THE NUTRITIVE VALUE OF SPELT (TRITICUM SATIVUM SPELTA) FOR DAIRY CATTLE

By

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AN ABSTRACT

Submitted to the College of Agriculture
Michigan State University of Agriculture and Applied Science
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Dairy

1959

Approved C. F. Huffman

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Pertinent literature concerning the distribution, yield, proximate composition, and nutritive value of the grains commonly known as spelt (*Triticum sativum spelta*) and emmer (*Triticum sativum dicoccum*) has been reviewed. Compared with other cereals neither of these crops is of great quantitative importance, except in certain areas, and on individual farms. Throughout the United States as a whole, emmer is grown to a greater extent than spelt, but the latter may be produced in larger amounts in parts of Michigan than is generally realized. Reliable data on the composition and nutritive value of both grains is scanty and, for spelt in particular, is negligible. The present study was designed to provide data that might be useful in formulating dairy rations containing spelt.

Ten samples of spelt were received from three elevator companies, after writing to twenty-two companies requesting samples for analysis. Analytical results showed that spelt, as normally fed, has a composition very similar to that of oats and may be expected to have a similar feeding value. A digestibility trial, designed to measure digestibility coefficients directly and not by difference, also showed that the T.D.N. value of spelt approximates to the values usually quoted for oats. Further evidence for the equivalence in nutritive value of oats and spelt was obtained from a feeding trial in which spelt was evaluated against oats and corn as a growth supplement for dairy heifers. The spelt and oats groups produced the same average liveweight gains, which were significantly lower than the average gain of the corn group.

It was concluded that spelt may be substituted for oats on a weight for weight basis in dairy cattle rations. Spelt, ground to a modulus of 3.33, has a T.D.N. value for dairy cows of 74 on a dry matter basis and 65-67 as fed. The digestible crude protein content of spelt was found to be 8.4% on a dry matter basis and 7.5% as fed.

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ACKNOWLEDGEMENTS

The writer wishes to express his sincere thanks to Dr. C. F. Huffman, Research Professor of Dairy, for his constant guidance and expert advice so generously given at all times, to Dr. Charles Lassiter, Associate Professor of Dairy, for making arrangements to conduct the experiments, to Dr. Roy Emery, Assistant Professor of Dairy, for his stimulating arguments and critical reading of the manuscript, to Mr. J. P. Everett, M. S., Graduate Assistant in Dairy, for statistical assistance, and to his wife Margaret Morgan, N. D. D., for technical assistance at certain stages of the investigation.

Grateful acknowledgement is also made of the help given by Ed Smiley and his staff at the Dairy Barns in the preparation of feeds and weighing of cattle.

The writer is also indebted to the W. K. Kellogg Foundation for the generous award of a Fellowship that permitted a year's study in the U.S.A., during which time this work was undertaken, and to the British Ministry of Agriculture, Fisheries, and Food for the necessary year's leave of absence.

LIST OF TABLES

Table		Page
1	Yields of Grains in Pounds per Acre from Various Areas	10
2	Comparative Yields of Spelt, Wheat, and Oats in Pounds Per Acre from Cass and St. Joseph Counties	13
3	The Proximate Chemical Composition of Triticum Spelta	35
4	The Weights and Composition of Faeces and Composition of Spelt	41
5	Details of Cattle Used in the 3 Trial Groups	46
6	Requirements for Growing Heifers and Nutrients Supplied by Various Rations . . .	48
7	Weights of Hay Offered and Consumed per Heifer and the Average Daily Intake of Grain, and Hay per 100 lb. of Body Live-weight (lb.)	52
8	Liveweights and Liveweight Gains of all Animals in the Trial (lb.)	54
9	Analysis of Variance of Total Liveweight Gains for the 90-day Feeding Trial	55
10	T.D.N. Recommended and Consumed, and Expected Daily Gain (lb.)	59

TABLE OF CONTENTS

	Page
INTRODUCTION	1
REVIEW OF LITERATURE	3
General Data	3
Yield Data	7
Chemical Composition and Digestibility of Spelt and/or Emmer	14
Feeding Experiments with Emmer and/or Spelt . .	23
Summary	32
THE PROXIMATE COMPOSITION AND DIGESTIBILITY OF TRITICUM SPELTA	34
Proximate Composition	34
Apparent Digestibility of Proximate Constituents of Spelt	36
Results	40
THE RELATIVE VALUES OF SPELT, CORN, AND OATS FED WITH HAY AS GROWTH SUPPLEMENTS FOR DAIRY HEIFERS	45
Experimental Procedure	45
Results	51
DISCUSSION	56
SUMMARY AND CONCLUSION	60
LITERATURE CITED	61

INTRODUCTION

Throughout the world the more efficient livestock producers utilize a system of rationing farm animals such as that typified by the Total Digestible Nutrient System or the Starch Equivalent System. In spite of their shortcomings, these systems permit a more efficient utilization of available foods for livestock. The application of these systems has been made possible through the accumulation of considerable amounts of data on the chemical composition and digestibility coefficients of the more important feeds under a wide range of conditions and with various animals. Such data have been collected and summarized by authorities like Morrison (1956) or Schneider (1947) for T.D.N. values, or like Woodman (1957) for the Starch Equivalent System.

These data are reasonably complete for the more usual cereal grains--wheat, barley, oats, rye, and corn. Cereal production, however, is not confined to these and in some areas of the world other grains such as spelt-wheat (*Triticum sativum spelta*) are important. For many of these grains there is a lack of good data concerning their chemical composition, digestibility, and performance in feeding trials. Spelt is a grain typical of this group.

The studies that embody the major portion of this dissertation were carried out to provide data for the nutritive value of spelt that would be useful in the formulation of rations for dairy cattle and, it is hoped, help to make good the deficiency of information at least to some extent.

REVIEW OF LITERATURE

The grains _Triticum sativum spelta_ and _Triticum sativum dicoccum_ are commonly known as "spelt" and "emmer," respectively. Both of these are referred to by farmers and merchants as "speltz," which implies that they are the same, whereas they are distinct types of wheat. Martin and Leighty (1924) suggested that the term "speltz" should be discarded. Although the words "spelt" and "emmer" are used in an interchangeable manner according to Morrison (1956) very little "spelt" as such is grown in the United States; and Champlin and Morrison (1918) state that what is normally referred to as "spelt" or "speltz" is in fact "emmer." Hummel (1906) also states that "spelt" is often confused with "emmer." Spelt and emmer are distinguished from other wheats by the fact that most of the kernels are not removed from the chaff or glumes during threshing. Externally, they resemble barley, but differ in that each hull has two kernels in place of the one of barley.

Martin and Leighty (1924) have summarized the evidence proving that emmer and spelt are different species of wheat. Thus the somatie cells of emmer contain 28 chromosomes whilst spelt contain 42. Also, in the United

States spelt is better adapted to humid regions, and is comparable to soft red winter wheat in that respect. Emmer is more suited to regions of low rainfall, being similar, therefore, to hard red winter wheat. Emmer is characterized by pithy culms and pubescent leaves as opposed to the hollow culms and glabrous leaves of spelt. Emmer is distinguished from spelt by its compact spikes and by the short narrow pedicel that is attached to the base of the spikelets of the threshed grain.

Emmer has been known and apparently cultivated for a very long period. Martin and Leighty (1924) cite evidence that it has been found among the ruins of lake dwellers in Switzerland. Snyder (1904) has reported receiving from Egypt a sample of emmer kernels that were identical with the kernels of emmer grown in Minnesota. This sample was obtained from the interior ruins of an Egyptian pyramid built some 3,750 years ago. According to Martin and Leighty (1924) emmer was also grown by the Romans, and that wild emmer, (*Triticum dicoccum dicoccoides*), found on the slopes of Mount Hermon in Syria may have been the prototype of cultivated varieties of emmer. The crop was introduced, so it seems, into the United States by "German immigrants from South Russia" who settled in the Dakotas; Carleton (1911) believes it was known to northwestern farmers as early as 1875-1880.

