THE UNIVERSITY OF MINNESOTA

GRADUATE SCHOOL

Report

of

Committee on Examination

This is to certify that we the undersigned, as a committee of the Graduate School, have given Raymond Aune final oral examination for the degree of

Master of Science.

We recommend that the degree of

Master of Science

be conferred upon the candidate.

W. H. Peters
Chairman

C H Eckles

Philip A. Anderson

Date May 29-1922

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THE UNIVERSITY OF MINNESOTA

GRADUATE SCHOOL

Report

of

Committee on Thesis

The undersigned, acting as a Committee of the Graduate School, have read the accompanying thesis submitted by Raymond Aune for the degree of Master of Science. They approve it as a thesis meeting the requirements of the Graduate School of the University of Minnesota, and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science.

W. H. Peters
Chairman

O. H. Eckles

Philip A. Anderson

Date May, 29 - 1922

THE SUITABILITY OF SEVERAL RATIONS FOR WINTERING LAMBS

A THESIS

PRESENTED TO THE FACULTY OF THE GRADUATE SCHOOL
OF THE
UNIVERSITY OF MINNESOTA

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR
THE DEGREE OF MASTER OF SCIENCE

BY

RAYMOND AUNE, B. S.

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INTRODUCTION

The development of sheep raising as it concerns those now interested in the production of mutton and wool centered in England and Spain. About the year 1500 both these countries were recognized as the greatest sheep countries of the world. Domestic sheep were brought to America by the early Spaniards and English colonists. The main object was to furnish wool and only incidentally to furnish part of the family meat supply. Sheep raising gradually moved westward slightly ahead of the homesteading of the Central Section and the Western Range. The division of the range territory into farms has resulted in a marked decrease in the number of large flocks kept in the western states. Wyoming and Montana have 50 per cent less sheep at present than they had in 1910. Likewise Mexico and other western states have suffered a heavy decline in numbers. This decrease on the range has been replaced to some extent by the spreading out in the distribution of the sheep of the country and already we find small flocks of sheep on farms throughout almost every state. It is probable that in the future a much higher percentage of the mutton and the wool output of the country will come from these comparatively small flocks maintained in conjunction with mixed farming and a consequent smaller percentage of it from the large flocks of the range sections.

The United States ranks as one of the principal mutton producing countries of the world. as shown in the following table (1).

Table I. Countries leading in the production of wool and mutton.

Country	Date of census	Number of sheep
Australia	June 1920	78,000,000
Argentina	Dec. 1918	45,309,000
United States	Jan. 1921	45,067,000
Russia(Europe)	1914	37,240,000
United Kingdom	June 1920	23,407,000
Union South Africa	1919	28,492,000
New Zealand	1920	23,915,000

The behavior of the mutton and wool markets both since 1914 has attracted a great deal of attention to the sheep growing industry. There have been times when prices for both wool and mutton have been abnormally high and times when one or both have been abnormally low. These fluctuations have been due largely to unusual war time conditions and the status of trade following the close of the war. Underlying these variations, however, there has been a more significant and more normal situation that indicates a steady strong demand for American grown mutton and lamb.

The per capita consumption of mutton and lamb has increased from 4.7 pounds in 1917 to 6.3 pounds in 1921.

Wool consumption has also increased, but a great deal of the wool used has been imported from other countries. Present tariff protection on both wool and mutton is restricting to some extent the importation of these products. Taking these two factors together, increased home consumption of mutton and wool and a fairly reliable inclination on the part of the federal government to protect the legitimate interests of the sheep grower in any reasonable way, is it not sound logic to prophesy a successful future for the American sheep grower?

Prospective values for lambs and wool and the special economies incident to their production insure for farm sheep raising a large and permanent place, either on those farms where sheep raising is made a speciality or where flocks form a permanent part of a system of mixed farming.

In maintaining the farm flock many perplexing problems arise. The writer has had continual contact with the general problems that arise in the care and management of the farm flock. While pursuing under graduate-study the writer has devoted considerable time to the study of problems pertaining to the sheep industry. There is a great deal of information available on most of these problems.

There has been one problem however that has always appealed to the writer as an important one in sheep production, upon which little definite information seems to be available. That is the problem of developing young breeding stock so that it will be capable of the most efficient production when mature. Too much emphasis cannot be placed upon the importance of improving the ewe flock of a sheep breeding enterprise. Hitherto a greater part of the emphasis has been placed on the need for good rams. But in order to make more rapid progress it is necessary to have both excellent parentage and proper development. The development or growth of the lambs is determined just as much by environment, especially feed, as by the hereditary characteristics transmitted by the parents.

As mentioned the feed is of great importance in the growing of lambs. It becomes necesary to select rations somewhat different from those used in the fattening process. For this reason the problem of determining the most satisfactory rations for producing growth in lambs is one of great importance from a practical standpoint. Rations used by successful breeders and Experiment Stations will be considered. As a basis on which to discuss this problem we must know something about the nature of growth and the factors affecting growth. Lastly, an original feeding trial comparing different grain rations for growing ewe lambs has been conducted and will be discussed in detail.

Chapter I

RATIONS FED BY SOME OF THE SUCCESSFUL BREEDERS.

To get a better idea of how the successful sheep breeders feed their ewe lambs, sixty circular letters were sent out. The following are the breeders who replied and the rations they consider a success for wintering ewe lambs;

1. H. H. Pond & Son, Minneapolis, Minn.

Oats	1 lb.	Clover or alfalfa	2 to 3 lb.
		Corn silage	ad libitum.

2. A. Broughton's Sons, Albany, Wis.

Oats	ad libitum.	Alfalfa	ad libitum.
		Corn silage	1 lb.

3. R. E. Martin, Bozeman, Montana.

Oats	.75 to 1 lb.	Clover and alfalfa	ad libitum.

4. Gray & Cummins, Pipestone, Minn.

Oats	.75 lb.	Clover	2 lb.
		Corn stover	ad libitum.
		Oat straw	ad libitum.

5. Eddinfield Farms, Mt. Pleasant, Ia.

Corn	50 %)	.5 to 1 lb.	Clover	ad libitum.
Oats	50 %)		Corn fodder	ad libitum.

6. Joseph Jennings, Lee's Summit, Mo.

Corn	50 %)	.75 lb.	Clover or upland hay	ad libitum.
Oats	50 %)		Corn stover	ad libitum.

