	0.50	2.38	2.80
144	297837P	Ethiopia	18.50	0.52	2.84	3.11
145	297849P	Ethiopia	17.90	0.53	2.98	3.22
146	191400P	Spain	20.20	0.49	2.42	2.79
147	192516P	Portugal	19.90	0.49	2.47	2.82
148	194034P	Ethiopia	18.10	0.49	2.75	3.00
149	195728P	Ethiopia	18.00	0.49	2.75	2.99
150	199995P	Ethiopia	17.90	0.50	2.79	3.03
151	204021P	Portugal	00.00	0.00	0.00	0.00
152	204040P	Portugal	19.40	0.46	2.38	2.70
153	204054P	Portugal	19.80	0.51	2.61	2.95
154	274003P	Ethiopia	20.10	0.51	2.56	2.92
155	8000	Ethiopia	20.70	0.58	2.84	3.23
156	191370P	Italy	20.00	0.51	2.56	2.92
157	191471P	Italy	21.80	0.54	2.52	2.97
158	191616P	Portugal	21.00	0.51	2.47	2.88
159	191635P	Portugal	20.40	0.49	2.42	2.80
160	191805P	Portugal	20.50	0.51	2.52	2.90

Table A8. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
161	191955P	Portugal	21.10	0.56	2.65	3.07
162	192505P	Portugal	22.80	0.55	2.42	2.93
163	196087P	Ethiopia	18.80	0.50	2.65	2.94
164	196095P	Ethiopia	23.40	0.55	2.38	2.92
165	204043P	Portugal	19.00	0.44	2.33	2.63
166	177964P	Turkey	20.40	0.51	2.52	2.89
167	185723P	Portugal	22.50	0.52	2.33	2.82
168	191812P	Portugal	22.30	0.54	2.42	2.91
169	191816P	Portugal	22.30	0.55	2.47	2.95
170	192609P	Portugal	22.60	0.54	2.42	2.92
171	193890P	Ethiopia	19.40	0.51	2.65	2.98
172	195696P	Ethiopia	22.80	0.59	2.61	3.12
173	195726P	Ethiopia	22.30	0.55	2.47	2.95
174	254012P	Unknown	22.80	0.51	2.24	2.75
175	185412P	Portugal	22.60	0.55	2.47	2.97
176	185734P	Portugal	21.20	0.53	2.52	2.94
177	191788P	Portugal	20.10	0.53	2.65	3.01
178	192168P	Portugal	20.80	0.52	2.52	2.91
179	195705P	Ethiopia	21.30	0.50	2.38	2.80
180	196906P	Ethiopia	19.90	0.53	2.70	3.05
181	297852P	Ethiopia	21.80	0.55	2.56	3.02
182	185726P	Portugal	21.20	0.56	2.65	3.07
183	185721P	Portugal	21.80	0.53	2.47	2.92
184	177950P	Turkey	23.50	0.56	2.38	2.92
185	7150	Russia	00.00	0.00	0.00	0.00
186	195719P	Ethiopia	18.60	0.49	2.65	2.93
187	191941P	Portugal	20.30	0.50	2.47	2.84

Table A8. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
188	191988P	Portugal	23.00	0.53	2.33	2.85
189	196090P	Ethiopia	19.90	0.52	2.61	2.96
190	265007P	Yugoslavia	19.80	0.51	2.61	2.95
191	274681P	Poland	19.50	0.48	2.47	2.80
192	191640P	Portugal	22.30	0.53	2.38	2.86
193	192510P	Portugal	21.50	0.54	2.52	2.95
194	264951P	Italy	21.00	0.51	2.47	2.88
195	192504P	Portugal	20.80	0.51	2.47	2.87
196	192734P	Portugal	17.40	0.46	2.65	2.87
197	150380P	Tunisia	20.00	0.50	2.52	2.87
198	185191P	Portugal	19.50	0.49	2.52	2.84
199	Ward	U.S.A.	19.00	0.47	2.47	2.77
200	Leeds	U.S.A.	19.00	0.47	2.47	2.77

[1/] Dry weight basis.

[2/] Adjusted to 13.5% protein using curvilinear equation.

Table A9. Protein and lysine values for 200 durum wheats grown at Awasa, Ethiopia in 1973.

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
1	7528	Egypt	18.60	0.49	2.65	2.93
2	192086P	Portugal	19.70	0.53	2.70	3.04
3	192129P	Portugal	00.00	0.00	0.00	0.00
4	192618P	Portugal	22.60	0.59	2.61	3.11
5	268456P	Afghanistan	00.00	0.00	0.00	0.00
6	6880	Tunisia	00.00	0.00	0.00	0.00
7	265005P	Yugoslavia	00.00	0.00	0.00	0.00
8	192119P	Portugal	00.00	0.00	0.00	0.00
9	137744P	Iran	00.00	0.00	0.00	0.00
10	195089P	Ethiopia	00.00	0.00	0.00	0.00
11	220129P	Afghanistan	00.00	0.00	0.00	0.00
12	3068	Ethiopia	21.00	0.53	2.56	2.97
13	297838P	Ethiopia	22.10	0.57	2.61	3.08
14	8066	Ethiopia	22.70	0.61	2.70	3.20
15	193867P	Ethiopia	00.00	0.00	0.00	0.00
16	7293	Egypt	20.90	0.56	2.70	3.10
17	192120P	Portugal	00.00	0.00	0.00	0.00
18	196907P	Ethiopia	00.00	0.00	0.00	0.00
19	195059P	Ethiopia	00.00	0.00	0.00	0.00
20	7325	India	21.50	0.54	2.52	2.95
21	7517	Egypt	00.00	0.00	0.00	0.00
22	192107P	Portugal	24.30	0.62	2.56	3.15
23	7796	Ethiopia	19.80	0.51	2.61	2.95
24	8123	Ethiopia	00.00	0.00	0.00	0.00
25	4561	India	18.30	0.48	2.65	2.92

Table A9. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
26	193887P	Ethiopia	00.00	0.00	0.00	0.00
27	8635	Ethiopia	00.00	0.00	0.00	0.00
28	191827P	Portugal	00.00	0.00	0.00	0.00
29	3150	Tunisia	00.00	0.00	0.00	0.00
30	7506	Egypt	22.80	0.60	2.65	3.16
31	7267	Egypt	22.80	0.60	2.65	3.16
32	193888P	Ethiopia	17.80	0.47	2.65	2.89
33	195081P	Ethiopia	00.00	0.00	0.00	0.00
34	191850P	Portugal	00.00	0.00	0.00	0.00
35	191982P	Portugal	23.60	0.57	2.42	2.98
36	192201P	Portugal	00.00	0.00	0.00	0.00
37	192442P	Portugal	00.00	0.00	0.00	0.00
38	212835P	Iran	00.00	0.00	0.00	0.00
39	195095P	Ethiopia	24.10	0.65	2.70	3.28
40	195717P	Ethiopia	18.50	0.48	2.61	2.88
41	191836P	Portugal	00.00	0.00	0.00	0.00
42	7523	Egypt	23.40	0.57	2.47	3.01
43	192197P	Portugal	00.00	0.00	0.00	0.00
44	192620P	Portugal	23.60	0.61	2.61	3.16
45	195099P	Ethiopia	00.00	0.00	0.00	0.00
46	191848P	Portugal	23.50	0.61	2.61	3.15
47	194037P	Ethiopia	19.50	0.51	2.65	2.98
48	191127P	Spain	00.00	0.00	0.00	0.00
49	220689P	Afghanistan	00.00	0.00	0.00	0.00
50	191145P	Spain	00.00	0.00	0.00	0.00
51	166854P	Turkey	00.00	0.00	0.00	0.00
52	191632P	Portugal	00.00	0.00	0.00	0.00