Spelt appears to be of much later origin than emmer, but it has been grown in Europe for some 250 years. Martin and Leighty (1926) stated that it was introduced into the United States during the 1890's, was grown experimentally in California as early as 1893, and later was introduced by the United States Department of Agriculture from Germany.

Up to the 1920's at least, the production of both grains in Europe appeared to be restricted to Central and Eastern Europe on land too poor for normal wheat crops, and emmer assumed greatest importance in regions of low rainfall. Statistics concerning the crops are restricted to both crops together, but it seems that emmer was the dominant crop where these statistics are available. Martin and Leighty (1924) concluded that the acreage of both spelt and emmer was decreasing in all countries and they were being replaced by other cereal crops. The total production of both crops in the United States in 1909 was 573,622 acres with an estimated yield of 12,702,710 bushells. By 1919 this acreage had fallen to 166,829 acres with a yield of 2,607,868 bushells. (The bushell was assumed to be 40 pounds by these writers.) In a more recent publication Martin and Leighty (1938) report a total acreage of 344,000 acres of both crops but state that most of this was emmer and that only a few hundred acres of spelt are grown, mainly in the eastern half of the United States. In all years South and North Dakota were responsible for over 70% of the total acreage of these crops, whilst the acreage contribution by Michigan was little more than 1% at 6,742 and 2,674 acres in 1909 and 1919, respectively. The 1929 figures show only 200 acres of emmer in Michigan and Martin and Leighty (1938) gave no data for spelt for this year for Michigan.

Brown (1942) has summarized the position concerning spelt in Michigan. He states that in the "Thumb"-area of Michigan "speltz" means spring sown emmer, which will winter kill if fall sown, while in southwestern Michigan "speltz" means fall sown spelt which will not produce a crop of grain when spring sown. So far as the place of spelt in the economy of Michigan farms is concerned, Brown (1942) states that it is grown as a feed crop and seldom moves far from the farm where it is grown. Further, he states that the acreage devoted to this crop is largely governed by the regulations for payment under the Agricultural Adjustment Administration, and because of acreage limits imposed on wheat production, cultivation of spelt permits the growing of another grain crop for home-farm consumption.

For these reasons statistics illustrating the quantitative importance of spelt in farm rations in Michigan are not available, but there appears to be a considerable interest in the crop and production may be greater than is generally believed.

Yield Data

The fact that crops of spelt and emmer are grown and used is sufficient justification for studying their nutritive value so that the most efficient use may be made of the crops. To what extent the growing of these grains is justified is a matter for conjecture, but clearly yield in relation to nutritive value is a matter of prime importance.

One of the difficulties that arises in assessing comparative yields is that of bushell weight. In their excellent review of experiments with emmer and spelt, Martin and Leighty (1924) state that no standard bushell weights for emmer and spelt have been established by Federal statutes in the United States. For their report a value of 32 pounds per bushell was used, but this represents the approximate weight of grain as it is obtained from the separator, most of it being still in the chaff. The United States Census Bureau used 40 pounds per bushell for reporting statistics of these grains. There are variations between states though as indicated by the following:

State	Bushell Weight (lb.)	Grain
Illinois	40	Emmer, Spelt, or Speltz
Iowa	40	Emmer, Spelt, or Speltz
Kansas	40	Emmer, Spelt, or Speltz
Minnesota	40	Spelt or Speltz
North Dakota	40	Spelt or Speltz
Pennsylvania	40	Spelt or Speltz
West Virginia	40	Spelt or Speltz
South Dakota	45	Spelt or Speltz
Nebraska	48	Emmer, Spelt, or Speltz

Other data cited by these same authors indicate values from various experimental stations ranging from 25-60 pounds per bushell. Brown (1942) reported that during a survey of spelt conducted in 1939 in Cass and St. Joseph Counties of Michigan the accepted test weight for spelt varied from 30 to 40 pounds per bushell depending upon the particular locality. He also stated that there was "a growing tendency to consider the legal test weight of oats, 32 pounds per bushell, to be the proper test weight for spelt and likewise to consider the price per bushell of oats to apply to spelt."

For these reasons comparisons of yield data between areas must be carefully considered prior to drawing conclusions, and as pointed out by Martin and Leighty (1924) yields are best quoted as pounds of threshed grain per acre.

Chilcott and Thornber (1901) reported that emmer is more drought resistant than barley or oats and yielded up to 63 bushells (2835 lb.) per acre. The most comprehensive data on yields throughout the United States though are those provided by Martin and Leighty (1924). They have summarized and discussed the average yields of the leading varieties of winter and spring emmer, spelt, barley, and oats at fifty-two experimental stations from 1901 onwards. Table 1, which the writer has abstracted from their data, provides the main results.

In area 1 barley and oats were more productive than emmer but similar to winter spelt. The figures for wheat are not given but apparently the yield of free kernels from the winter spelt was below that of winter wheat. In area 2 emmer and spelt were out yielded by barley and oats, and similar results were obtained in area 3, while winter spelt appeared to out yield spring oats in area 4.

As a general recommendation Martin and Leighty (1924) stated that winter emmer should not be grown in any part

Table 1

Yields of Grains in Pounds per Acre from Various Areas

Area	Winter Emmer	Spring Emmer	Winter Spelt	Spring Barley	Spring Oats
1. South Atlantic (Humid)	838	--	1738	1723	1449
2. Mississippi and St. Lawrence Valleys (Sub-humid)	1012	1630	1567	1845	1740
3. Great Plains (Semi-arid)	513	1474	--	1614	1662
4. Western Basin and Coast Area	1092	--	1395	1794	1348

of the United States or Canada. Spring emmer should only be grown in northern and eastern areas of South Dakota and the southern part of Minnesota for the purpose of increasing crop diversification, since on the average it is outyielded even in these states by spring barley and oats. They also concluded that although winter spelt is more productive than barley and oats in a limited portion of Maryland and Virginia, it does not produce as high net yields as winter wheat even in the best areas where it is grown. This latter point is particularly important when considering estimates of yields for emmer or spelt, because most of the kernels remain enclosed in the chaff or glumes, these latter products forming a good proportion of the total yield. Thus Saunders (1904), in describing varieties of emmer and spelt used in Canadian experiments, reported that emmer and spelt might contain 21-27% and 27-38% of hulls, respectively. Similarly Zavitz (1919) found that four varieties each of emmer and spelt grown in Ontario during twelve seasons gave an average of 19.6% of hulls in emmer and 28.0% of hulls in spring sown spelt. Determinations in the United States showed emmer and spelt to consist usually of 20-30% of hulls; because threshed emmer usually contains less hulls than spelt, when these crops are compared with wheat about 22% of emmer and 25% of spelt should be regarded as hulls (Martin and Leighty, 1924).

There is further evidence that yields of emmer are generally low. Thus the Annual Report for 1918 of the Idaho Experimental Station gives 13.3 bushells per acre for emmer, while Breithaupt (1918) from Oregon reported 15.6 bushells per acre for winter emmer compared with 18.0 bushells per acre of spring emmer and 23.4 bushells per acre of spelt. Here the bushell weight was stated as 32 pounds. Wiasko and Cromer (1919) in Indiana cited the following figures--23 bushells per acre for emmer compared with 52.6 bushells for oats, 13.7 for spring wheat, 29.2 for winter wheat and 27.8 for barley.

So far as spelt in Michigan is concerned, valuable data have been accumulated by Brown (1942) for cereal yields, obtained from farm management and farm account records for the years 1935-40. Table 2, which has been derived from Brown's (1942) data compares the yield of spelt with wheat and oats in Cass and St. Joseph Counties of Michigan.

In five of the six years, spelt was outyielded by wheat, but spelt produced more than oats in four years. In variety trials in the same areas in the years 1937-1940 Brown (1942) found that except in one year when the spelt outyielded wheat that both spelt and wheat produced about the same in pounds of grain per acre.