7. W. E. Haenke, Evelth, Minn.

Oats	80 %)	1 lb.	Clover	1 lb.
Bran	20 %)		Corn fodder	ad libitum.

8. S. M. Elkins, Bloomington, Ill.

Oats	1.5 lb.	Clover (preferred)	ad libitum.
		Alfalfa (second choice)	

9. R. R. Wheaton, Caledonia, Minn.

Oats 50 %	)	.75 lb	Clover	2 lb.
Bran 50 %	)		Corn silage	1.5 to 2 lb.
			Oat straw	ad libitum.

10. W. F. Renk, Sun Prairie, Wis.

Oats 2/3 part	)	1 lb.	Clover and alfalfa	ad libitum.
Bran 1/3 part	)		Roots	1 lb.
or			Corn silage	.75 lb.
Barley 25 %	)			
Oats 50 %	)	1 lb.		
Bran 25 %	)			

11. Geo. Mc Kerrow & Son, Pewakee, Wis.

Oats 75 %	)	.5 lb.	Clover or alfalfa	ad libitum.
Bran 25 %	)			

12. T. F. Jones, Everly, Ia.

Oats 40 %	)		Clover	1.5 lb.
Corn 40 %	)	1 lb.	Corn silage	1 lb.
Bran 20 %	)		Corn fodder	ad libitum.

13. Smith Bros., Union Center, Wis.

Oats 50 parts	)		Clover	ad libitum.
Corn 20 parts	)	1 lb.		
Bran 10 parts	)			

14. Ed. Fissette, Rogers, Minn.

Oats 70 %	)		Clover	ad libitum.
Corn 20 %	)	.75 lb	Corn fodder	ad libitum.
Bran 10 %	)			

15. H. E. Powell, Ionia, Michigan.

Oats 70 %	)		Clover	ad libitum.
Corn 20 %	)	.5 lb.	Corn silage	2 lb.
Bran 10 %	)			

16. E. L. Bitterman, Mason City, Ia.

Oats 20 %	)		Clover	2 lb.
Corn 60 %	)	.75 lb.	Corn fodder	ad libitum.
Bran 20 %	)		Corn stover	ad libitum.

17. Johnson Bros., Lakeville, Minn.

Oats 45 % Corn 45 % Bran or oilmeal 10 %	1 lb.	Clover or alfalfa	ad libitum.
or			
Oats 2 parts Corn 1 part	1 lb.		

18. Bob White Stock Farm, Rome, Ia.

Oats 50 % Corn 20 % Bran 20 % Oilmeal 10 %	1 lb.	Clover or alfalfa Oat straw	2.5 lb. ad libitum.

19. Pabst Stock Farm, Oconomowoc, Wis.

Oats 50 % Corn 10 % Bran 30 % Oilmeal 10 %	.5 to 1 lb.	Clover or alfalfa Corn silage or alfalfa silage	ad libitum. 1 lb.

20. Richards & Richards, Lodi, Wis.

Oats 50 % Corn 20 % Bran 20 % Oilmeal 10 %	.75 lb.	Clover or alfalfa	ad libitum.

21. Dolph Bros, Plymouth, Ind.

Oats 20 % Corn 50 % Bran 20 % Oilmeal 10 %	1 lb.	Clover Corn silage	ad libitum. ad libitum.

22. J. P. Ring, Anoka, Minn.

Oats 50 % Bran 20 % Corn 20 % Oilmeal 10 %	1 lb.	Clover Corn stover	ad libitum. ad libitum.

23. W. T. Wardwell, Springfield Center, N. Y.

Oats 35 % Bran 18 % Corn 35 % Oilmeal 12 %	1 lb.	Clover Alfalfa	ad libitum. ad libitum.

24. J. S. Billings & Son, Fergus Falls, Minn.

Oats	70 %)	.75 lb.	Clover	2 lb.
Corn	10 %)		Oatstraw	ad libitum.
Barley	10 %)			
Bran	10 %)			

25. J. B. Conley, Verndale, Minn.

Oats	200 lb.)	1 lb.	Clover or
Bran	100 lb.)		alfalfa 2 lb.
Oilmeal	25 lb.)		Corn silage .5 lb.
Barley	20 lb.)		Oat straw ad libitum.

26. Walnut Farm, Donerail, Kentucky.

Oats	300 lb.)		Alfalfa or
Bran	50 lb.)	1 lb.	soybean hay
Cottonseed meal	50 lb.)		ad libitum.
or			
Oats	300 lb.)		
Bran	50 lb.)	1 lb.	
Barley	100 lb.)		

27. J. C. Andrew, West Point, Ind.

Oats	60 %)		Mixed hay ad libitum.
Bran	30 %)	2 lb.	Corn silage 1 to 2 lb.
Oilmeal	10 %)		

28. A. L. Savers, Lakeville, Minn.

Oats	40 %)		Clover	ad libitum.
Bran	40 %)	1 lb.	Silage	ad libitum.
Oilmeal	20 %)			

29. Joseph Pogatchnik & Sons, Albany, Minn.

Mixed hay ad libitum.
Oat straw ad libitum.
Corn stover ad libitum.
Corn Silage 1 lb.

There is quite a variation in the rations used, especially in the kind and amount of grain fed. All the breeders favor a legume hay, especially alfalfa if available. Clover is a more common crop in Minnesota and is on most of the farms.

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The legume hay in over 50 per cent of the cases is fed ad libitum and when limited the usual amount is 1.5 to 2 pounds per lamb daily.

In no case was there any objection raised against good quality silage for ewe lambs. The only reason that some of the breeders do not feed it, is because they do not have it. The amount of silage fed ranged from 3/4 of a pound to 2 pounds per lamb daily, however, about one-half of the breeders fed the silage ad libitum. The average amount fed was slightly more than one pound daily.

All the breeders with one exception fed grain. Oats makes up from 20 per cent to 100 per cent of every grain ration. Bran is the second most common feed, which is used in over 75 per cent of the rations. Corn ranks third, being used in 53 per cent and oilmeal fourth, which is used in 35 per cent of the grain rations. Barley and cottonseed meal occur occassionally. Most of the sheep breeders feed a grain ration of a large variety, of which the most common is the standard ration of corn, oats, bran and oilmeal. The amounts of each constituent vary with the different breeders. The most common proportion is corn 20 per cent, oats 50 per cent, bran 20 per cent and oilmeal 10 per cent; while the average of those reported is oats 44 per cent, corn 26 per cent, bran 20 per cent and oilmeal 10 per cent. The second most common ration is corn, oats and bran of different proportions. The average proportions as reported by the breeders is corn 35 per cent, oats 51 per cent and bran 14 per cent. Several of the breeders fed oats alone, or corn and oats, or oats and bran.