Table A9. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
53	193871P	Ethiopia	19.60	0.52	2.65	2.99
54	195096P	Ethiopia	19.20	0.49	2.56	2.87
55	195724P	Ethiopia	20.40	0.52	2.56	2.94
56	194031P	Ethiopia	20.50	0.54	2.65	3.04
57	272537P	Hungary	00.00	0.00	0.00	0.00
58	193862P	Ethiopia	22.30	0.59	2.65	3.13
59	193869P	Ethiopia	21.50	0.58	2.70	3.14
60	8161	Peru	20.50	0.52	2.56	2.94
61	151205P	Ethiopia	22.00	0.58	2.65	3.12
62	191970P	Portugal	27.10	0.73	2.70	3.44
63	192006P	Portugal	21.50	0.58	2.70	3.14
64	185300P	Argentina	00.00	0.00	0.00	0.00
65	191819P	Portugal	20.90	0.56	2.70	3.10
66	194830P	Ethiopia	21.30	0.57	2.70	3.13
67	195711P	Ethiopia	23.60	0.59	2.52	3.07
68	196091P	Ethiopia	00.00	0.00	0.00	0.00
69	210911P	Pakistan	00.00	0.00	0.00	0.00
70	7855	Ethiopia	21.30	0.54	2.56	2.99
71	196097P	Ethiopia	21.20	0.55	2.61	3.03
72	113396P	Egypt	00.00	0.00	0.00	0.00
73	134930P	Portugal	00.00	0.00	0.00	0.00
74	177951P	Turkey	00.00	0.00	0.00	0.00
75	184537P	Portugal	00.00	0.00	0.00	0.00
76	191239P	Spain	00.00	0.00	0.00	0.00
77	195710P	Ethiopia	00.00	0.00	0.00	0.00
78	196098P	Ethiopia	19.90	0.52	2.61	2.96
79	196102P	Ethiopia	00.00	0.00	0.00	0.00

Table A9. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
80	165113P	Turkey	23.90	0.59	2.47	3.04
81	185753P	Portugal	23.60	0.61	2.61	3.16
82	192743P	Portugal	23.50	0.62	2.65	3.20
83	192839P	Portugal	00.00	0.00	0.00	0.00
84	166838P	Turkey	20.00	0.53	2.65	3.01
85	7778	Ethiopia	20.30	0.54	2.70	3.07
86	8455	U.A.R.	00.00	0.00	0.00	0.00
87	145720P	Arabia	20.40	0.53	2.61	2.98
88	196089P	Ethiopia	22.20	0.55	2.52	2.99
89	196103P	Ethiopia	22.40	0.58	2.61	3.09
90	196908P	Ethiopia	26.40	0.67	2.56	3.27
91	220426P	Egypt	00.00	0.00	0.00	0.00
92	225310P	Iran	00.00	0.00	0.00	0.00
93	191182P	Spain	00.00	0.00	0.00	0.00
94	192683P	Portugal	23.20	0.64	2.79	3.32
95	234861P	Ethiopia	26.50	0.69	2.61	3.32
96	273997P	Ethiopia	22.40	0.59	2.65	3.14
97	7770	Ethiopia	00.00	0.00	0.00	0.00
98	113398P	Egypt	00.00	0.00	0.00	0.00
99	196092P	Ethiopia	18.40	0.48	2.61	2.88
100	244342P	Ethiopia	17.90	0.46	2.61	2.85
101	119326P	Turkey	19.60	0.50	2.56	2.90
102	191412P	Morocco	00.00	0.00	0.00	0.00
103	191971P	Portugal	00.00	0.00	0.00	0.00
104	192461P	Portugal	00.00	0.00	0.00	0.00
105	192742P	Portugal	24.10	0.61	2.56	3.14
106	195100P	Ethiopia	00.00	0.00	0.00	0.00

Table A9. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
107	195106P	Ethiopia	18.30	0.47	2.61	2.87
108	195698P	Ethiopia	22.50	0.58	2.61	3.10
109	273996P	Ethiopia	20.80	0.55	2.65	3.05
110	7234	Russia	00.00	0.00	0.00	0.00
111	7239	Russia	00.00	0.00	0.00	0.00
112	165119P	Turkey	00.00	0.00	0.00	0.00
113	166837P	Turkey	00.00	0.00	0.00	0.00
114	191629P	Portugal	00.00	0.00	0.00	0.00
115	196096P	Ethiopia	00.00	0.00	0.00	0.00
116	204015P	Portugal	20.90	0.53	2.56	2.97
117	226573P	Ethiopia	21.90	0.58	2.65	3.11
118	195701P	Ethiopia	23.90	0.61	2.56	3.13
119	297841P	Ethiopia	21.20	0.55	2.61	3.03
120	194028P	Ethiopia	18.00	0.49	2.75	2.99
121	194035P	Ethiopia	24.90	0.63	2.56	3.19
122	195729P	Ethiopia	21.80	0.57	2.65	3.11
123	196093P	Ethiopia	00.00	0.00	0.00	0.00
124	166977P	Turkey	20.80	0.56	2.70	3.10
125	191010P	Spain	00.00	0.00	0.00	0.00
126	191958P	Portugal	00.00	0.00	0.00	0.00
127	192019P	Portugal	00.00	0.00	0.00	0.00
128	192841P	Portugal	00.00	0.00	0.00	0.00
129	210946P	Cyprus	00.00	0.00	0.00	0.00
130	7235	Russia	00.00	0.00	0.00	0.00
131	8493	Russia	19.80	0.54	2.75	3.09
132	094733P	Ethiopia	00.00	0.00	0.00	0.00
133	191021P	Spain	22.80	0.60	2.65	3.16

Table A9. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
134	191087P	Spain	00.00	0.00	0.00	0.00
135	191089P	Spain	00.00	0.00	0.00	0.00
136	191186P	Spain	00.00	0.00	0.00	0.00
137	191832P	Portugal	00.00	0.00	0.00	0.00
138	191952P	Portugal	00.00	0.00	0.00	0.00
139	192036P	Portugal	00.00	0.00	0.00	0.00
140	192606P	Portugal	00.00	0.00	0.00	0.00
141	192711P	Portugal	00.00	0.00	0.00	0.00
142	192741P	Portugal	00.00	0.00	0.00	0.00
143	262656P	Russia	00.00	0.00	0.00	0.00
144	297837P	Ethiopia	20.90	0.56	2.70	3.10
145	297849P	Ethiopia	19.00	0.52	2.75	3.05
146	191400P	Spain	00.00	0.00	0.00	0.00
147	192516P	Portugal	00.00	0.00	0.00	0.00
148	194034P	Ethiopia	20.00	0.51	2.56	2.92
149	195728P	Ethiopia	19.10	0.49	2.56	2.87
150	199995P	Ethiopia	19.20	0.49	2.56	2.87
151	204021P	Portugal	22.40	0.56	2.52	3.00
152	204040P	Portugal	00.00	0.00	0.00	0.00
153	204054P	Portugal	20.00	0.52	2.61	2.96
154	274003P	Ethiopia	00.00	0.00	0.00	0.00
155	8000	Ethiopia	23.80	0.62	2.61	3.17
156	191370P	Italy	20.80	0.55	2.65	3.05
157	191471P	Italy	00.00	0.00	0.00	0.00
158	191616P	Portugal	19.90	0.52	2.61	2.96
159	191635P	Portugal	00.00	0.00	0.00	0.00
160	191805P	Portugal	00.00	0.00	0.00	0.00