Table 2

Comparative Yields of Spelt, Wheat, and Oats in Pounds Per Acre from Cass and St. Joseph Counties

Year	Spelt		Wheat		Ratio of Wheat to Spelt	Oats		Ratio of Oats to Spelt
	Total Acres	Yield	Total Acres	Yield		Total Acres	Yield	
1935	200.0	1,122	362.0	1,218	1.09	172.5	940	0.84
1936	121.2	793	233.7	885	1.12	102.5	774	0.98
1937	226.5	1,463	1,463	1,294	0.88	158.5	970	0.66
1938	256.6	962	962	1,153	1.20	269.8	946	0.98
1939	425.9	747	747	1,034	1.38	274.9	995	1.33
1940	197.7	1,108	1,108	1,272	1.15	350.8	1,472	1.24

Thus so far as the Michigan data are concerned, spelt shows up more favorably than does emmer in other states, since it can certainly produce as much as wheat or oats. The justification for growing it will then depend largely upon the feeding value of the spelt compared with other cereals. No data are available for emmer in Michigan, but according to Brown (1958) and Nelson (1958) this grain is unimportant, and little, if any, is grown in the area.

Chemical Composition and Digestibility of Spelt and/or Emmer

Perhaps the most revealing fact concerning the composition of spelt and emmer is the shortage of data, particularly for spelt. In the discussion set out below, values for the proximate constituents of analysis have been expressed in percentages of the dry matter to permit ease of comparison. Also all figures from the original papers have been rounded off to the nearest place of decimals, although in many original papers two decimal places are quoted.

One of the earliest sets of analyses was that reported by Ladd (1898) who analysed whole emmer, hulled emmer, and emmer hulls and obtained the following results:

	% Dry Matter	% Crude Protein	% Crude Fibre	% Ether Extract	% Ash	% Nitrogen-free Extract
Whole Emmer	91.1	10.8	11.1	2.8	5.3	70.0
Emmer Hulls	95.4	2.9	38.5	1.7	14.1	42.2
Hulled Emmer	90.0	13.0	3.3	3.1	2.0	78.6

These figures illustrate well the effect of removal of hull in lowering the fibre content and as a consequence probably increasing the nutritional value to a level similar to wheat or barley. Another interesting point is that removal of hull lowers the ash content of the grain considerably. Ladd's (1898) figures have also been quoted by Hummel (1906) while this latter worker also gives analytical results for emmer samples from Minnesota thus:

% Dry Matter:	89.1
% Crude Protein:	11.8
% Crude Fibre:	13.8
% Ether Extract:	2.6
% Ash:	4.4
% Nitrogen-free Extract:	68.1

Other early figures were provided by Shepherd, Saunders and Knox (1901) for the proximate constituents of whole grain, husk plus grain, and husk of speltz (presumably emmer) samples. The figures obtained were:

	% Dry Matter	% Crude Protein	% Crude Fibre	% Ether Extract	% Ash	% Nitrogen-free Extract
Husk & Grain	89.8	12.9	12.8	2.8	3.3	68.2
Husk	91.9	2.6	42.5	1.6	8.1	45.2
Grain	89.4	16.3	2.5	3.1	1.6	76.5

These are the same figures as those quoted by Chilcott and Thornber (1901) and also by Wilson and Skinner (1903). The effect of removal of hulls is again evident, but the ash content of the husk was lower in this second example. According to Shepherd *et al*. (1901) only three analyses were made.

Knight, Hepner, and Nelson (1908) analysed emmer as pure grain and also in slight admixture with oats and wheat. (Knight, Hepner, and Nelson, 1911). The 1911 results are also those quoted by Faville (1910) for emmer used in his feeding trials. An unspecified number of analyses were conducted but the results obtained were as follows:

	1908	1910
% Dry Matter:	91.2	91.8
% Crude Protein:	10.4	10.1
% Crude Fibre:	7.9	11.0
% Ether Extract:	2.7	3.1
% Ash	3.4	4.0
% Nitrogen-free Extract:	75.6	71.8

Further data have been reported by Shepherd and Koch (1909) for speltz, which again was probably emmer, used in their digestibility studies, thus:

% Dry Matter:	91.3
% Crude Protein:	12.4

% Crude Fibre:	9.6
% Ether Extract:	2.4
% Ash:	3.5
% Nitrogen-free Extract:	72.1

Chamberlain (1909) carried out what appears to be the most extensive series of analyses on emmer. This included 24 samples of United States grown emmer and 1 sample of foreign black emmer, with the following average results:

	24 Samples	Foreign Sample
% Dry Matter	91.3	91.1
% Crude Protein	13.3	12.0
% Crude Fibre	11.3	10.7
% Ether Extract	1.9	1.5
% Ash	4.1	3.9
% Nitrogen-free Extract	69.4	71.9

There is little published data for the chemical composition of emmer since these early reports, with the one exception of the report of Christenson and Hopper (1936), who gave one set of analyses. Their results were:

% Dry Matter:	87.2
% Crude Protein:	18.0
% Crude Fibre:	10.3
% Ether Extract:	2.1
% Ash	4.1
% Nitrogen-free Extract:	65.5

Data for spelt are fewer than for emmer. Goodwin (1926) cites Kellner's data for spelt wheat both with and without husk. These figures together with those for moisture, crude protein, and crude fibre of spelt provided by Freeman (1939) are as follows:

	Goodwin		Freeman
	With Husk	Without Husk	
% Dry Matter	86.3	86.2	88.2
% Crude Protein	12.7	16.1	11.7
% Crude Fibre	17.9	3.0	12.9
% Ether Extract	1.6	2.1	--
% Ash	2.7	2.1	--
% Nitrogen-free Extract	65.2	76.7	--

The effect of husk removal in improving composition is again obvious, but it will be noticed that the effect on ash content in this case was practically negligible.

Morrison (1956) has summarized the composition of emmer for 42 samples. Presumably most or all of the figures given above have been included in his average values, although the writer has been unable to find a total of 42 analyses. The average values given by Morrison are:

% Dry Matter	91.1
% Crude Protein	13.3
% Crude Fibre	10.7
% Ether Extract	2.1

% Ash	4.1
% Nitrogen-free Extract	69.8

The total number of samples of spelt analysed for the figures cited by Goodwin (1926) is not known, but if considerable there appears to be little difference between emmer and spelt except perhaps for a slightly higher protein content and slightly lower fibre content in the former. Both grains have a composition similar to that of oats and Morrison's (1956) conclusions were that "both emmer and spelt resemble oats in composition and when a large proportion of hulls is removed in threshing, emmer will resemble barley more than oats in composition." It may be added here that Morrison does not quote any figures for spelt as such, and he possibly has incorporated data for spelt into the average values he gives for emmer.

Digestibility coefficients for the proximate principles of emmer are quoted by Morrison (1956) who uses the same values as those cited by Schneider (1947). These values are:

Constituent	Digestibility Coefficient
Organic Matter	81
Crude Protein	80
Crude Fibre	29
Nitrogen-free Extract	88
Ether Extract	87

These values were obtained from three original sources and are the only original references to digestibility trials with either emmer or spelt that are available. Each of these trials is discussed in more detail below.

Hummel (1906) carried out digestion trials using 2 sheep for 4 days and compared the following feeds:

(1) 4 lb. of alfalfa plus 6-7 lb. of unground emmer

(2) 3 lb. of alfalfa plus 6-7 lb. of ground emmer

(3) 8.5-9 lb. of alfalfa alone.

He concluded from his results that a ration of alfalfa hay and emmer has a high digestibility especially of protein and carbohydrates. Grinding of emmer appeared to increase the digestibility of the protein, ether extract, and fibre but when the crude fibre and nitrogen-free extract were considered jointly as carbohydrate there was no difference between ground and unground emmer. Hummel calculated the following average digestion coefficients for the constituents of emmer.

Constituent	Digestibility Coefficient*
Dry Matter	94
Crude Protein	87

*These values have been rounded off to the nearest whole number. Hummel quotes them to the second place of decimals.

Constituent	Digestibility Coefficient
Ether Extract	92
Crude Fibre	84
Carbohydrates	97

All constituents were shown to have a high apparent digestibility and the high value for crude fibre is particularly noticeable.