The amount of grain fed varies from none to 2 pounds daily per lamb. About 55 per cent of the breeders feed one pound of grain and 28 per cent feed 3/4 of a pound.

Chapter II

RATIONS FED AT SEVERAL OF THE EXPERIMENT STATIONS.

Circular letters were also sent out to some of the experiments stations in order to secure similiar information to that secured from the successuul sheep breeders. The following are the experiment stations communicated with and the rations they prefer for wintering ewe lambs:

1. Indiana.

Oats	.5 lb.	Clover	1 to 2 lb.
		Corn silage	2 lb.

2. Iowa.

Oats 6 parts)		Alfalfa or	
Corn 1 part)	1 lb.	clover	ad libitum.
or			
Oats 6 parts)			
Corn 1 part)			
Bran .5 part)	1 lb.		
oilmeal .5 part)			

3. Pennsylvania.

Oats 300 parts)		Alfalfa	ad libitum.
Corn 100 parts)		Corn silage	ad libitum.
Bran 50 parts)	3/4 lb up to Jan., 15th and		
Oilmeal 25 parts)	1 lb. there after.		

4. Minnesota.

Corn 35 %)		Alfalfa	1.5 lb.
Oats 35 %)		Corn silage	.75 lb.
Bran 20 %)			
Oilmeal 10 %)	1.5 lb.		

5. Illinois.

Oats 3 parts)		Alfalfa	ad libitum.
Corn 1 part)		Corn silage	ad libitum.
Bran 1 part)	1 lb.		
Oilmeal .5 part)			

6. Montana.

Oats	80 %	.75 lb.	Alfalfa or clover	ad libitum.
Bran or cottonseed meal	20 %			

7. North Dakota

Oats	75 %	.5 to 1 lb.	Alfalfa	2.5 lb.
Bran	25 %			

8. Kentucky.

Oats	50 %	.25 lb.	Clover or Alfalfa	ad libitum.
Bran	50 %			

9. Kansas.

Oats	70 %	.25 lb.	Alfalfa	1 lb.
Bran	20 %		Corn stover	ad libitum.
Oilmeal	10 %		Corn fodder	ad libitum.
			Corn silage	2 lb.

10. Wisconsin.

Oats	3 parts	.5 lb.	Clover or alfalfa	ad libitum.
Bran	1 part		Corn silage	2 lb.
Oilmeal	.5 part			

11. Michigan.

Oats	1/3 part	.75 to 1 lb	Clover and silage	ad libitum.
Bran	1/3 "			
Corn	1/3 "			

12. Wyoming.

Oats	150 parts	1 lb.	Alfalfa	ad libitum.
Bran	100 parts		Oat and pea silage	1 lb.
Corn	50 parts			
Cottonseed meal	30 parts			
Linseed meal	10 parts			

13. New York.

Oats	60 %	.5 lb.	Legume hay	ad libitum.
Bran	30 %		Corn silage	1 lb.
Oilmeal	10 %			

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14. Oregon.

Barley 2/3 part Bran 1/3 part	.75 lb.	Vetch hay	ad libitum.
		Corn silage	ad libitum.

15. Nebraska.

Oats or cracked corn 20 % Oats 80 %	.75 lb.	Corn silage	ad libitum.

16. Colorado.

Barley	.5 lb.	Alfalfa	ad libitum.
or			
Barley 25 % Oats 75 %	.5 lb.		

17. Washington.

Wheat 4 parts Bran 4 parts Linseed meal 1 part	.5 lb.	Alfalfa	.9 lb.
		Silage	3.7 lb.
or			
Corn 4 parts Bran 4 parts Cottonseed meal 1 part	.5 lb.		

18. Nevada.

Mixed alfalfa Red top Timothy	3 lb.
Corn silage	3 lb.

19. Utah.

Alfalfa	ad libitum.
Corn silage	ad libitum.

The rations used by the above experiment stations vary a great deal because of the large territory they represent. It is observed that in the corn belt section and its immediate surroundings, the most common rations in their order of popularity are as follows: corn, oats, bran and oilmeal;

oats, bran and oilmeal; and oats and bran. This corresponds quite closely to the rations used by a large number of breeders. The proportions and amounts fed are in a general way similiar to those used by some of the successful sheep breeders.

Even though there is a general ration most common to the Experiment Stations and the Successful sheep breeders, it is fed in less than 25 per cent of the cases. This shows that there is no absolute ration preferred by all the breeders, or not even a majority, hence the desirability of securing some additional information concerning rations for ewe lambs.

Chapter III.

REVIEW OF LITERATURE.

THE GROWTH OF ANIMALS.

Definition of Growth---Growth is the sum of the changes through which the animal passes in its progress to maturity. Davenport (2) defines growth as "increase in volume" while Huxley (3) defines it as "increase in size". Growth is the process by which an individual reaches its final size and consists in the increasing of weight and stature by the formation of new tissue. Mendel (4) considers growth as "the resultant of an inherent growth impulse--an internal factor--and a suitable environment, the latter including the food supply--an external factor."

Growth for an individual begins simultaneously with the life of that individual at the moment the egg of the mother unites with the sperm of the father. With this union is imparted a stimulus, which together with inheritance, forms the foundation of its development.

The "inherent tendency" is of first importance, while nutrition is secondary. "The rhythm of cell division is limited for every class of animals and for every individual, therefore, even with the greatest intake of food growth will never exceed a certain limit". (5) "Nutrition which is often looked upon as a controlling factor, can do no more than give free scope to the inherent tendency to grow". (4)

Growth is essentially a cell division process, which Donaldson (6) defines as follows: "The constituent cells of the body enlarge, divide, and in turn enlarge, at the same time that some of them cease to divide further. The number of these latter cells increases rapidly, while the relative number of the dividing cells diminishes. The body increases in weight so long as the dividing cells continue to multiply and the others to enlarge." Lee (4) has presented the analysis of growth in these words: "All growth, whether of the cells, the tissues, or the organs, is the result of no more than three processes, viz.,

1. Multiplication of cells.
2. Enlargement of cells.
3. Deposition of intercellular substance.

Marshal (7a) states "growth like reproduction involves cell division. As a mass of living substance increases the cells must multiply, for every cell has assigned to it a size limit beyond which it cannot pass. Cell division goes on, though with gradually decreasing frequency through practically the whole of life; tissue formation continues but from an early period of development onward, there is a progressive diminution in the power of growth. Increase in the number of cells is, however, specially characteristic of the embryonic period. In the latter stages growth occurs largely through cell-enlargement and the deposition of intercellular substance".