Table A9. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
161	191955P	Portugal	22.90	0.61	2.70	3.21
162	192505P	Portugal	23.70	0.59	2.52	3.07
163	196087P	Ethiopia	20.40	0.51	2.52	2.89
164	196095P	Ethiopia	19.80	0.51	2.61	2.95
165	204043P	Portugal	00.00	0.00	0.00	0.00
166	177964P	Turkey	00.00	0.00	0.00	0.00
167	185723P	Portugal	00.00	0.00	0.00	0.00
168	191812P	Portugal	19.00	0.53	2.79	3.09
169	191816P	Portugal	00.00	0.00	0.00	0.00
170	192609P	Portugal	00.00	0.00	0.00	0.00
171	193890P	Ethiopia	21.30	0.55	2.61	3.03
172	195696P	Ethiopia	22.20	0.60	2.70	3.18
173	195726P	Ethiopia	22.20	0.58	2.61	3.08
174	254012P	Unknown	00.00	0.00	0.00	0.00
175	185412P	Portugal	21.70	0.55	2.56	3.01
176	185734P	Portugal	22.90	0.56	2.47	2.98
177	191788P	Portugal	00.00	0.00	0.00	0.00
178	192168P	Portugal	18.10	0.47	2.61	2.86
179	195705P	Ethiopia	22.40	0.57	2.56	3.05
180	196906P	Ethiopia	22.60	0.56	2.52	3.01
181	297852P	Ethiopia	24.20	0.59	2.47	3.06
182	185726P	Portugal	00.00	0.00	0.00	0.00
183	185721P	Portugal	00.00	0.00	0.00	0.00
184	177950P	Turkey	00.00	0.00	0.00	0.00
185	7150	Russia	00.00	0.00	0.00	0.00
186	195719P	Ethiopia	21.00	0.53	2.56	2.97
187	191941P	Portugal	22.00	0.56	2.56	3.03

Table A9. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
188	191988P	Portugal	00.00	0.00	0.00	0.00
189	196090P	Ethiopia	21.70	0.56	2.61	3.06
190	265007P	Yugoslavia	00.00	0.00	0.00	0.00
191	274681P	Poland	00.00	0.00	0.00	0.00
192	191640P	Portugal	00.00	0.00	0.00	0.00
193	192510P	Portugal	00.00	0.00	0.00	0.00
194	264951P	Italy	00.00	0.00	0.00	0.00
195	192504P	Portugal	00.00	0.00	0.00	0.00
196	192734P	Portugal	22.70	0.61	2.70	3.20
197	150380P	Tunisia	00.00	0.00	0.00	0.00
198	185191P	Portugal	00.00	0.00	0.00	0.00
199	Ward	U.S.A.	17.20	0.46	2.70	2.90
200	Leeds	U.S.A.	00.00	0.00	0.00	0.00

[1/] Dry weight basis.

[2/] Adjusted to 13.5% protein using curvilinear equation.

Table A10. Protein and lysine values for 200 durum wheats grown at Debre Zeit, Ethiopia in 1973.

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
1	7528	Egypt	18.40	0.48	2.65	2.92
2	192086P	Portugal	18.70	0.47	2.52	2.80
3	192129P	Portugal	18.10	0.45	2.52	2.77
4	192618P	Portugal	17.10	0.46	2.70	2.90
5	268456P	Afghanistan	00.00	0.00	0.00	0.00
6	6880	Tunisia	19.40	0.52	2.70	3.02
7	265005P	Yugoslavia	00.00	0.00	0.00	0.00
8	192119P	Portugal	18.00	0.47	2.65	2.90
9	137744P	Iran	00.00	0.00	0.00	0.00
10	195089P	Ethiopia	17.90	0.47	2.65	2.89
11	220129P	Afghanistan	00.00	0.00	0.00	0.00
12	3068	Ethiopia	18.20	0.48	2.65	2.91
13	297838P	Ethiopia	17.70	0.47	2.65	2.88
14	8066	Ethiopia	17.30	0.45	2.61	2.82
15	193867P	Ethiopia	16.50	0.45	2.75	2.91
16	7293	Egypt	00.00	0.00	0.00	0.00
17	192120P	Portugal	18.50	0.46	2.52	2.79
18	196907P	Ethiopia	18.10	0.49	2.75	3.00
19	195059P	Ethiopia	17.40	0.47	2.75	2.96
20	7325	India	00.00	0.00	0.00	0.00
21	7517	Egypt	18.40	0.48	2.61	2.88
22	192107P	Portugal	17.70	0.45	2.56	2.79
23	7796	Ethiopia	18.60	0.48	2.61	2.89
24	8123	Ethiopia	16.60	0.44	2.70	2.87
25	4561	India	20.10	0.48	2.42	2.78

Table A10. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
26	193887P	Ethiopia	19.60	0.51	2.61	2.94
27	8635	Ethiopia	20.80	0.52	2.52	2.91
28	191827P	Portugal	19.90	0.50	2.52	2.87
29	3150	Tunisia	00.00	0.00	0.00	0.00
30	7506	Egypt	19.00	0.47	2.52	2.82
31	7267	Egypt	21.50	0.53	2.47	2.91
32	193888P	Ethiopia	18.20	0.47	2.61	2.86
33	195081P	Ethiopia	19.70	0.50	2.56	2.90
34	191850P	Portugal	00.00	0.00	0.00	0.00
35	191982P	Portugal	20.50	0.51	2.52	2.90
36	192201P	Portugal	18.20	0.48	2.65	2.91
37	192442P	Portugal	18.30	0.45	2.47	2.73
38	212835P	Iran	00.00	0.00	0.00	0.00
39	195095P	Ethiopia	16.40	0.42	2.61	2.77
40	195717P	Ethiopia	14.40	0.39	2.75	2.79
41	191836P	Portugal	00.00	0.00	0.00	0.00
42	7523	Egypt	16.90	0.46	2.75	2.93
43	192197P	Portugal	17.90	0.45	2.56	2.80
44	192620P	Portugal	18.30	0.47	2.61	2.87
45	195099P	Ethiopia	20.20	0.50	2.52	2.88
46	191848P	Portugal	00.00	0.00	0.00	0.00
47	194037P	Ethiopia	00.00	0.00	0.00	0.00
48	191127P	Spain	00.00	0.00	0.00	0.00
49	220689P	Afghanistan	00.00	0.00	0.00	0.00
50	191145P	Spain	00.00	0.00	0.00	0.00
51	166854P	Turkey	00.00	0.00	0.00	0.00
52	191632P	Portugal	19.80	0.50	2.56	2.91