Shepherd and Koch (1909) conducted a similar trial using 2 sheep but they do not state the collection periods. They used brome hay as the accompanying roughage in an initial trial and followed this by two further trials in which oat straw and alfalfa were used as roughage sources. Their calculated digestion coefficients together with the overall average for the digestion coefficients for the constituents of emmer when fed with various roughages are as follows:

Accompanying Roughage	Crude Protein	Crude Fibre	Ether Extract	Nitrogen-free Extract
Brome Hay	84	51	94	93
Alfalfa Hay	80	50	90	89
Oat Straw	73	--	81	83
Average	79	50	88	88

These authors state that difficulty was experienced with the crude fibre determinations and no values are given for the trial with oat straw because of this.

Christenson and Hopper (1936) estimated the digestibility of emmer using alfalfa hay as the accompanying roughage. These were better trials since twelve wether lambs were used as experimental animals with 10-day collection periods. The average digestibility coefficients reported by them are as follows:

Constituent	Digestibility Coefficient
Dry Matter	76
Organic Matter	77
Crude Protein	79
Crude Fibre	34
Ether Extract	81
Nitrogen-free Extract	83

These values are lower than those of the other workers particularly with regard to the crude fibre figure. With the exception of the crude fibre value, Schneider's figures are averages of the foregoing results, but he quotes a digestion coefficient of 29 for crude fibre and it is not known how this value was obtained. Because of the very short collection period of 4 days used by Hummel (1906), it is difficult to justify the inclusion of his results into the average calculation, and use of Christenson and Hopper's (1936) values would appear to be the best.

The content of digestible nutrients in emmer have also been calculated by Chamberlain (1909) using digestibility coefficients obtained with steers by Kellner (1905). Kellner's values were:

Constituent	Digestibility Coefficient
Crude Protein	75
Crude Fibre	44
Ether Extract	71
Nitrogen-free Extract	75

These values have also been used for the calculation of the digestible nutrients in spelt wheat in Goodwin's (1926) translation of Kellner's book, "Scientific Feeding of Farm Animals." Thus it seems that Chamberlain (1909) used for emmer digestion coefficients obtained with spelt.

Feeding Experiments with Emmer and/or Spelt

Here again there is a paucity of worthwhile information. Most of the work that has been carried out was conducted in the early part of the century in South Dakota. This perhaps was to be expected in view of the prominence of emmer in the area compared with other areas. The results for various feeding trials are discussed below in relation to the type of stock with which the trials were conducted. It is difficult to assess the full value of the trials for modern conditions especially since little attention was paid to mineral supplementation in the rations used.

Sheep. Chilcott and Thornber (1901) compared the relative food values of speltz (emmer) and barley as single grain rations for fattening sheep. They gave feeder lambs free access to brome grass hay and fed equal quantities of speltz or barley. The lambs averaged 83.4 lb. liveweight at the start and the speltz-fed group gained a total of 25.0 lb. in 105 days compared with a gain of 37.9 lb. in the barley group. The average weekly rate of gain and grain conversion ratio was 1.67 lb. and 7.47 for the speltz group, and 2.53 and 5.09 for the barley group. The authors concluded that speltz was worth two thirds as much per bushell as barley for feeding to fattening lambs.

Emmer was also used by Buffum and Griffith (1902) in lamb-feeding trials. Groups of five lambs were given *ad lib* allowances of alfalfa hay and a gradually increasing amount of corn, wheat, barley, or emmer up to a maximum allowance of 1½ lb. of grain daily. Other groups were given wheat and emmer, or wheat and barley in equal amounts in place of a single grain. The results showed up very favorably towards emmer since the authors concluded that the conversion rate for the hay plus emmer group was as good as for the hay plus corn group. The poorest gains were made by the group receiving equal parts of wheat and emmer. These workers suggested that emmer has a feeding value at least equal to corn.

Contrasting with these results are those of Wilson and Skinner (1903) who compared the feeding value of whole and ground speltz against other cereals. They used 9 lambs per treatment averaging 79 lb. and 112 lb. at the start and finish of the experiment. Ground speltz gave a poorer conversion ratio than whole speltz--8.3 compared with 7.2 and both of these were inferior to the conversion ratios of wheat (5.8), corn (5.3), macaroni wheat (6.5), corn and bran (6.2), and macaroni wheat and bran (6.3).

Wilson and Skinner (1904) repeated this type of trial and fed speltz, macaroni wheat, bread wheat, corn, oats, barley, millett, corn and speltz, and macaroni wheat and speltz in equal quantities to supplement an *ad lib* allowance of hay. They found that speltz had to be fed at 1-2 lb. more than other grains to produce one pound of liveweight gain. Mixtures of equal parts of corn and speltz, and barley and speltz produced better results than speltz fed alone, and the results were better than would be expected from the relative amounts of each grain present, suggesting that speltz is best mixed with other grains for lamb feeding.

Other work with lambs was carried out by Faville (1909). He compared the relative values for lamb fattening from 60 lb. liveweight of rations of alfalfa hay plus corn, barley, or emmer. He found that the alfalfa plus emmer group did not do as well as the other two groups which were about equal, and estimated that 27% less alfalfa and 28% less grain was required when barley replaced emmer in the ration. In a later experiment, Faville (1910) found emmer and barley gave very similar results but considered this was due to the poor sample of barley used that year.

More recently Hackedorn, Sotola and Singleton (1931) showed that alfalfa hay and Dakota grown speltz was not as good a feed for lambs as locally grown (Washington) corn. They calculated that the following quantities of cereals were required per pound of liveweight gain in lambs: speltz (emmer), 4.0; wheat, 3.7; barley, 3.9; Eastern corn, 3.2; locally grown corn, 3.0; and oats, 3.9. Lambs fed wheat, barley, and oats were all valued equally at market but the speltz fed group was rated 5% lower.

Beef Cattle. Wilson and Skinner (1906) compared the feeding values of emmer, oats, millet, and corn in rations for beef calves, yearlings at pasture, and for fattening bullocks. They claimed from their results that oats were the best of these grains for calves but were little different from maize since approximately equal quantities of each were required per pound of liveweight gain. When yearlings were at grass, emmer proved to be superior to other grains requiring 5.2 lb. of emmer compared with 7.0 lb. of corn per pound of liveweight gain. The rate of fattening on emmer at 1.69 lb. per day was lower than the 1.84 lb. produced on corn. Cattle consuming emmer did not eat as much hay per pound of gain as did cattle receiving other grains, suggesting according to the authors that "the husk of emmer is a good substitute for hay."

These same investigators (Wilson and Skinner, 1907) also compared the value of whole and ground speltz (emmer) with corn for fattening steers. They used four treatments: (1) prairie hay plus whole speltz, (2) prairie hay plus shelled corn, (3) prairie hay plus whole speltz, and shelled corn mixed, (4) prairie hay plus ground speltz. The results showed that the pounds of grain per pound of gain varied from 4.7 for the shelled corn group to 8.8 for the ground speltz group, while the whole speltz and mixed grains gave values of 6.0 and 5.9, respectively. The consumption of ground speltz was lower than that of whole speltz, possibly because of reduced palatability. The apparently lower value of ground speltz is similar to the result found with lambs by the same workers. Wilson and Skinner (1906) calculated that 1.4 lb. of speltz (emmer) was equal to 1.0 lb. of corn for steer feeding.

Emmer was further used in an experiment by Wilson (1915) aimed at comparing the feeding value of corn or sorghum silage with various grains. He found that a daily ration of 11 lb. of corn silage, 17 lb. of emmer, and 1.7 lb. of oil meal (probably linseed) produced satisfactory liveweight gains of 2.2 lb. daily from 835 to 1,085 lb. In a second trial 17 lb. of silage, 16 lb. of emmer, and 1.7 lb. of oil meal produced a similar result. Wilson (1915) considered emmer to be the best small grain to feed with corn silage.

Dairy Cows. Experimental data on the value of emmer or spelt for dairy cows are particularly scarce. Wilson and Skinner (1901) conducted an experiment to test the feeding value of emmer, barley, and corn fed with the same kind of roughage for milk production. They estimated that 17.5 lb. of emmer were required to produce 1 lb. of butter fat compared with 15.5 lb. of corn or barley, and concluded emmer was not equal to barley or corn for milk production but was better for maintaining body weight, since cows receiving emmer gained on the average 18 lb., compared with a 9 lb. gain on barley and a 16 lb. loss on corn. There was no effect on the percentage of butter fat.