Boveri (7a) has declared that cell-division is regulated by the proportion of chromatin material to cytoplasm, the growth ceasing when a certain definite proportion of chromosomes to that of the cells is attained.

In order to thoroughly understand growth one must have a comprehensive knowledge of the nutrition, chemistry and physiology of the animal body. In a general practical manner growth may be said to be the increase in body weight or stature which can be estimated by weights and skeletal measurements.

The Measurements of Growth---Until within the last decade the majority of conclusions with regard to growth have been based upon body weights. It soon became known that weight alone cannot represent growth. Weight and skeletal growth are somewhat independent of each other. Aron (8) from his experiments concludes that the force which he calls "growth tendency" is more noticeable in the skeleton than in other parts of the body. If an animal fasts the skeleton grows at the expense of the rest of the body; the fatty tissues being used first, and the other organs later, since the more important organs are also the more resistant. In his opinion the force that induces growth is within the skeletal frame-work, the muscular tissue possessing apparently no specific "growth tendency".

About 1880 an attempt was made to measure growth by metabolism and Carl Voit (9) published a monograph in which he expressed the prevailing idea of the time which was that the growth period was characterized by a relatively large food requirement and "intensity of metabolism" He writes, "It is generally believed that the youthful organism is the seat of a particulaly active metabolism.

It is commonly supposed that an animal grows slowly at an early age, and increases more rapidly as the age advances. This conception is of course erroneous.

There are different ways of expressing growth. Growth may be represented by the amount of matter produced within certain periods of time. The rate of growth may be shown by the percentage of increased matter of each period over the preceding weight or measurement. By this method of representation an animal weighing 500 pounds and gaining 2 pounds a day is not growing at such a rapid rate as one weighing 100 pounds and gaining 1/2 pound a day.

For accuracy in measuring growth at least two factors must be considered---weight and skeletal measurement. According to Waters (10) it is possible for an animal to grow in height and remain at constant weight for extended periods of time, or in extreme cases, even to make skeletal growth while losing in weight. The skeleton continues to grow to a certain extent whether the tissues are storing food or losing energy because of a limited ration. Eckles (11) has shown the greater effect of feed on weight than on skeletal growth."A difference in rations fed that resulted in a variation of 46 per cent in gain in weight between two groups resulted in a difference of only 7 per cent in the growth of the skeleton." The weight of an animal cannot be used alone as a fair measure of growth when the weight in relation to the growth of the skeleton can so readily be made to fluctuate between such wide limits. Attempts have been made to find a way to represent growth by a single term but as yet no satisfactory measure has been devised. It seems necessary to represent the growth of the body tissue in one term, and that of the skeleton by another. So far, no more satisfactory method than weight has been suggested for measuring increase in body tissue, and the skeletal growth by certain measurements.

Numerous skeletal measurements have been used by investigators with nearly all classes of stock. Eckles (11 & 12) after studying monthly measurements on a large number of dairy heifers from birth to maturity came to the conclusion "that any of the several measurements may be used as a measure of the growth of the skeleton. On account of the small limit of error, and the ease with which it is taken, the height at withers is selected as the measure of skeletal growth." F. B. Mumford (13) in measuring swine also considers "height at the withers" as the most accurate of many measurements taken by him.

It may seem somewhat impossible to represent the general skeletal growth by one measurement, since all the parts do not increase in the same proportion but are widely different. Eckles(11) has found in dairy heifers that "while one part of the body may double and another part, triple itself, the relation of one part to another is very constant at all ages". "A measurement taken of the growth of one part of the body makes it possible to estimate closely the rapidity of growth and the time at which it occurs". Eckles (11) concludes "that any of the fundamental measurements of the body may be used with a fair degree of accuracy as an index of skeletal growth."

Rate of Growth---The rate of growth varies with the age. It is the greatest during prenatal life, being the most rapid just after fertilization, declining rapidly following birth and gradually declining until growth ceases.

Minot (14) in his study of embryo chicks and rabbits, estimated that over 98 per cent of the original power of growth is lost before hatching or birth. He says " We start out at birth with less than 2 per cent of the original growth power with which we were endowed. Over 98 percent of the loss is accomplished before birth and less than 2 per cent after birth."

A study of curves representing the rate of growth in man, guinea pigs, rabbits, and chickens indicate that it is closely correlated with age. Periods of rapid development are also periods of rapid decline in the power of growth. Wilson (15) writes "During the individual development the energy of cell division is most intense in the early stages and diminishes more and more as the limit of growth is approached."

Marshall (7b) makes a similiar statement "the process of growth goes on with gradually decreasing frequency throughout practically the whole life; tissue formation continues,but from an early period of development onwards there is a progressive diminution in the power of growth."

After studying litters of pigs and comparative figures for man, rabbits, rats and chicks, Lowrey (16) says, "All these forms agree with the general law that the rate of growth is by far most rapid at the beginning of prenatal life, decreasing at first rapidly then more slowly throughout prenatal and postnatal life."

Minot (8) states that the "rate of growth diminishes almost uninterruptedly from the time onwards when the animal recovers from the post-natal loss of weight. This diminution is rapid at first but afterward slower. There is a progressive loss in the power to grow, beginning almost immediately after birth. The loss of the growth power is equally demonstrable in the case of man (as in guinea pigs) and there can be no doubt that it is true at least of all mammals."

Foster (17) says, "It seems as if the impetus to growth given at impregnation gradually dies out." "In the early stages of growth, therefore, the anabolic processes, which tend to build up tissue, predominate, while as time goes on the katabolic processes gain more and more over the anabolic until at maturity the two tend to become substantially balanced."

Contrary to the view that growth and age are closely correlated is the opinion of Davenport(2) that "the reason why the animal ceases at length to grow is not because there is a necessary limit to growth force at a certain distance from impregnation but because it is in the nature of the species that the individual should cease to grow at this point. The indefinite growth of this part, the limited growth of that, are as much group characters as any structural quality." Ferry (18) studying rats shows growth to be a function of size rather than age. Stunted rats were afterward capable of growing at a "rate normal for their size rather than for their age."