Table A10. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
53	193871P	Ethiopia	19.00	0.48	2.56	2.86
54	195096P	Ethiopia	00.00	0.00	0.00	0.00
55	195724P	Ethiopia	19.30	0.49	2.56	2.88
56	194031P	Ethiopia	18.40	0.48	2.61	2.88
57	272537P	Hungary	00.00	0.00	0.00	0.00
58	193862P	Ethiopia	17.40	0.46	2.65	2.87
59	193869P	Ethiopia	16.70	0.45	2.75	2.92
60	8161	Peru	00.00	0.00	0.00	0.00
61	151205P	Ethiopia	17.50	0.45	2.61	2.83
62	191970P	Portugal	21.00	0.54	2.61	3.02
63	192006P	Portugal	19.50	0.50	2.61	2.94
64	185300P	Argentina	00.00	0.00	0.00	0.00
65	191819P	Portugal	18.70	0.49	2.65	2.94
66	194830P	Ethiopia	18.00	0.48	2.70	2.95
67	195711P	Ethiopia	18.10	0.48	2.70	2.95
68	196091P	Ethiopia	15.80	0.44	2.79	2.92
69	210911P	Pakistan	18.90	0.47	2.52	2.81
70	7855	Ethiopia	19.10	0.48	2.52	2.82
71	196097P	Ethiopia	18.30	0.46	2.56	2.82
72	113396P	Egypt	17.60	0.49	2.79	3.02
73	134930P	Portugal	00.00	0.00	0.00	0.00
74	177951P	Turkey	00.00	0.00	0.00	0.00
75	184537P	Portugal	00.00	0.00	0.00	0.00
76	191239P	Spain	00.00	0.00	0.00	0.00
77	195710P	Ethiopia	17.00	0.45	2.70	2.89
78	196098P	Ethiopia	14.90	0.40	2.75	2.82
79	196102P	Ethiopia	14.20	0.40	2.84	2.88

Table A10. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
80	165113P	Turkey	00.00	0.00	0.00	0.00
81	185753P	Portugal	18.90	0.49	2.61	2.90
82	192743P	Portugal	18.70	0.48	2.56	2.85
83	192839P	Portugal	18.90	0.48	2.56	2.86
84	166838P	Turkey	00.00	0.00	0.00	0.00
85	7778	Ethiopia	16.50	0.43	2.65	2.82
86	8455	U.A.R.	13.30	0.40	3.02	3.01
87	145720P	Arabia	20.70	0.54	2.61	3.00
88	196089P	Ethiopia	17.70	0.47	2.65	2.88
89	196103P	Ethiopia	16.30	0.44	2.70	2.85
90	196908P	Ethiopia	17.20	0.44	2.61	2.81
91	220426P	Egypt	19.80	0.49	2.52	2.86
92	225310P	Iran	00.00	0.00	0.00	0.00
93	191182P	Spain	00.00	0.00	0.00	0.00
94	192683P	Portugal	16.80	0.46	2.75	2.93
95	234861P	Ethiopia	15.50	0.37	2.42	2.53
96	273997P	Ethiopia	15.60	0.42	2.75	2.86
97	7770	Ethiopia	00.00	0.00	0.00	0.00
98	113398P	Egypt	17.50	0.44	2.56	2.78
99	196092P	Ethiopia	17.20	0.44	2.61	2.81
100	244342P	Ethiopia	17.10	0.45	2.65	2.85
101	119326P	Turkey	17.20	0.44	2.56	2.76
102	191412P	Morocco	00.00	0.00	0.00	0.00
103	191971P	Portugal	00.00	0.00	0.00	0.00
104	192461P	Portugal	00.00	0.00	0.00	0.00
105	192742P	Portugal	17.70	0.43	2.47	2.70
106	195100P	Ethiopia	19.20	0.49	2.56	2.87

Table A10. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
107	195106P	Ethiopia	17.20	0.44	2.56	2.76
108	195698P	Ethiopia	17.80	0.47	2.65	2.89
109	273996P	Ethiopia	17.70	0.46	2.61	2.84
110	7234	Russia	00.00	0.00	0.00	0.00
111	7239	Russia	00.00	0.00	0.00	0.00
112	165119P	Turkey	00.00	0.00	0.00	0.00
113	166837P	Turkey	00.00	0.00	0.00	0.00
114	191629P	Portugal	18.70	0.47	2.52	2.80
115	196096P	Ethiopia	17.50	0.45	2.61	2.83
116	204015P	Portugal	19.40	0.48	2.52	2.84
117	226573P	Ethiopia	19.40	0.48	2.52	2.84
118	195701P	Ethiopia	18.10	0.48	2.70	2.95
119	297841P	Ethiopia	17.00	0.46	2.75	2.94
120	194028P	Ethiopia	17.40	0.46	2.65	2.87
121	194035P	Ethiopia	17.40	0.45	2.61	2.82
122	195729P	Ethiopia	18.30	0.46	2.56	2.82
123	196093P	Ethiopia	17.60	0.46	2.61	2.83
124	166977P	Turkey	00.00	0.00	0.00	0.00
125	191010P	Spain	21.20	0.55	2.61	3.03
126	191958P	Portugal	00.00	0.00	0.00	0.00
127	192019P	Portugal	00.00	0.00	0.00	0.00
128	192841P	Portugal	00.00	0.00	0.00	0.00
129	210946P	Cyprus	00.00	0.00	0.00	0.00
130	7235	Russia	20.00	0.49	2.47	2.83
131	8493	Russia	21.20	0.50	2.38	2.80
132	094733P	Ethiopia	19.30	0.49	2.56	2.88
133	191021P	Spain	00.00	0.00	0.00	0.00

Table A10. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
134	191087P	Spain	00.00	0.00	0.00	0.00
135	191089P	Spain	00.00	0.00	0.00	0.00
136	191186P	Spain	00.00	0.00	0.00	0.00
137	191832P	Portugal	18.20	0.47	2.61	2.86
138	191952P	Portugal	19.00	0.47	2.47	2.77
139	192036P	Portugal	00.00	0.00	0.00	0.00
140	192606P	Portugal	20.20	0.49	2.42	2.79
141	192711P	Portugal	18.70	0.47	2.52	2.80
142	192741P	Portugal	17.70	0.43	2.42	2.65
143	262656P	Russia	00.00	0.00	0.00	0.00
144	297837P	Ethiopia	16.80	0.43	2.56	2.74
145	297849P	Ethiopia	16.30	0.44	2.70	2.85
146	191400P	Spain	17.20	0.44	2.61	2.81
147	192516P	Portugal	00.00	0.00	0.00	0.00
148	194034P	Ethiopia	19.90	0.50	2.52	2.87
149	195728P	Ethiopia	16.90	0.43	2.56	2.75
150	199995P	Ethiopia	17.00	0.44	2.61	2.80
151	204021P	Portugal	20.30	0.50	2.47	2.84
152	204040P	Portugal	00.00	0.00	0.00	0.00
153	204054P	Portugal	00.00	0.00	0.00	0.00
154	274003P	Ethiopia	15.60	0.42	2.70	2.81
155	8000	Ethiopia	17.00	0.45	2.65	2.84
156	191370P	Italy	18.00	0.47	2.65	2.90
157	191471P	Italy	00.00	0.00	0.00	0.00
158	191616P	Portugal	19.30	0.47	2.47	2.79
159	191635P	Portugal	19.60	0.47	2.42	2.76
160	191805P	Portugal	19.60	0.48	2.47	2.80