Olson (1931) conducted two feeding trials with dairy cows. In the first he fed a basic ration of alfalfa hay and corn silage together with a concentrate mixture of emmer, oats, linseed, and wheat bran. Emmer was replaced by corn or barley in the mixture for comparative purposes. In the second trial emmer was compared with barley only. Olson concluded the following points:

1. Emmer is equal to barley in feeding value.
2. There is no significant difference between emmer and barley in their ability to maintain body weight.
3. Emmer is as palatable as barley for dairy cows.
4. Emmer should be ground for dairy cows.
5. Emmer with nearly all hulls removed, as used in the trial, is to be preferred.
6. Emmer may be substituted for barley on a pound for pound basis without upsetting the nutritive value of the ration.

It should be noted here that unlike all the other experiments described, the hulls of emmer in this case were removed. Attention has already been drawn to the effect of removal of hulls on improving the composition of emmer.

Pigs. Wilson and Skinner (1907) studied the value of emmer for pork production. They found that whole emmer was superior to both ground emmer and a corn and emmer mixture, in terms of efficiency of food conversion. But it is unlikely that this trial was significant in really demonstrating that whole emmer was better than ground emmer because the pigs were allowed free access to the feed and grinding appeared to improve palatability so that consumption of the ground emmer was much greater.

A better trial was conducted by Snyder (1907). He compared the relative values of corn, emmer, and barley for fattening pigs. He used three groups of 20 pigs with an average liveweight of 80 lb. All pigs were fed ground grain and all had access to alfalfa hay. The mean daily liveweight gain was 1.02 lb., 0.77 lb., and 0.81 lb. for the corn, emmer, and barley groups, respectively, over a period of 94 days. The corresponding conversion rates were 4.70, 6.18, and 5.90, respectively. This was a fairly clear indication that for pigs emmer was inferior to both corn and barley. Similar results were obtained in a second trial conducted by Snyder (1907) in which he compared three groups of twelve pigs averaging 150 lb. liveweight on diets of corn, 50% corn and 50% emmer, and 50% corn and 50% barley, for a trial period of 43 days. The corn plus emmer group gained on the average 1.35 lb. per day compared with 1.53 lb. for the corn alone and 1.45 lb. for the corn plus barley. Snyder concluded that where emmer was to be fed to pigs it was best used mixed with corn.

More recently Freeman (1939, 1941) has studied the value of spelt for pigs, comparing it against oats. A total of 19 pigs were in 4 groups, each of which received a basal protein and mineral supplement.

		Daily Liveweight Gain (lb.)	Conversion Ratio
Group 1	50% spelt and 50% corn	1.32	4.33
Group 2	25% spelt and 75% corn	1.27	4.22
Group 3	50% oats and 50% corn	1.11	4.17
Group 4	25% oats and 75% corn	1.23	3.98

The average daily liveweight gains and conversion ratios for each group are also shown. The pigs were fattened from 54 lb. up to 190 lb. liveweight.

The author concluded that the higher rates of gain of the spelt fed groups were due to the greater palatability of those mixtures, and hence higher food consumption. Although there was little difference in food conversion rates, Freeman suggested the lower values for oats was due to a lowered food intake in the oat fed groups which averaged 20 lb. less total feed per 100 lb. of gain than the spelt fed groups. He considered that had feed been restricted the efficiency of both groups would have been about equal and concluded that spelt is approximately equal to oats for pigs.

Summary. From the foregoing discussion a number of conclusions may be drawn. Compared with emmer, spelt is comparatively unimportant as a crop throughout the United States as a whole, but it might be important in some areas such as parts of Michigan, where its potential yield approximates that of other cereal crops. Because emmer and not spelt is usually grown, most of the data concerning the composition and digestibility of these crops are confined to emmer, but the quantity of data is little. The composition and digestibility data that are available suggest that emmer and spelt are similar to oats in nutritional value, but if the hulls be removed they are similar to wheat or barley. This conclusion is generally confirmed by the limited number of feeding trials that have been conducted with all classes of stock. The majority of these have been confined to sheep and beef cattle, but these are hardly typical of modern conditions.

With the exception of two experiments, there have been no data produced for the value of these crops for dairy cattle, and the better of these two experiments used emmer from which the hulls had been removed, and thus was not typical of the way in which emmer or spelt is usually fed. Most of the experiments with pigs, while determining in a general way the inferiority of emmer or spelt to cereals other than oats, may be criticized for lack of numbers and failure to control or equalize food intake.

In view of the paucity of worthwhile information, the investigations described in this report were initiated as a preliminary study to provide fuller and more accurate data on the nutritive value of spelt for dairy cattle. Spelt and not emmer was used because of the greater interest in the former crop in Michigan. The investigation was carried in two parts:

1. The proximate composition and digestibility with dairy cows was studied.
2. The value of spelt was compared against oats and corn, as a cereal supplement for growing dairy heifers.

THE PROXIMATE COMPOSITION AND DIGESTIBILITY
OF TRITICUM SPELTA

This study was designed to produce standards for the composition and T.D.N. values of spelt that might be used as guides in the formulation of rations containing spelt. An attempt was made to collect a series of samples that would be typical of the crop by circulating a letter to twenty-two elevator companies in Michigan, explaining the purpose of the study and requesting samples of grains known as spelt, speltz, or emmer. Only ten samples were received and all of these were of spelt.

Proximate Composition

On receipt at the laboratory all samples of spelt were ground for analysis in a Wiley laboratory mill fitted with a 1 mm. hole size screen. After grinding they were allowed to attain moisture equilibrium with the surrounding atmosphere and then bottled. Crude protein, crude fibre, ether extract, and total ash contents were determined by the official A.O.A.C. methods (1955). Moisture was determined in the milled samples by drying in an electric oven at 100° C. to constant weight.

All results, for the proximate principles, given below, are expressed on a dry matter basis, to allow uniform comparison between samples. The analytical results obtained, together with the average values are given in Table 3.

Table 3

The Proximate Chemical Composition of Triticum Spelta

Sample No.	Dry Matter %	Crude Protein %	Crude Fibre %	Ether Extract %	Ash %	Nitrogen-free Extract %
1	91.3	12.8	12.6	1.7	2.7	72.2
2	92.1	11.5	11.5	1.9	3.4	71.7
3	92.3	11.4	12.7	2.2	6.2	66.5
4	91.8	14.5	9.8	1.3	2.9	71.5
5	92.2	12.6	10.6	1.9	3.5	71.4
6	92.6	13.2	9.2	2.0	3.6	74.0
7	92.5	10.6	11.0	1.9	4.5	72.0
8	92.7	10.9	11.1	2.0	3.7	74.5
9	93.2	10.3	11.2	2.1	3.6	72.8
10	92.8	11.9	11.8	1.7	4.9	69.8
Average		11.9	11.2	1.9	3.9	71.0

All the results appear to fall in the range that one might expect from the limited data quoted in the review of literature.

Apparent Digestibility of Proximate Constituents of Spelt

This investigation was carried out using a portion of the consignment of ground spelt that was also used for the growth trial reported in the next section of the thesis. This was sample 10, the composition of which is given in Table 3. The sample had been ground to a modulus of 3.33 for feeding. Three mature dry Holstein cows, Nos. 107, K213, and A77, were used for the trial which was conducted in the metabolism stalls at the Dairy Department Experimental Barn that permit automatic quantitative collection and separation of faeces and urine.