Mendel's and Osborne's (22) results do not support the view that the capacity to grow is lost with age, independently of whether it has or has not functioned during the period usually associated with increase in size. "It appears as if the capacity to grow is only lost by the exercise of this fundamental property of the animal organism."

When an animal reaches a size that is characteristic for its kind it ceases to grow, and it may appear that this happens because the cells of the body have lost the power of further growth. That the cessation of growth is not due to such a loss of power is shown by the ability of many animals to regenerate a lost part. In some animals practically all the organs of the body show this remarkable regenerative power, so there can be no doubt that the cessation of growth is not due to the loss of power of the cells to grow, but as Morgan (19) states "it is due to an inhibitory factor which limits growth."

Minot (20) believes that the diminution in the power to grow is due to "an increase in the differentiation of the protoplasm." "During the early periods of life the young material is produced and the protoplasm is undifferentiated. During the later stages of existence all the differentiation goes on, and the organism gradually becomes old. When the cells acquire the faculty of passing beyond the simple stage to the more complete organism they lose something of their vitality, of their power of growth, and of their possibilities of perpetuation."

The majority of experimental evidence correlates very closely the rate of growth with the age of a normal individual.

Growth Under Adverse Conditions---The limit of the size of an animal is determined by heredity. The size which the animal actually attains, within the definitely fixed limit, is related very directly to the way it is nourished during the growin period.

In a number of cattle experiments at Missouri (10) it has been found that an immature animal may remain at constant body weight for a long period of time, and yet increase in height and apparently decreases its store of fat. The skeleton grew, or the bones at least lengthened, and without doubt a portion at least of the fat was resorbed. The chemical composition of the adipose tissue showed a decline in the per cent of fat of the maintenance animals as compared with the check, and likewise an increase in the water and protein content. The height growth of animals on maintenance and full feed was quite similiar for several months, later however the full feed animal slightly gained on the maintenance animal, when the nutritive planes of the two animals were reversed, precisely the same results were noted.

The length of the period in which the poorly fed animal will gain in height as rapidly as the highly nourished one will depend upon the constitutional vigor of the individual and the amount of excess fat it is carrying.

A young animal may gain in weight and at the same time lose fat, just as the highly specialized dairy cow may produce a large quantity of milk and at the same time lose in stored body fat. This can only happen in the case of an animal when it is fed under its maximum capacity to grow. Not being supplied with sufficient feed to accomplish this, the animal persumably burns up its own body fat to supplement its feed in an effort to grow to the full limit of its capacity.

The animal has recourse to any or all of the following ways to reach a normal size: (10)

"1. By growing steadily from birth to maturity, as with a uniform and ample food supply.

2. By storing fat in a period of abundant food supply to assist in tiding over a limited period of sparse food supply without serious interruption of growth.

3. By prolonging somewhat the growth period.

4. By an increase in the rate of growth in a period of liberal feeding following a period of low nourishment and low gain.

Aron (5) has demonstrated that growth must cease when the reserve is gone and that a stunted animal will be the outcome. He believes that stunting is far more harmful to young animals than to old animals.

Morgulis (21) from experiments with laboratory animals concludes that "periodic starvation is more detrimental to the organism than acute starvation followed by a liberal food supply."

Haitai (23) has concluded that "so far as the weight of body and central nervous system are concerned, the effect of a 21 day period of partial starvation on albino rats 30 days old is eventually completely compensated."

Osborne and Mendel (24) found that the growth impulse can be retained and exercised at periods far beyond the age at which growth ordinarily ceases. In the case of rats in which the gain of body weight ordinarliy ceased before the age of 300 days, resumption and completion of growth were readily obtained at an age of more than 550 days. Even after very prolonged periods of suppression of growth, the rats were able subsequently to reach the full size characteristic of their species. In this respect there seemed to be no impairment of the individual. The satisfactory resumption of growth was attained not only after stunting and underfeeding, but also after the cessation of growth. The growth in this case was resumed at a size normal for the animal's size at the time. "Though the time of reaching full size may be greatly retarded due to lack of feed etc., growth can ultimately be completed even during the course of long continued retardation."

While a few cases of permanent stunting have been observed, the rate of growth, instead of being decreased, proves to be accelerated after suppression. This has also been observed in the cat by Schapiro (25), in the rat by Thompson and Mendel(29), in the salamander by Springer (26) and in the child by Boas (27) and Hess (28)

A variation in the ration of animals may have some effect on the symmetry of the animal form. Lack of nourishment will retard the development of the individual. The question which arises is, will the animal of smaller stature be in the same proportion with repect to all the organs and the different parts of its body as though it had been nourished to its full capacity and had attained its normal size and maximum development?

Waters (30) found that the more highly nourished the animals were, the more rapid the gain in width of hips relative to increase in height. This means that the height growth of the poorly fed animals was relatively much more rapid than the width growth. When the animals were maintained upon a low nutritive plane the effect upon their skeletal width development was more immediate and more marked than it was upon their skeletal height development. The lower the nutritive plane, the more marked was this tendency. Waters concludes that "the height growth is more persistent than the width growth."

Factors Influencing Growth.

Internal Secretions---Kellicot (31) attempts to solve the mysteries of growth as follows: "It seems quite likely, that in organisms in general the normal growth of each tissue or of each organ is controlled separately by a specific internal secretion. These substances may regulate either through inhibition or acceleration and the effect produced may be due either to the presence or the with drawal of the specific substance."

It is quite well established that the removal of certain glands produces a poor physiological condition, cessation of growth and even death, and that the feeding of the extract of the corresponding gland of another animal causes rapid recovery and growth. This leads us to believe that those glands secrete a substance which regulates growth.

The important glands which are considered to influence growth are;the testes and ovaries, the pituitary body, the thymus, the thyroid, the parathyroid, the adrenal bodies and the pineal body.

According to Abderhaldon (32) one of the most prominent results of the removal of the sexual glands is an abnormal growth of the bones. In castrates it is frequently found that especially the tibia and the femur are prolonged. Apparently castration affects the general metabolism. The greater tendency of castrates toward obesity is well known.

The glands furnishing the internal secretion of the reproductive organs play a prominent part in the development of the sexual characteristics.

Steinach (33) found that feeding testes material was ineffective, but he reports that when young male rats were first castrated and then had transplanted under the skin the ovary of a female of the same species, the secondary characteristics of the male were not developed, but on the contrary the male rat exhibited the female characteristics.