Table A10. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
161	191955P	Portugal	18.70	0.48	2.61	2.89
162	192505P	Portugal	15.60	0.42	2.70	2.81
163	196087P	Ethiopia	00.00	0.00	0.00	0.00
164	196095P	Ethiopia	16.10	0.44	2.75	2.89
165	204043P	Portugal	19.40	0.48	2.52	2.84
166	177964P	Turkey	00.00	0.00	0.00	0.00
167	185723P	Portugal	19.80	0.49	2.47	2.81
168	191812P	Portugal	19.60	0.48	2.47	2.80
169	191816P	Portugal	00.00	0.00	0.00	0.00
170	192609P	Portugal	00.00	0.00	0.00	0.00
171	193890P	Ethiopia	15.90	0.43	2.75	2.88
172	195696P	Ethiopia	17.00	0.45	2.70	2.89
173	195726P	Ethiopia	00.00	0.00	0.00	0.00
174	254012P	Unknown	16.80	0.43	2.56	2.74
175	185412P	Portugal	19.80	0.49	2.52	2.86
176	185734P	Portugal	19.00	0.46	2.42	2.72
177	191788P	Portugal	19.10	0.48	2.52	2.82
178	192168P	Portugal	18.40	0.46	2.52	2.78
179	195705P	Ethiopia	19.00	0.47	2.52	2.82
180	196906P	Ethiopia	17.70	0.45	2.56	2.79
181	297852P	Ethiopia	19.00	0.48	2.56	2.86
182	185726P	Portugal	16.00	0.44	2.75	2.88
183	185721P	Portugal	17.10	0.44	2.61	2.80
184	177950P	Turkey	18.90	0.47	2.52	2.81
185	7150	Russia	00.00	0.00	0.00	0.00
186	195719P	Ethiopia	15.70	0.43	2.75	2.87
187	191941P	Portugal	17.50	0.44	2.52	2.73

Table A10. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
188	191988P	Portugal	00.00	0.00	0.00	0.00
189	196090P	Ethiopia	16.30	0.42	2.61	2.76
190	265007P	Yugoslavia	00.00	0.00	0.00	0.00
191	274681P	Poland	00.00	0.00	0.00	0.00
192	191640P	Portugal	00.00	0.00	0.00	0.00
193	192510P	Portugal	17.10	0.43	2.52	2.71
194	264951P	Italy	17.30	0.45	2.61	2.82
195	192504P	Portugal	18.10	0.46	2.56	2.81
196	192734P	Portugal	17.60	0.47	2.70	2.92
197	150380P	Tunisia	19.30	0.49	2.56	2.88
198	185191P	Portugal	17.10	0.45	2.65	2.85
199	Ward	U.S.A.	18.00	0.45	2.52	2.76
200	Leeds	U.S.A.	17.40	0.43	2.52	2.73

[1/] Dry weight basis.

[2/] Adjusted to 13.5% protein using curvilinear equation.

Table A11. Protein and lysine values for 200 durum wheats grown at Holletta, Ethiopia in 1973.

No.	C.I. Or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
1	7528	Egypt	12.50	0.34	2.79	2.74
2	192086P	Portugal	11.00	0.33	3.02	2.88
3	192129P	Portugal	12.00	0.34	2.84	2.75
4	192618P	Portugal	10.70	0.31	2.98	2.82
5	268456P	Afghanistan	11.10	0.33	2.98	2.84
6	6880	Tunisia	10.30	0.31	3.07	2.89
7	265005P	Yugoslavia	00.00	0.00	0.00	0.00
8	192119P	Portugal	10.50	0.33	3.16	2.99
9	137744P	Iran	12.30	0.35	2.88	2.82
10	195089P	Ethiopia	10.70	0.34	3.21	3.05
11	220129P	Afghanistan	11.20	0.31	2.79	2.66
12	3068	Ethiopia	14.40	0.40	2.84	2.89
13	297838P	Ethiopia	11.90	0.36	3.02	2.93
14	8066	Ethiopia	11.60	0.33	2.88	2.78
15	193867P	Ethiopia	14.90	0.40	2.75	2.82
16	7293	Egypt	10.30	0.30	2.98	2.80
17	192120P	Portugal	10.50	0.31	2.98	2.81
18	196907P	Ethiopia	14.20	0.39	2.79	2.83
19	195059P	Ethiopia	12.30	0.36	2.98	2.91
20	7325	India	10.30	0.31	3.02	2.85
21	7517	Egypt	11.70	0.34	2.93	2.83
22	192107P	Portugal	10.50	0.32	3.07	2.90
23	7796	Ethiopia	13.90	0.38	2.79	2.81
24	8123	Ethiopia	12.10	0.36	2.98	2.90
25	4561	India	10.00	0.31	3.11	2.92

Table A11. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
26	193887P	Ethiopia	13.10	0.37	2.88	2.86
27	8635	Ethiopia	11.30	0.34	3.07	2.95
28	191827P	Portugal	10.50	0.32	3.07	2.90
29	3150	Tunisia	10.60	0.29	2.79	2.63
30	7506	Egypt	11.40	0.34	3.02	2.91
31	7267	Egypt	12.50	0.36	2.88	2.83
32	193888P	Ethiopia	12.70	0.37	2.93	2.88
33	195081P	Ethiopia	12.90	0.37	2.93	2.90
34	191850P	Portugal	10.90	0.32	3.02	2.88
35	191982P	Portugal	10.70	0.31	2.93	2.78
36	192201P	Portugal	10.80	0.34	3.21	3.06
37	192442P	Portugal	10.10	0.30	3.02	2.83
38	212835P	Iran	00.00	0.00	0.00	0.00
39	195095P	Ethiopia	10.40	0.31	3.02	2.85
40	195717P	Ethiopia	14.00	0.38	2.75	2.77
41	191836P	Portugal	10.00	0.31	3.16	2.97
42	7523	Egypt	12.80	0.41	3.21	3.17
43	192197P	Portugal	10.80	0.32	3.02	2.87
44	192620P	Portugal	14.30	0.39	2.75	2.79
45	195099P	Ethiopia	12.60	0.36	2.93	2.88
46	191848P	Portugal	12.80	0.36	2.84	2.80
47	194037P	Ethiopia	13.70	0.40	2.98	2.99
48	191127P	Spain	10.40	0.34	3.34	3.17
49	220689P	Afghanistan	00.00	0.00	0.00	0.00
50	191145P	Spain	11.10	0.35	3.16	3.03
51	166854P	Turkey	00.00	0.00	0.00	0.00
52	191632P	Portugal	12.00	0.35	2.98	2.89

Table A11. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
53	193871P	Ethiopia	13.90	0.40	2.93	2.95
54	195096P	Ethiopia	10.00	0.32	3.25	3.06
55	195724P	Ethiopia	13.40	0.39	2.98	2.97
56	194031P	Ethiopia	15.40	0.45	2.93	3.03
57	272537P	Hungary	00.00	0.00	0.00	0.00
58	193862P	Ethiopia	12.20	0.37	3.07	3.00
59	193869P	Ethiopia	13.50	0.41	3.07	3.07
60	8161	Peru	00.00	0.00	0.00	0.00
61	151205P	Ethiopia	15.10	0.46	3.07	3.15
62	191970P	Portugal	14.00	0.46	3.30	3.32
63	192006P	Portugal	00.00	0.00	0.00	0.00
64	185300P	Argentina	9.80	0.35	3.67	3.46
65	191819P	Portugal	12.10	0.42	3.48	3.40
66	194830P	Ethiopia	16.40	0.48	2.93	3.09
67	195711P	Ethiopia	17.00	0.49	2.93	3.12
68	196091P	Ethiopia	17.60	0.48	2.75	2.97
69	210911P	Pakistan	12.80	0.39	3.07	3.03
70	7855	Ethiopia	14.50	0.43	2.98	3.03
71	196097P	Ethiopia	17.00	0.47	2.79	2.98
72	113396P	Egypt	13.20	0.42	3.25	3.23
73	134930P	Portugal	8.90	0.31	3.57	3.32
74	177951P	Turkey	00.00	0.00	0.00	0.00
75	184537P	Portugal	10.80	0.34	3.16	3.01
76	191239P	Spain	11.10	0.33	2.98	2.84
77	195710P	Ethiopia	12.50	0.37	3.02	2.97
78	196098P	Ethiopia	15.70	0.44	2.84	2.96
79	196102P	Ethiopia	12.30	0.37	3.07	3.00