Usually digestibility studies with concentrates are carried out by the difference technique, where the digestibility of roughage plus concentrate is first determined followed by the digestibility of the roughage, and the digestibility of the concentrate is then calculated by difference. Huffman (1958, Personal Communication) frequently has observed that this method may produce abnormal results, particularly for the crude fibre fraction of grain. Because of this it was decided to determine the apparent digestibility of spelt as the sole feed and not to use hay or other roughage. Beach (1906) first showed that the digestibility of a concentrate could be determined in this way. He fed two dry cows exclusively on corn meal for a period of 130 days and determined the digestibility of the meal from the faeces collected during the last week of this period. Using the same animals Beach (1906) determined the digestibility of hay and from all his results concluded that the digestible nutrients of corn meal were utilized by cattle more efficiently than the digestible nutrients of hay and that the exclusive feeding of meal produced no undesirable effects. Forbes et al. (1931) extended this type of study to compare the digestibility of corn fed alone and in combination with roughage, and showed that with the exception of values for ether extract, the digestibilities computed from the mixed rations agreed fairly well with those obtained directly from corn meal when fed alone. From daily analyses of faeces samples, these workers also demonstrated that a period of at least 10 days should be allowed from the start of all meal feeding to the collection of the first faeces samples, to ensure complete elimination of roughage residues from the previous ration.

In the present study the dry cows used had been fed an all hay diet prior to the start of the preliminary feeding period of the digestion trial. They were switched from the hay to a ration of 15 lb. of spelt per head daily which was fed in two portions of 6 lb. and 9 lb. at 7.00

hours and 16.00 hours. A preliminary period of 12 days was used prior to moving the cows into the metabolism stalls and they were allowed to settle for one day in the stalls before starting collection of faeces. Faeces were weighed and sampled at the same time, 13.00 hours, each day, and from each day's weight of faeces a 2.5% sample was taken into a glass jar to which 10 ml. of concentrated hydrochloric acid had been added to facilitate preservation. Sampling continued for a total collection period of 10 days, and the whole of the bulked daily faeces samples was used, firstly for dry matter estimations and then was ground for undigestible nutrient estimation. The dry matter contents of the faeces were obtained by drying these complete samples for 75 hours at 99° C. A Wiley laboratory mill was used to grind the stored samples and the nutrients in the faeces were determined by the official A.O.A.C. methods. A 1 mm. hole size screen was again used in the mill.

The experimental cows ate their full ration of spelt readily during the preliminary period, but some difficulty was obtained with No. 107 during the third, fourth, and fifth days of the collection period. However, this animal eventually ate the full amounts of spelt offered and during the whole period consumed the same total amount of of feed (150 lb.) as the other two cows. Because of the slight food refusal, it was considered wise to extend the collection period from the usual 7 days to 10 days. This was important because as Blaxter, Graham, and Wainmam (1956) point out, when a constant food intake is used in a digestibility trial the error of the digestibility coefficient is determined by the weight of undigestible nutrient excreted per unit of time. The recorded value of this weight will vary because of errors arizing from variations in the efficiency of the digestive process from time to time and errors in the analysis or weighing of the faeces. These are largely independent errors. More important are the so-called "end point" errors caused by irregular expulsion of faeces in that the animal may defaecate just before or after the end of a collection period. As these workers state, the longer the collection period, the lower the "end point" errors.

In the present experiment, the effect of stopping collection after 7 days compared with 10 days cannot be accurately assessed because the dry matter contents of the faeces after that time were not determined. However, if the dry matter content were the same as after a 10-day collection, calculation shows the following digestibility values after 7 and 10-day collections.

% Digestibility of Dry Matter

Cow No.	7 days	10 days
107	79.7	72.4
K213	75.1	72.3
A77	74.4	70.7

The digestibility appears to be lower after the 10-day period particularly in the case of the cow that was slightly "off feed"--No. 107.

Results

The weights of the fresh and dry faeces and the proximate composition of both the faeces samples and the spelt sample used for the digestion trial are given in Table 4.

Balance sheet data for the weights of the various nutrients fed and excreted are shown below, together with the coefficients of apparent digestibility for each cow separately.

No. 107

Weights of Nutrients Fed and Excreted (lb.)

	Dry Matter	Crude Protein	Crude Fibre	Ether Extract	Nitrogen-free Extract	Organic Matter
Food	132.75	15.8	15.7	2.30	92.5	126.2
Faeces	36.64	4.0	8.6	.62	17.3	30.5
Difference	96.11	11.8	7.1	1.68	75.2	95.7
Digestibility Coefficient	72.4	74.0	45.2	73.0	81.3	76.0

Table 4

The Weights and Composition of Faeces and Composition of Spelt

Cow	Wt. of Fresh Faeces (lb.)	Dry Matter %	Wt. of Dry Faeces (lb.)	Percentage of Dry Matter					
				Crude Protein	Crude Fibre	Ether Extract	Nitrogen-free Extract	Ash	Organic Matter
107	177.00	20.7	36.64	11.2	23.5	1.7	47.2	16.7	83.3
K213	192.50	20.2	38.88	12.9	24.2	1.4	45.1	16.4	83.7
A77	183.75	20.0	36.75	12.1	23.9	1.6	47.5	14.9	85.1
	Spelt	88.5	---	11.9	11.8	1.7	69.7	4.9	95.1

No. K213

Weights of Nutrients Fed and Excreted (lb.)

	Dry Matter	Crude Protein	Crude Fibre	Ether Extract	Nitrogen-free Extract	Organic Matter
Food	132.75	15.8	15.7	2.30	92.5	126.2
Faeces	38.88	5.0	9.4	.54	17.4	32.5
Difference	93.87	10.8	6.3	1.76	75.1	93.7
Digestibility Coefficient	70.7	68.5	40.1	76.5	81.1	74.3

No. A77

Weights of Nutrients Fed and Excreted (lb.)

	Dry Matter	Crude Protein	Crude Fibre	Ether Extract	Nitrogen-free Extract	Organic Matter
Food	132.75	15.8	15.7	2.30	92.5	126.2
Faeces	36.75	4.5	8.8	.65	17.5	28.7
Difference	96.00	11.3	6.9	1.65	75.0	97.5
Digestibility Coefficient	72.3	71.5	44.0	72.0	81.1	78.0

The agreement between the various coefficients of apparent digestibility for all constituents is good. From these, the following average values, expressed to the nearest whole number have been calculated and are offered as the coefficients to be used for the calculation of the T.D.N. value of spelt.

Constituent	Digestibility Coefficient
Dry Matter	72
Organic Matter	76
Crude Protein	71
Crude Fibre	43
Ether Extract	74
Nitrogen-free Extract	81

These values may be compared with those of Kellner, cited by Goodwin (1926) when it is found that the values for fibre and ether extract are similar in both cases, whilst the current study produced a slightly lower apparent digestibility for crude protein and rather higher figure for nitrogen-free extract.

The T.D.N. value for the spelt used in this study calculated in the manner indicated by Morrison (1956) is 72.9 for the moisture-free sample and 64.5 for the sample as fed. The starch equivalent calculated using Kellner's factors for digestible nutrients and a value number of 95 the same as oats (Goodwin, 1926) is 68.7 in the dry matter and 60.8 as fed.

More general figures for T.D.N. and starch equivalent may be calculated using the average analytical figures for the 10 samples of spelt reported above. The average T.D.N. value proved to be 74.1 in the dry matter (i.e. 66.7-65.2

at 10.0% and 12.0% moisture) and the average starch equivalent 69.8 in the dry matter (62.7 and 61.4 at 10.0% and 12.0% moisture).

THE RELATIVE VALUES OF SPELT, CORN, AND OATS FED WITH HAY AS GROWTH SUPPLEMENTS FOR DAIRY HEIFERS

This study consisted of a feeding trial designed so that information obtained might support the conclusions from the digestibility trial concerning the nutritive value of spelt. A total of 15 heifers from the University herd was used in three groups, each of which was allocated a ration of hay plus spelt, hay plus corn, or hay plus oats. Because only mixed breeds were available each group consisted of 2 Holstein and 2 Brown Swiss heifers, and 1 Guernsey heifer.

Experimental Procedure

Full details of the allocation of the animals to groups are shown in Table 5.

The experiment started on December 15, 1958, and continued for the next 90 days. From Table 5 it will be noticed that eleven of the heifers had been bred, but none longer than 51 days, prior to December 15. Effects due to foetal development were therefore expected to be negligible.