Pathological conditions in the pituitary body have been so frequently connected with abnormal growth that this gland has at times been conceded to bear a close relation to the process of growth. The attempts to modify growth by increasing the normal amount of pituitary secretion present in the body have yielded various results.

Schafer (34) reports that the hypertrophy of the pituitary body results in over development of the skeleton, He concludes that "only a part of the organ produces hormones which stimulate the growth of the body generally and of the skeleton particularly"

Howell (35) agrees stating,"the secretion of the anterior lobe of the pituitary body is connected with the process of growth, particularly of the skeleton."

Schafer (36) claims "that the addition of small amounts of pituitary substances (anterior) to the food of young animals appears to favor their growth; at least it does not impede it." On the other hand Cushing (37) states that repeated injections of the extracts of the anterior lobe failed to produce any constant disturbances except loss of weight. Carletti (38) also found that the injecting into young animals with a pituitary emulsion retarded growth of the bones, especially with regard to length.

Negative results were also obtained by Aldrich (38) and Miller (38) in feeding the anterior and posterior lobe of the pituitary gland. Caselli (38) noted no effect on growth after long continued injections of whole pituitary glycerine extracts but found that ingestion retarded growth in some instances.

Fodera and Pittain(38) observed that emaciation resulted from injection of pituitary extracts. Sandi (38) fed large quantities of ox pituitary to young mice and guinea pigs for a period of two months and found that there was a notable arrest of growth. Wilzen (39) retarded the growth of young fowls by the addition to the diet of fresh parts of the anterior lobe of ox pituitary. This was shown both in the body weight and in the length of the long bones.

The weight of the above evidence indicates that the pituitary body either injected or ingested is able to cause a diminution in rate of growth in young animals.

The physiology of the thymus gland is rather obscure, in fact nothing that is definite can be said about its function except that perhaps the gland is concerned in some way with the process of growth. It was at one time supposed that the gland reaches its maximum size at birth and afterwards undergoes a process of atrophy so that it is entirely absent in adult life. However, more careful observations indicate on the contrary that the gland retains its size and persumably its full activity until the periods of puberty.

Nickerson (40) reports the investigation of a calf which had a thymus in place of a thyroid. The calf was a dwarf with a relatively large head, pug nose, short body, and very short legs. He concludes that the thymus plays a very important part in the growth and development of an animal.

Hutchinson (41) considers the thymus to be associated with growth in young animals. Howell (35) has reported that its removal in young animals results in "first, a stage of increased fat formation and, later one of malnutrition which is shown strikingly in the atrophic and undeveloped conditions of the bones." Paton and Goodall(35) and Haskin (42) on the other hand, find that the removal of the thymus even on the day of birth, has no effect on the rate of growth of guinea pigs.

Howell (35) makes the following statement regarding the thyroid gland, "the loss of function of the thyroid gland results in a late development of the length of bones."

Haskins (43) informs us that the thyroid accelerates the process of carbohydrate metabolism.

Kojima (44) found that the removal of the thyroid gland in rats produces a diminution of nitrogen and calcium output, but that thyroid feeding produces a decrease in body weight and a diminution of nitrogen and gaseous metabolism in all animals whether normal, or those having had the thyroid gland removed, or the parathyroids removed.

Leschier (45) believes that there is a substance produced in the thyroid gland which exerts a very marked influence upon ovarian functions. The cretin, who has no thyroid gland does develop sexually.

Writing of cretinism Mac Leod (46) states that when the thyroid gland is wasted away at birth the condition of cretinism soon becomes developed.

It is not until recently that the importance of the parathyroids has been known. Quite long ago it was dicovered that the complete removal of the thyroid proper in herbivorous animals is not attended by fatal results, later however, it was observed that if the parathyroids also are removed these animals die. Since than it has been shown that when the parathyroids alone are removed, the animals die quickly. When the thyroids alone are removed the animal may survive for a long time, but develop a condition of chronic mal nutrition. Contrary results have been obtained by some investigators. Kojima (44) experimenting with rats found that the removal of the parathyroids did not cause death immediately, but he found that there was an increase of calcium in the urine and less retained in the body. The nitrogenous metabolism showed no definite change.

The experimental results in regard to the importance of the parathyroids has been quite contrary, but it is evident that these glands are of great importance in the proper growth of any animals.

The adrenals may play a part in the role of digestion according to Looper and Vespy(47) who found that intra-muscular injections of adrenalin in human beings caused an increase in the secretion of hydrochloric acid in the stomach as well as augmentation and acceleration of the contractions in the digestive tract.

The functions of the pineal body are obscure. In cases where its extirpation has been successfully accomplished(in the fowl) it has been found that growth is stimulated and the sexual organs develop more quickly. Haskins (43) found that the feeding of the pineal substance produced no detectable effect on growth or organ weight.

The results secured by investigators working with ductless glands is at times contradictory and very little definite information is available. However, their importance in relation to growth can be readily recognized and it is very possible that in the next few years even more important relations will be found.

Pregnancy.

The popular belief is that pregnancy causes a great strain on the body weight of the dam.

Edlefsen and Hensen (48) in separate investigations found that the actual growth of pregnant guinea pigs is slower than that of males of the same age. Minot (48) found that breeding animals after parturition were about 8 per cent heavier than corresponding unmated ones, and concludes, "Gestation does not represent a tax upon the parent but a stimulus--it does not impair growth but on the contrary favors it." (19a). Similiar results were secured by Watson (48).

Eckles(49) has concluded that pregnancy does not check the growth of dairy heifers to any appreciable extent.

Mumford (13b) found no evidence "that the period of pregnancy has a retarding effect upon the growth of the young mother." On the contrary he secured real evidence to indicate an increased tendency to grow, apparently as a direct effect of pregnancy.

The experimental evidence with the different species leads one to believe that the growth of an animal is not materially influenced by pregnancy.

Lactation.

Lactation is a very different phenomenon from gestation. The lactating mother is called upon actually to elaborate from the ingested food materials a large amount of nutriment in the form of milk for the maintenance of her offspring.

Watson (48) who secured a gain in weight of rats during pregnancy, found a rapid loss with both rats and guinea pigs during lactation. Similiar results were secured by Minot (14).

Eckles (11) found lactation to have a strong tendency to check growth and the more immature the animal at the time of the lactation the greater is the check on growth, and the more is the tendency for the check to be a permanent one.