Table A11. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
80	165113P	Turkey	9.00	0.30	3.34	3.10
81	185753P	Portugal	10.20	0.33	3.30	3.12
82	192743P	Portugal	9.70	0.31	3.25	3.04
83	192839P	Portugal	11.40	0.35	3.07	2.95
84	166838P	Turkey	00.00	0.00	0.00	0.00
85	7778	Ethiopia	12.40	0.33	2.70	2.64
86	8455	U.A.R.	15.70	0.46	2.98	3.10
87	145720P	Arabia	10.90	0.34	3.21	3.06
88	196089P	Ethiopia	12.70	0.39	3.07	3.02
89	196103P	Ethiopia	13.80	0.40	2.93	2.95
90	196908P	Ethiopia	16.30	0.47	2.88	3.04
91	220426P	Egypt	14.30	0.41	2.93	2.97
92	225310P	Iran	9.80	0.31	3.16	2.96
93	191182P	Spain	11.00	0.34	3.11	2.98
94	192683P	Portugal	12.00	0.39	3.25	3.17
95	234861P	Ethiopia	12.60	0.38	3.02	2.97
96	273997P	Ethiopia	14.30	0.42	2.98	3.02
97	7770	Ethiopia	10.40	0.32	3.16	2.99
98	113398P	Egypt	15.90	0.46	2.93	3.06
99	196092P	Ethiopia	15.20	0.43	2.88	2.98
100	244342P	Ethiopia	13.70	0.39	2.88	2.89
101	119326P	Turkey	00.00	0.00	0.00	0.00
102	191412P	Morocco	10.00	0.31	3.16	2.97
103	191971P	Portugal	12.30	0.34	2.84	2.77
104	192461P	Portugal	10.20	0.30	2.98	2.79
105	192742P	Portugal	12.20	0.35	2.88	2.81
106	195100P	Ethiopia	13.10	0.37	2.88	2.86

Table A11. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
107	195106P	Ethiopia	13.20	0.38	2.88	2.87
108	195698P	Ethiopia	15.40	0.43	2.84	2.94
109	273996P	Ethiopia	14.70	0.42	2.88	2.95
110	7234	Russia	10.50	0.31	2.98	2.81
111	7239	Russia	11.10	0.34	3.07	2.93
112	165119P	Turkey	10.00	0.32	3.25	3.06
113	166837P	Turkey	00.00	0.00	0.00	0.00
114	191629P	Portugal	11.30	0.35	3.11	2.99
115	196096P	Ethiopia	9.70	0.32	3.30	3.09
116	204015P	Portugal	15.40	0.43	2.84	2.94
117	226573P	Ethiopia	14.30	0.41	2.88	2.93
118	195701P	Ethiopia	14.60	0.42	2.93	2.99
119	297841P	Ethiopia	14.10	0.42	3.02	3.05
120	194028P	Ethiopia	14.10	0.42	2.98	3.01
121	194035P	Ethiopia	15.00	0.43	2.88	2.96
122	195729P	Ethiopia	15.40	0.43	2.84	2.94
123	196093P	Ethiopia	17.40	0.47	2.70	2.91
124	166977P	Turkey	11.00	0.35	3.21	3.07
125	191010P	Spain	11.40	0.35	3.07	2.95
126	191958P	Portugal	12.00	0.35	2.98	2.89
127	192019P	Portugal	11.80	0.36	3.07	2.97
128	192841P	Portugal	10.50	0.32	3.07	2.90
129	210946P	Cyprus	11.70	0.36	3.11	3.01
130	7235	Russia	11.20	0.34	3.11	2.99
131	8493	Russia	11.60	0.34	2.98	2.87
132	094733P	Ethiopia	11.60	0.34	2.98	2.87
133	191021P	Spain	00.00	0.00	0.00	0.00

Table A11. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
134	191087P	Spain	11.50	0.34	3.02	2.91
135	191089P	Spain	11.30	0.35	3.11	2.99
136	191186P	Spain	11.60	0.35	3.02	2.92
137	191832P	Portugal	13.40	0.40	3.02	3.01
138	191952P	Portugal	12.40	0.36	2.93	2.87
139	192036P	Portugal	11.20	0.33	3.02	2.89
140	192606P	Portugal	12.00	0.34	2.84	2.75
141	192711P	Portugal	12.60	0.37	2.98	2.93
142	192741P	Portugal	11.10	0.34	3.07	2.93
143	262656P	Russia	00.00	0.00	0.00	0.00
144	297837P	Ethiopia	14.30	0.41	2.88	2.93
145	297849P	Ethiopia	14.90	0.44	2.98	3.05
146	191400P	Spain	11.30	0.34	3.07	2.95
147	192516P	Portugal	11.30	0.33	2.98	2.85
148	194034P	Ethiopia	15.10	0.43	2.88	2.97
149	195728P	Ethiopia	15.80	0.44	2.84	2.96
150	199995P	Ethiopia	13.90	0.40	2.93	2.95
151	204021P	Portugal	11.90	0.36	3.07	2.98
152	204040P	Portugal	11.30	0.33	2.93	2.81
153	204054P	Portugal	11.70	0.35	3.07	2.97
154	274003P	Ethiopia	16.30	0.44	2.75	2.90
155	8000	Ethiopia	14.00	0.41	2.93	2.96
156	191370P	Italy	13.50	0.38	2.84	2.84
157	191471P	Italy	11.90	0.35	2.98	2.89
158	191616P	Portugal	11.80	0.34	2.93	2.84
159	191635P	Portugal	11.80	0.35	3.02	2.93
160	191805P	Portugal	12.00	0.35	2.93	2.85

Table A11. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
161	191955P	Portugal	15.00	0.44	2.93	3.01
162	192505P	Portugal	12.40	0.36	2.93	2.87
163	196087P	Ethiopia	18.90	0.51	2.70	2.99
164	196095P	Ethiopia	19.90	0.53	2.70	3.05
165	204043P	Portugal	11.90	0.36	3.02	2.93
166	177964P	Turkey	12.60	0.36	2.93	2.88
167	185723P	Portugal	10.00	0.33	3.30	3.10
168	191812P	Portugal	12.60	0.36	2.93	2.88
169	191816P	Portugal	12.40	0.36	2.98	2.91
170	192609P	Portugal	11.40	0.35	3.11	3.00
171	193890P	Ethiopia	15.80	0.44	2.79	2.92
172	195696P	Ethiopia	15.10	0.46	3.07	3.15
173	195726P	Ethiopia	14.50	0.41	2.88	2.94
174	254012P	Unknown	11.60	0.35	3.07	2.96
175	185412P	Portugal	14.20	0.39	2.75	2.78
176	185734P	Portugal	12.90	0.36	2.79	2.76
177	191788P	Portugal	12.10	0.36	2.98	2.90
178	192168P	Portugal	12.80	0.37	2.93	2.89
179	195705P	Ethiopia	13.00	0.36	2.84	2.81
180	196906P	Ethiopia	14.20	0.39	2.79	2.83
181	297852P	Ethiopia	16.90	0.45	2.70	2.89
182	185726P	Portugal	13.80	0.37	2.70	2.72
183	185721P	Portugal	12.90	0.36	2.79	2.76
184	177950P	Turkey	12.70	0.35	2.79	2.75
185	7150	Russia	12.60	0.33	2.65	2.60
186	195719P	Ethiopia	15.30	0.44	2.88	2.98
187	191941P	Portugal	11.90	0.34	2.88	2.80

Table A11. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
188	191988P	Portugal	12.40	0.34	2.75	2.68
189	196090P	Ethiopia	13.90	0.39	2.84	2.86
190	265007P	Yugoslavia	00.00	0.00	0.00	0.00
191	274681P	Poland	13.50	0.36	2.70	2.70
192	191640P	Portugal	15.60	0.41	2.65	2.77
193	192510P	Portugal	13.70	0.37	2.75	2.76
194	264951P	Italy	14.20	0.38	2.70	2.74
195	192504P	Portugal	14.60	0.38	2.61	2.67
196	192734P	Portugal	13.40	0.37	2.79	2.79
197	150380P	Tunisia	13.30	0.37	2.79	2.78
198	185191P	Portugal	12.50	0.35	2.84	2.78
199	Ward	U.S.A.	00.00	0.00	0.00	0.00
200	Leeds	U.S.A.	00.00	0.00	0.00	0.00

[1/] Dry weight basis.