Table 5

Details of Cattle Used in the 3 Trial Groups

	No. of Heifer	Breed	Date of Birth	Date Bred	Initial Liveweight
Group 1--	3063	Brown Swiss	11/17/1957	--	980
Hay + Corn	3064	Brown Swiss	9/22/1957	--	867
	627	Holstein	3/22/1957	11/26/1958	972
	630	Holstein	7/ 4/1957	8/22/1958	823
	2040	Guernsey	2/ 8/1957	10/25/1958	806
Group 2--	3056	Brown Swiss	4/ 8/1957	3/11/1958	994
Hay + Oats	3061	Brown Swiss	7/14/1957	--	903
	625	Holstein	8/10/1957	18/11/1958	1038
	633	Holstein	8/ 4/1957	--	728
	2042	Guernsey	6/ 8/1957	25/11/1958	794
Group 3--	3057	Brown Swiss	5/21/1957	31/10/1958	998
Hay + Spelt	3053	Brown Swiss	14/26/1957	31/10/1958	953
	624	Holstein	2/23/1957	17/11/1958	1026
	626	Holstein	13/17/1957	28/11/1958	915
	2044	Guernsey	8/ 9/1957	17/11/1958	782

Since only a small number of animals was available, it was not possible to match groups perfectly for breed, weight, and age; and the allocation to groups was randomized so that equal numbers of the same breed appeared in each group. This allocation produced average liveweights of 885.6 lb., 891.4 lb., and 934.8 lb. for groups 1, 2, and 3, respectively.

Rationing of the animals was such that each animal received the same quantity of cereal dry matter daily, and the same quantity of hay per 100 lb. of body liveweight. Thus the spelt and oats group each received 5 lb. of grain per head daily while 5.2 lb. of corn was fed per head daily to the corn group. The moisture contents of the oats, spelt, and corn were 11.2%, 11.2%, and 14.8%, respectively. Hay was offered at the rate of 1.5 lb. per 100 lb. of body liveweight. The hay was weighed daily to the nearest 0.5 lb.

Table 6 gives the National Research Council's (1956) recommendations for the nutrient requirements of dairy heifers, together with estimates of the total digestible nutrients and digestible crude protein supplied by rations of the type just described.

It may be noted that the hay plus corn group were supplied with T.D.N. slightly in excess of recommended

Table 6

Requirements for Growing Heifers and Nutrients Supplied by Various Rations

Wt. of Animal (lb.)	Daily Gain (lb.)	Requirements (lb.)		Nutrients Supplied (lb.) Hay + Corn		Nutrients Supplied (lb.) Hay + Oats	
		T.D.N.	D.C.P.	T.D.N.	D.C.P.	T.D.N.	D.C.P.
700	1.3-1.4	9.25	0.875	9.41	1.42	8.80	1.54
800	1.2-1.3	10.00	0.900	10.16	1.57	9.55	1.69
900	1.2-1.3	10.25	0.925	10.91	1.73	10.30	1.85
1000	1.2-1.3	11.00	0.950	11.66	1.88	11.05	2.00
1100	1.2-1.3	11.50	0.975	12.41	2.03	11.80	2.25

requirements, while the oats group received rather less nutrients than the suggested quantities for the live-weight gains indicated in the table. The protein supply was more than adequate at all levels. At this stage, the value of spelt, of course, was not known, but it was considered that rationing in the manner indicated would enable spelt to be classified as being more like oats or corn for practical feeding purposes, in rations reasonably typical of what might be used in farm practice. It is necessary to point out at this stage that adequate minerals were ensured by the addition of 1 lb. of sodium chloride and 1 lb. of dicalcium phosphate per 100 lb. of grain.

All heifers were housed in separate stalls, and each animal's section of feeding trough was isolated from adjacent sections by wooden partitions, to prevent any animal's stealing from neighboring animals. Hay was fed twice daily, approximately three-fifths of the daily allowance per animal being offered at 15.30-16.00 hours and the remaining two-fifths at 08.00 hours the next day. Grain was fed immediately before the afternoon feed of hay. All hay was weighed in a steel basket to the nearest half pound. It was appreciated that rationing systems have not the accuracy of applicability implied in this procedure, but since hay supplied a considerable proportion of the nutrient intake per animal, it was necessary to ration hay carefully and also to record hay consumption as accurately as possible. This was carried out in the manner indicated below.

Each afternoon the feeding passage was swept perfectly clear of hay residues and the total daily rations placed in the passage in front of the appropriate cow. Three-fifths of this was then offered to each cow, and the remaining two-fifths the next morning. Handling of the hay resulted in the fracturing of pieces of dry leaf and stem. Similar pieces accumulated on the floor of the feeding passage as overspill from the animals' actions in eating the hay placed before them. This accumulation of pieces of hay, or "fragmentation" loss, had to be accounted for together with any refusals of hay, to obtain an accurate idea of the actual hay consumption of each animal. It was not possible to assign a definite fragmentation loss to each animal separately, but each afternoon the total loss was weighed and this weight divided equally among all the heifers in the experiment. Hay refusals were subtracted for each animal separately. It is believed that a good measurement of actual hay consumption was obtained in this way.

The hay used was chiefly good quality lucerne, but occasionally it was necessary to feed bromegrass hay. However on any one day all cattle received the same type of hay. Consumption of hay was good, and no difficulty was experienced with any of the heifers except No. 625, in the oats group. This animal tended to be more restless than the others and threw lumps of hay into the feeding passage. Although every effort was made to put these back periodically during the day, hay consumption for this animal was rather lower than the other cattle in all periods. All grain allowances were readily consumed in a matter of minutes.

Liveweights were recorded at the beginning of the trial and after 30, 60, and 90 days. Each weight represented the average of three weighings on three successive days (i.e. the 60-day weight was the average of the weights on the 59th, 60th, and 61st days). Hay allowances were adjusted after 30 and 60 days to allow for the increased liveweight. The trial was therefore arbitrarily split into 3 periods, each of 30 days.

Results

Details of the food consumption during each period of the trial are given in Table 7.

Table 7

Weights of Hay Offered and Consumed per Heifer and the Average Daily Intake of Grain, and Hay per 100 lb. of Body Liveweight (lb.)

	No. of Heifer	Total Daily Hay Offered Period 1	2	3	Total Daily Hay Consumed Period 1	2	3	Hay per 100 lb. body liveweight per day Period 1	2	3	Whole Trial	Grain per day
Group 1	3063	14.5	15.5	16.0	13.8	14.8	15.3	1.38	1.41	1.41	1.40	5.2
	3064	13.0	13.5	14.0	12.4	13.1	13.4	1.43	1.44	1.42	1.43	5.2
	627	14.5	15.0	15.5	13.5	14.1	14.8	1.37	1.37	1.39	1.37	5.2
	630	12.5	13.0	13.5	11.7	12.3	12.8	1.39	1.39	1.39	1.39	5.2
	2040	12.0	12.5	13.5	11.0	11.7	12.7	1.34	1.33	1.39	1.35	5.2
						Average		1.38	1.39	1.40	1.39	5.2
Group 2	3056	15.0	15.5	16.0	14.1	14.7	15.3	1.40	1.41	1.41	1.41	5.0
	3061	13.5	14.0	14.5	12.7	13.2	13.8	1.38	1.38	1.40	1.39	5.0
	625	15.5	16.0	16.0	13.1	14.2	14.6	1.25	1.34	1.33	1.31	5.0
	631	10.5	11.5	12.0	9.8	10.8	11.0	1.33	1.41	1.39	1.38	5.0
	2042	12.0	12.5	13.0	10.8	11.7	12.2	1.34	1.39	1.39	1.37	5.0
						Average		1.34	1.39	1.38	1.37	5.0
Group 3	3059	15.0	15.5	16.0	13.8	14.4	15.5	1.36	1.40	1.37	1.38	5.0
	3058	14.5	15.0	15.5	13.7	14.3	14.7	1.41	1.42	1.42	1.42	5.0
	624	15.5	16.0	16.0	14.4	15.3	15.3	1.39	1.44	1.40	1.41	5.0
	626	13.5	14.0	14.5	12.7	13.7	13.8	1.37	1.43	1.39	1.40	5.0
	2044	12.0	12.0	12.5	10.9	11.4	11.8	1.38	1.39	1.39	1.39	5.0
						Average		1.38	1.42	1.39	1.40	5.0

The data in Table 7 indicate that hay consumption per head per 100 lb. of body liveweight was remarkably constant throughout. This is true of individual animals as well as the average for groups in each of the 3 periods. These figures were obtained by taking the average of the liveweights at the beginning and end of the periods, and dividing by the total consumption of hay per head in each period. Any difference in liveweight gains, therefore, should have been caused by differences in the nutritive value of the grain rations, because the largest difference in hay intake in any one period such as the 1.25 lb. for No. 625 and 1.43 lb. for No. 2064 in period 1 represents only 1.8 lb. of hay per day for a 1000 lb. animal, i.e. a difference in T.D.N. intake of 0.9 lb. which is extremely small and becomes negligible when averages are considered.