F. B. Mumford (13c) states "the period of lactation is a heavy drain on young sows." The records of his investigation show clearly that when a young sow is suckling a large litter of pigs, growth is inhibited.

Sex.

The male of most species is larger at birth and maturity than the female. Studies of growth curves of both sexes in different species evidence wide variations in rate of growth at different times, particularly at the time of sex maturity.

Proteins that Stimulate Growth.

Since protein constitutes the fundamental chemical basis of the cell, it is natural to devote attention in the first place to this food principle. Protein digestion consists of a breaking down, by means of cleavage and hydration, into proteoses, peptones, polypeptids and amino acids. The amino acids are termed by some as the fundamental "building stones" and are absorbed by the blood and carried to the tissues of the body where they may be resynthesized to form the proteins required by the animal body. In the pioneer investigations, studies on the nitrogen balance in young animals yielded results from which it was concluded that the conditions for the disintegration of protein are less developed in young animals than in mature animals, so that the growing organs rapidly withdraw circulating protein and build it into tissue protein.

In consideration of the accumulation of data extending over several decades, Rubner denied these conclusions, and showed that the diet of the growing animal is by no means relatively rich in protein. He concludes that growth is not proportional to the quantity of protein consumed." Important though this pioneer work may have been in the development of our present day conception, the view point of the men who carried it out was very much narrowed on account of the lack of knowledge concerning the structure of the protein molecule. No allowance was made for the fact, which has been firmly established, that the protein molecule may vary extremely in regard to the units of which it is composed, and that the growing tissues may demand, not so much an abundance of protein as such but rather a proper supply of all the building stones which are required for growth.(50)

There is a marked variation in the units of which different proteins are composed. If any of these units should be essential for growth and the animal be unable to manufacture the missing unit for itself, it is clear that growth could not proceed however much protein not containing the necessary unit we might feed to the animal. It is an application of the law of the minimum and is analogous with the failure of growth which has long been known to ensue when certain inorganic substances are witheld from the animal. A ration might be perfectly balanced as judged by the nitrogen intake and output, and yet if it should fail to contain even one of the essential units and the animal should be incapable of supplying this unit, then would the ration be inadequate for growth.

These important facts are the outcome of modern work, and they have been established by observations on the growth of young animals fed with a "basal ration" to which were added mixtures of amino acids or various proteins which differ considerably from one another in the nature of the units entering into their make-up.

Among the most important observations (51--77) have been those of Mendel and Osborne and Mc Collum and his collaborators. The animals chosen for Mendel and Osborne's experiments were young white rats . Large batches of these animals were fed on a basal ration consisting of protein-free milk(containing the inorganic salts, the sugars, traces of protein, and accessory substances), to which were added more carbohydrates, purified fat, and the protein whose influence on growth it was desired to study. A normal growth curve was obtained by feeding liberal amounts of casein, lactalbumin of milk and ovalbumin and ovovitellin of egg. The following proteins produced a normal curve of growth from vegetable food stuffs. These are edestin (hempseed), globulin (squash seed), excelsin (Brazil nut), glutelin (corn), globulin (cottonseed), glutenin (wheat), glycinin (soybean), and cannabin (hempseed).

That growth proceeds normally when any one of these proteins is fed abundantly does not, however, necessarily indicate that each contains in adequate amounts all the necessary units to meet the protein demands of the growing tissues. In the case of casein, for example, one of the units, namely, glycocoll, which is the simplest of all amino acids, is entirely missing, and another, cystine, which is a sulphur containing amino-acid, is present only in small amounts. The absence of glycocoll, however, is not of importance, because the animal can manufacture it for itself. In the case of cystine, which the tissues cannot manufacture themselves, the deficiency has to be made up by feeding an excess of casein so as to cover the needs of the tissues for this amino acid.

When the supply of casein is limited on the other hand, the curve of growth becomes subnormal, because an insufficient supply of cystine is thereby offered. Similiar results have been obtained in the case of edestin, a protein from hempseed. This is deficient in the diamino acid, lysine. Fed in abundance edestin gave a normal curve of growth, but when fed in insufficient amounts the curve failed to ascend properly, which, however, it could be made to do by adding some lysine to the edestin.

There is a large group of proteins which fail to permit of any growth no matter in what amounts they may be added to the basal ration. These include; legumelin (soybean), vignin (vetch), gliadin (wheat or rye), legumin (pea), legumin (vetch), hordein (barley), conglutin (lupine), gelatine (horn), zein (corn), and phaseolin (kidney bean).

The adequacy to maintain growth of any of these proteins varies according to the deficiency in their amino acids. In the case of gliadin of wheat or rye, glycocoll is lacking, and lysine present in only small amounts. The absence of glycocoll can not, however explain the inadequacy of gliadin as a foodstuff for growth. It must be the lysine that is at fault.

A still more deficient protein is the zein of corn. With this as the only protein added to the basal ration, the curve of growth actually descends. The missing units of this protein are glycocoll, lysine, and tryptophane, and it is very significant that if the latter two amino acids are supplied along with zein, an almost normal curve of growth will result. Some improvement can even be brought about by giving tryptophane alone. In attacking the problem from this view point, Hopkins and Willcock (53) made observations on the survival period of young rats; that is, the period during which the animals survived when fed on a basal diet mixed either with zein alone, or with zein plus small quantities of tryptophane. It was found that, with zein alone, the rats were unable to maintain growth; they lost in weight and died in from about a week to about a month. Other rats fed on the same amount of basal ration and zein, but to which was also added some tryptophane, altho they did not grow, were capable of maintaining the body weight and lived in some instances for nearly a month and a half. There were other indications of the efficiency of the two diets. The rats fed on zein alone were very inactive, the hair was ruffled, the eyes were half closed, and the ears, feet and tail were cold. On the other hand the rats to which tryptophane was also given manifested a striking different behavior, being active and more or less normal until just before death. That both groups of animals failed to live more than 44 to 48 days is partially accounted for by the absence in the zein of the other unit, lysine. Had this been added along with the tryptophane it is probable, in the light of Mendel's and Osborne's observations, that the animals would have survived much longer.

Miss Wheeler (54) also observed the beneficial effect of tryptophane addition to zein foods.

Buckner, Nallau and Kastle (80) have verified the conclusions of Mendel and Osborne in the feeding of mixtures of grain of high and low lysine content to chickens.