[2/] Adjusted to 13.5% protein using curvilinear equation.

Table A12. Protein and lysine values for 200 durum wheats grown at Fort Collins, Colorado, U.S.A. in 1973.

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
1	7528	Egypt	12.80	0.36	2.84	2.80
2	192086P	Portugal	14.50	0.41	2.84	2.89
3	192129P	Portugal	15.90	0.43	2.75	2.88
4	192618P	Portugal	13.00	0.37	2.88	2.86
5	268456P	Afghanistan	12.50	0.36	2.93	2.87
6	6880	Tunisia	12.80	0.37	2.93	2.89
7	265005P	Yugoslavia	12.30	0.36	2.98	2.91
8	192119P	Portugal	13.00	0.39	3.02	2.99
9	137744P	Iran	10.80	0.34	3.21	3.06
10	195089P	Ethiopia	14.30	0.41	2.93	2.97
11	220129P	Afghanistan	12.50	0.37	2.98	2.92
12	3068	Ethiopia	15.40	0.43	2.79	2.89
13	297838P	Ethiopia	16.40	0.45	2.79	2.95
14	8066	Ethiopia	16.70	0.46	2.79	2.97
15	193867P	Ethiopia	16.60	0.47	2.84	3.01
16	7293	Egypt	16.70	0.45	2.70	2.87
17	192120P	Portugal	15.70	0.43	2.75	2.87
18	196907P	Ethiopia	16.60	0.47	2.84	3.01
19	195059P	Ethiopia	14.90	0.43	2.93	3.01
20	7325	India	15.60	0.42	2.70	2.81
21	7517	Egypt	16.10	0.45	2.79	2.93
22	192107P	Portugal	17.70	0.46	2.61	2.84
23	7796	Ethiopia	18.60	0.49	2.65	2.93
24	8123	Ethiopia	16.20	0.46	2.84	2.98
25	4561	India	15.20	0.41	2.75	2.84

Table A12. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
26	193887P	Ethiopia	18.20	0.48	2.65	2.91
27	8635	Ethiopia	15.20	0.43	2.88	2.98
28	191827P	Portugal	15.40	0.42	2.75	2.85
29	3150	Tunisia	15.20	0.41	2.75	2.84
30	7506	Egypt	14.70	0.42	2.88	2.95
31	7267	Egypt	13.70	0.38	2.79	2.80
32	193888P	Ethiopia	15.00	0.43	2.88	2.96
33	195081P	Ethiopia	16.60	0.46	2.79	2.96
34	191850P	Portugal	13.50	0.40	2.98	2.97
35	191982P	Portugal	13.30	0.39	2.93	2.92
36	192201P	Portugal	16.60	0.44	2.70	2.87
37	192442P	Portugal	14.80	0.41	2.79	2.86
38	212835P	Iran	10.70	0.29	2.75	2.59
39	195095P	Ethiopia	17.60	0.47	2.70	2.92
40	195717P	Ethiopia	20.90	0.55	2.65	3.06
41	191836P	Portugal	16.00	0.44	2.79	2.93
42	7523	Egypt	14.90	0.43	2.88	2.96
43	192197P	Portugal	16.30	0.45	2.79	2.94
44	192620P	Portugal	20.00	0.50	2.52	2.87
45	195099P	Ethiopia	17.90	0.50	2.84	3.08
46	191848P	Portugal	17.10	0.46	2.70	2.90
47	194037P	Ethiopia	19.80	0.53	2.70	3.04
48	191127P	Spain	16.90	0.50	2.98	3.16
49	220689P	Afghanistan	00.00	0.00	0.00	0.00
50	191145P	Spain	15.90	0.43	2.75	2.88
51	166854P	Turkey	15.20	0.43	2.84	2.93
52	191632P	Portugal	18.10	0.51	2.84	3.09

Table A12. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
53	193871P	Ethiopia	20.20	0.53	2.65	3.02
54	195096P	Ethiopia	16.90	0.50	2.98	3.16
55	195724P	Ethiopia	20.60	0.55	2.70	3.09
56	194031P	Ethiopia	18.60	0.50	2.70	2.98
57	272537P	Hungary	14.60	0.39	2.70	2.76
58	193862P	Ethiopia	15.50	0.43	2.79	2.90
59	193869P	Ethiopia	18.60	0.52	2.79	3.07
60	8161	Peru	13.10	0.35	2.70	2.68
61	151205P	Ethiopia	17.50	0.45	2.61	2.83
62	191970P	Portugal	16.40	0.47	2.88	3.04
63	192006P	Portugal	15.10	0.43	2.88	2.97
64	185300P	Argentina	16.50	0.45	2.75	2.91
65	191819P	Portugal	16.30	0.47	2.93	3.08
66	194830P	Ethiopia	17.10	0.46	2.70	2.90
67	195711P	Ethiopia	17.00	0.45	2.70	2.89
68	196091P	Ethiopia	16.50	0.43	2.65	2.82
69	210911P	Pakistan	13.50	0.38	2.84	2.84
70	7855	Ethiopia	16.00	0.43	2.70	2.84
71	196097P	Ethiopia	18.50	0.50	2.70	2.97
72	113396P	Egypt	14.50	0.42	2.93	2.98
73	134930P	Portugal	15.00	0.43	2.88	2.96
74	177951P	Turkey	14.30	0.40	2.79	2.83
75	184537P	Portugal	14.50	0.41	2.88	2.94
76	191239P	Spain	14.00	0.41	2.93	2.96
77	195710P	Ethiopia	16.50	0.45	2.75	2.91
78	196098P	Ethiopia	16.10	0.43	2.70	2.84
79	196102P	Ethiopia	14.10	0.40	2.84	2.87

Table A12. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
80	165113P	Turkey	13.60	0.39	2.93	2.93
81	185753P	Portugal	13.90	0.40	2.88	2.90
82	192743P	Portugal	12.80	0.37	2.93	2.89
83	192839P	Portugal	14.20	0.40	2.84	2.88
84	166838P	Turkey	13.90	0.38	2.79	2.81
85	7778	Ethiopia	15.30	0.41	2.70	2.80
86	8455	U.A.R.	12.30	0.37	3.02	2.95
87	145720P	Arabia	13.20	0.38	2.93	2.91
88	196089P	Ethiopia	13.30	0.39	2.98	2.96
89	196103P	Ethiopia	15.50	0.42	2.75	2.85
90	196908P	Ethiopia	15.30	0.42	2.75	2.84
91	220426P	Egypt	13.30	0.38	2.88	2.87
92	225310P	Iran	14.30	0.40	2.79	2.83
93	191182P	Spain	15.30	0.43	2.84	2.94
94	192683P	Portugal	18.40	0.51	2.79	3.06
95	234861P	Ethiopia	18.90	0.52	2.75	3.04
96	273997P	Ethiopia	18.70	0.50	2.70	2.98
97	7770	Ethiopia	12.50	0.38	3.07	3.01
98	113398P	Egypt	16.30	0.46	2.84	2.99
99	196092P	Ethiopia	17.50	0.48	2.75	2.96
100	244342P	Ethiopia	17.20	0.48	2.79	2.99
101	119326P	Turkey	14.90	0.41	2.79	2.87
102	191412P	Morocco	14.10	0.40	2.88	2.92
103	191971P	Portugal	14.40	0.40	2.84	2.89
104	192461P	Portugal	15.00	0.41	2.75	2.83
105	192742P	Portugal	14.90	0.42	2.84	2.91
106	195100P	Ethiopia	16.50	0.46	2.79	2.96