The liveweight of the heifers, together with the liveweight gains in each period and for the whole experiment, are cited in Table 8. It may be seen from this table that the liveweight gains for the corn fed group were higher throughout the whole of the experiment but were most marked during the first 30 days. The spelt and oat fed groups produced remarkably similar gains throughout each of the 30-day periods and the total average gain

Table 8

Liveweights and Liveweight Gains of all Animals in the Trial (Lb.)

	No. of Heifer	Initial Liveweight	Wt. after 30 days	Gain	Wt. after 60 days	Gain	Wt. after 90 days	Gain	Total Gain
Group 1	3063	980	1022	42	1067	45	1107	40	127
	3064	847	887	40	924	37	964	40	117
	627	972	1013	41	1040	27	1075	35	103
	630	823	866	43	898	32	938	40	112
	2040	806	843	37	887	44	938	51	132
			Average:	40.6		37.0		41.2	118.2
Group 2	3056	994	1020	26	1062	42	1104	42	110
	3061	903	938	35	967	29	998	31	95
	625	1038	1050	12	1079	29	1111	33	74
	633	728	757	29	774	17	805	33	77
	2042	794	825	31	856	31	902	46	108
			Average:	26.6		29.6		37.0	92.8
Group 3	3059	998	1024	26	1059	35	1103	44	105
	3058	953	987	34	1016	29	1052	36	99
	624	1026	1044	18	1069	25	1106	37	80
	626	915	942	27	978	36	1007	29	92
	2044	782	803	21	831	28	872	41	90
			Average:	25.2		30.6		35.4	93.2

for these groups for the whole trial were essentially the same. The average daily liveweight gains were 1.03 lb. for the oats and spelt groups and 1.31 lb. for the corn fed group.

Analysis of variance of the total liveweight gains for the whole 90-day period, carried out to determine the equivalence of means described by Snedecor (1956), showed that the greater average liveweight gain of the corn group of approximately 25 lb. was significantly greater than the gain of the spelt and oats groups, at the 5% level, of probability. The summarized analysis of variance is shown in Table 9.

Table 9

Analysis of Variance of Total Liveweight Gains for the 90-day Feeding Trial

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F
Total	14	4,196.6		
Groups	2	2,117.2	1,058.6	6.25
Error	12	2,032.	169.4	
Table of F.		P = .01	F = 6.93	
		P = .05	F = 3.88	

DISCUSSION

It was mentioned in the review of literature that data concerning the composition and nutritive value of spelt for dairy cattle is negligible. However, from the limited data available it might have been anticipated that spelt and oats are of similar feeding value and may be substituted for one another in dairy rations. The main point demonstrated in the current investigation is the equivalence in nutritive value of oats and spelt.

The average values obtained for the proximate composition of spelt are very similar to those for oats with the exception of a somewhat lower ether-extract content in spelt and consequent slightly higher nitrogen-free extract. Since only 10 spelt samples were analysed, it is conceivable that the range of values and averages for the proximate constituents might be different had a larger number of samples been available. Thus additional studies to determine the average composition of spelt, together with studies of factors affecting the yield and composition of spelt would be desirable if the crop assumes any greater importance in farm practice.

Because of their similarity in composition, the T.D.N. values of spelt and oats might be expected to be of the same order. Again this was found to be so. Values for the T.D.N. and digestibility coefficients for the proximate constituents of oats have been summarized by Schneider (1947) and Morrison (1956). The National Research Council recommend a value of 70.1 the same as Morrison's figure for oats from areas excluding the Pacific coast. Only Schneider (1947) provides separate figures for T.D.N. and digestibility values obtained with cattle, while Morrison's (1956) data are from trials with both cattle and sheep. The range of values on a dry matter basis for the T.D.N. of oats cited by Schneider (1947), is 69.1-75.0, and the T.D.N. for spelt calculated in this study was 74.1 also on a dry matter basis. This value for spelt approximates closely to the average of the range for oats. Morrison's (1956) T.D.N. values for oats are a little higher at 77.7 (oats - not including the Pacific States), 79.2 (Pacific States' oats), and 77.5 (usual commercial feed). However when variations in the moisture content of grains as fed are considered it seems that for practical rationing purposes the T.D.N. value of spelt is very close to that of oats.

So far as the digestibility coefficients are concerned, the values for the various constituents of spelt and oats agree quite well with the exception of the coefficient for crude fibre. Schneider (1947) quotes a range of 6-30 for this constituent in oats, compared with 43 found in this study with spelt. It is possible that the lower values may be accounted for by the use of the difference method and not direct measurement in the estimation of the digestibility coefficients for oats.

The feeding trial with dairy heifers described above, has provided additional support for the similarity in nutritive value of oats and spelt. The results of this trial were rather remarkable in that both oats and spelt produced identical liveweight gains that were significantly lower at the 5% level than the gain of the corn fed group. It is of some interest from this trial to observe how well the T.D.N. rationing system used was able to predict the average daily liveweight gains of the spelt, oats, and corn fed groups of 1.03 lb., 1.03 lb., and 1.31 lb., respectively.

The T.D.N. requirements for heifers of various weights, the expected daily liveweight gain, and the calculated average T.D.N. consumed daily from the 3 rations are given in Table 10. The T.D.N. intakes were calculated using values of 50 for hay, 74.1 (dry matter basis for spelt), and 77.7 (dry matter basis) for oats.

It will be noted that the calculated T.D.N. value of the corn group was slightly below the standards at the

Table 10

T.D.N. Recommended and Consumed, and Expected Daily Gain (Lb.)

Weight	Daily Gain	Recommended T.D.N.	T.D.N. Consumed		
			Hay + Spelt	Hay + Oats	Hay + Corn
700	1.3-1.4	9.25	8.2	8.25	9.0
800	1.2-1.3	10.00	8.9	8.9	9.7
900	1.2-1.3	10.50	9.6	9.6	10.4
1000	1.2-1.3	11.00	10.3	10.3	11.1
1100	1.2-1.3	11.50	11.0	11.0	11.8

lighter weights and a little above at the heavier weights. The average liveweight gain for this group might therefore have been expected to be very similar to the daily gains quoted in the table, and this was so. The T.D.N. intakes for the oats and spelt groups were identical and the same recorded average liveweight gains of 1.03 lb. per day in each case, again might have been anticipated. Further, the spelt and oats groups consumed on the average 0.8 lb. of T.D.N. per day less than the corn group and the reduced average level of daily gain of 0.28 lb. was of the order expected. It seems, therefore, that the T.D.N. system used in this trial in which food intakes were carefully controlled and measured, predicted results satisfactorily.

SUMMARY AND CONCLUSION

Consideration of all of the foregoing data obtained in this investigation, permits the conclusion that spelt wheat in the form in which it is usually fed has a nutritive value for dairy cattle approximately equal to that of oats and that these foods may be substituted for one another on a pound for pound basis. It is appreciated that this study has provided only a small amount of additional information, but until further studies can be completed it is suggested that in formulating practical rations for dairy cattle, spelt should be considered as having a T.D.N. value of 74 on a dry matter basis, or 65-67 as fed, with a digestible crude protein content of 8.4% in the dry matter, and 7.5% as fed. Although the greater proportion of spelt grown is used for home consumption, if sold, the current market price for oats would be a fair charge for spelt. Since Brown's (1942) data showed that in Michigan spelt tended to be rather more productive than oats, there may be some justification for growing spelt for home consumption in place of oats or to increase crop diversification.

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