Table A12. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
107	195106P	Ethiopia	15.60	0.42	2.70	2.81
108	195698P	Ethiopia	18.10	0.48	2.65	2.90
109	273996P	Ethiopia	17.80	0.49	2.79	3.03
110	7234	Russia	12.30	0.35	2.88	2.82
111	7239	Russia	11.30	0.34	3.02	2.90
112	165119P	Turkey	13.80	0.39	2.88	2.90
113	166837P	Turkey	12.20	0.35	2.88	2.81
114	191629P	Portugal	13.90	0.39	2.84	2.86
115	196096P	Ethiopia	14.90	0.42	2.84	2.91
116	204015P	Portugal	13.90	0.40	2.93	2.95
117	226573P	Ethiopia	16.90	0.45	2.70	2.89
118	195701P	Ethiopia	17.60	0.48	2.75	2.97
119	297841P	Ethiopia	15.90	0.45	2.84	2.97
120	194028P	Ethiopia	17.20	0.46	2.70	2.90
121	194035P	Ethiopia	13.90	0.40	2.93	2.95
122	195729P	Ethiopia	15.00	0.41	2.75	2.83
123	196093P	Ethiopia	16.30	0.44	2.70	2.85
124	166977P	Turkey	14.90	0.41	2.79	2.87
125	191010P	Spain	14.70	0.41	2.84	2.90
126	191958P	Portugal	13.10	0.39	2.98	2.95
127	192019P	Portugal	12.70	0.37	2.98	2.93
128	192841P	Portugal	13.30	0.39	2.93	2.92
129	210946P	Cyprus	13.50	0.40	2.98	2.97
130	7235	Russia	13.20	0.37	2.84	2.82
131	8493	Russia	12.60	0.34	2.75	2.70
132	094733P	Ethiopia	14.20	0.41	2.88	2.92
133	191021P	Spain	12.10	0.36	2.98	2.90

Table A12. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
134	191087P	Spain	15.00	0.41	2.79	2.87
135	191089P	Spain	14.30	0.41	2.88	2.93
136	191186P	Spain	14.10	0.40	2.84	2.87
137	191832P	Portugal	14.30	0.40	2.84	2.88
138	191952P	Portugal	13.60	0.39	2.88	2.89
139	192036P	Portugal	15.30	0.41	2.70	2.80
140	192606P	Portugal	13.40	0.38	2.88	2.88
141	192711P	Portugal	13.80	0.39	2.84	2.85
142	192741P	Portugal	13.70	0.37	2.75	2.76
143	262656P	Russia	00.00	0.00	0.00	0.00
144	297837P	Ethiopia	16.70	0.45	2.70	2.87
145	297849P	Ethiopia	18.70	0.50	2.70	2.98
146	191400P	Spain	14.10	0.40	2.84	2.87
147	192516P	Portugal	12.40	0.36	2.93	2.87
148	194034P	Ethiopia	14.90	0.42	2.84	2.91
149	195728P	Ethiopia	14.00	0.40	2.88	2.91
150	199995P	Ethiopia	15.80	0.43	2.75	2.87
151	204021P	Portugal	15.00	0.42	2.84	2.92
152	204040P	Portugal	16.30	0.42	2.61	2.76
153	204054P	Portugal	13.20	0.39	2.98	2.96
154	274003P	Ethiopia	15.30	0.42	2.75	2.84
155	8000	Ethiopia	13.00	0.38	2.93	2.90
156	191370P	Italy	15.50	0.43	2.79	2.90
157	191471P	Italy	14.90	0.42	2.84	2.91
158	191616P	Portugal	14.60	0.41	2.84	2.90
159	191635P	Portugal	15.30	0.42	2.79	2.89
160	191805P	Portugal	13.30	0.37	2.84	2.83

Table A12. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
161	191955P	Portugal	15.80	0.45	2.88	3.01
162	192505P	Portugal	14.20	0.39	2.79	2.83
163	196087P	Ethiopia	19.30	0.49	2.56	2.88
164	196095P	Ethiopia	19.30	0.50	2.61	2.92
165	204043P	Portugal	15.10	0.41	2.75	2.83
166	177964P	Turkey	15.10	0.42	2.84	2.92
167	185723P	Portugal	15.90	0.43	2.70	2.83
168	191812P	Portugal	16.50	0.43	2.65	2.82
169	191816P	Portugal	16.80	0.46	2.75	2.93
170	192609P	Portugal	15.60	0.45	2.88	3.00
171	193890P	Ethiopia	16.70	0.45	2.70	2.87
172	195696P	Ethiopia	15.80	0.45	2.88	3.01
173	195726P	Ethiopia	17.30	0.46	2.70	2.91
174	254012P	Unknown	13.70	0.38	2.84	2.85
175	185412P	Portugal	15.60	0.45	2.93	3.04
176	185734P	Portugal	16.20	0.46	2.84	2.98
177	191788P	Portugal	15.30	0.44	2.88	2.98
178	192168P	Portugal	18.00	0.47	2.65	2.90
179	195705P	Ethiopia	17.80	0.48	2.75	2.98
180	196906P	Ethiopia	20.00	0.52	2.61	2.96
181	297852P	Ethiopia	21.00	0.55	2.65	3.06
182	185726P	Portugal	13.30	0.34	2.61	2.60
183	185721P	Portugal	12.80	0.37	2.93	2.89
184	177950P	Turkey	13.60	0.38	2.79	2.80
185	7150	Russia	14.00	0.40	2.88	2.91
186	195719P	Ethiopia	16.60	0.44	2.70	2.87
187	191941P	Portugal	14.10	0.40	2.84	2.87

Table A12. (Continued)

No.	C.I. or P.I. No.	Source	% Protein[1/]	% Lysine	Lysine/protein	Adjusted lysine/protein[2/]
188	191988P	Portugal	16.20	0.43	2.70	2.85
189	196090P	Ethiopia	15.50	0.44	2.84	2.95
190	265007P	Yugoslavia	11.90	0.34	2.93	2.84
191	274681P	Poland	15.90	0.43	2.75	2.88
192	191640P	Portugal	15.60	0.42	2.75	2.86
193	192510P	Portugal	14.80	0.40	2.75	2.82
194	264951P	Italy	16.10	0.45	2.84	2.98
195	192504P	Portugal	17.60	0.45	2.56	2.79
196	192734P	Portugal	14.70	0.43	2.93	2.99
197	150380P	Tunisia	16.90	0.50	2.98	3.16
198	185191P	Portugal	18.20	0.44	2.42	2.68
199	Ward	U.S.A.	16.40	0.45	2.75	2.90
200	Leeds	U.S.A.	16.80	0.45	2.70	2.88

[1/] Dry weight basis.

[2/] Adjusted to 13.5% protein using curvilinear equation.