Hart, Humphrey and Morrison (80(have shown that corn grain proteins, supplemented with small proportions of the proteins of corn fodder, served for growth with calves, with a storage of approximately 20 per cent of the ingested nitrogen.

Waters (83) secured exceptional results in pigs with the addition of proteins to corn. He mentions that only a part of the protein from corn is capable of supporting growth. "For the purpose of sustaining growth or for maintenance as far as protein may be required we should disregard zein, which is 41.4 per cent of the total protein contained in the corn. If we must discount the efficiency of the proteins of corn 41.4 per cent to arrive at their true value for supporting growth, then instead of corn having a nutritive ration of 1:9 or 10, it has a nutritive ratio of 1:16 to 1:20.

The nature of the protein in oats is not very well established, judging by the following statements. McCollum, Simmonds and Pitz (76) state "The oat kernel seems to contain proteins of a poorer quality than either the maize or the wheat kernel." In another publication they state that "The protein of the oat kernel has a slightly higher value for growth than has that of either wheat or corn, the amount furnished by 90 per cent of rolled oats is below the optimum for the support of growth in a rapidly growing species." Reports from the Wisconsin Station(84) state that in every case where the oat plant was fed, miserably poor offspring has resulted" The authors conclude,however that the results may be due to a deficiency of mineral matter.

McCollum and his associates (51) have recorded numerous observations upon the dietary value of the oat kernel. He states, "We have not yet been able to supplement oats with purified food ingredients and attain optimum results when the oat kernel constituted from 70 to 80 per cent of the food mixture. Gelatin combined with oat proteins forms a much better protein mixture than do casein and oat protein. We have not yet determined the cause, but it is evident that a high intake of oats over a long period causes injury to the rat."

Osborne and Mendel (73) make the following statement with regard to oats, "The successful growth of several of the rats to large size must, we believe, be interpreted to indicate that the total amount of protein of the oat kernel can furnish all the essential nitrogenous units if the intake of food and its concentration are adequate."

The above results do not permit us to draw any definite conclusions as to the value of the proteins of the oat kernel, altho it would appear that they are inferior to those of corn.

The principal protein of wheat yields on digestion as much as 40 per cent of a single amino acid, which forms only 14 per cent of the animal proteins. With this protein as the sole source of amino acids for growth, obviously a considerable part will be wasted.

Osborne and Mendel (85) found that the crude protein of wheat bran had a higher nutritive value for the growing animal than the embryo.

While the definite facts in regard to the proteins from cereal grains are somewhat obscure, certain investigators have obtained fairly satisfactory results through the use of a single grain as the sole source of protein, but only in cases where a high state of concentration of this grain has been used, and only when this grain has been duely supplemented with a sufficient amount of mineral matter and the necessary vitamines.

The various incomplete proteins are not all lacking the same amino acid. For this reason we might expect two or more incomplete proteins, when combined, to be able to supplement each other and better growth result than when either is fed alone. This is one of the basic reasons for rations of a variety of feeds usually giving better results than rations made up of single grains.

We must balance rations not only in respect to the proteins, carbohydrates and fats but also according to amino acids. A complete ration may be secured by mixing several incomplete substances together or to quote Mendel (9) "the amino acid short comings of one protein can be made good by supplementing it with another protein in which they do exist."

Carbohydrates.

Carbohydrates are absolutely essential for the normal metabolism in all animals of all ages. If they are not given with the food, they must be manufactured out of protein by the animal itself. It is not surprising, therefore, that their absence from the ration of growing animals should lead to abnormality in the rate of growth. Other than in regard to digestibility the different carbohydrates seem to be of nearly equal value. It is likely that the carbohydrate required by the tissues is glucose. The readiness with which the carbohydrates of the food become converted into this monosaccharide is probably the only determinant of its efficiency as food material.

Fats.

Although fats are an invariable constituent of practically every diet it is yet a debatable question as to whether they are esential to the maintenance of a healthy normal organism. Fats are closely associated with substances having similiar solubilities and physical properties; namely the lipoids, phosphatides, cholestral, pigments, etc. Since these substances are present in practically every cell, it is almost certain that they can be manufactured by the living protoplasm.

Until recently it was believed that fat was absolutely necessary for any organism, but recent discoveries have shown that fat alone is not absolutely necessary, but some accessory material which it may contain, because all fats do not suffice to produce growth. Vegetable oils as olive oil or almond oil, are inefficient in promoting growth.

Mineral Matter.

The importance of the mineral elements in the nutrition of farm animals has not been recognized until quite recently. It is conceded that the mineral elements such as calcium, magnesium, potassium, sodium, phosphorous, sulphur, iron, and chlorine are required in varying proportions by all animals. Until recent years it has been assumed that the mineral nutrients are contained in abundance in our feeding materials, and as a result little attention was given to the possibility of a deficiency.

Of the minerals mentioned above those in greatest demand during the life of the animal are calcium and phosphorous. This is because of their large use for skeleton development during the growing period of the animal. The other minerals mentioned are also in demand, but their supply is usually ample under ordinary conditions of feeding. For this reason the greatest amount of investigational work has been done with calcium and phosphorous.

Hart (86), McCollum (87) and Osborne and Mendel (88) have shown that inorganic phosphorous, in the form of calcium phosphate and other compounds, can serve as a complete source of phosphorous for a complete cycle of the animal life.

Hart, Steenbock and Fuller (89) state that grains in general are rich in phosphorous, but decidedly deficient in calcium. In the latter, roughages vary widely in their content.

That legume hays are rich in calcium has been shown by Burnett (90) who found that the addition of alfalfa meal to rations for hogs increased the strength of the bones. Hart, Steenbock and Fuller (89) also conclude that "legume hays are very rich in calcium". They also state that "ruminants consuming the usual roughage will ordinarily receive calcium enough for growth".

A lack of calcium does not necessarily inhibit the actual growth of an animal. Voit (91) concluded that animals which received rations low in mineral matter, but otherwise normal and plentiful increased normally in weight. Aron (92) compared the rate of gains made by dogs fed a ration high in calcium with gains made by similiar animals on a ration deficient in this mineral. The rate of gains was practically the same for both rations although the deficiency was so great in the one that the bones of the animal which received it were badly affected.

From the above experiment we may conclude that the calcium supply does not affect the rate of growth to any appreciable degree or determine the size of an individual when mature, though an inadequate supply will bring on abnormal conditions.

The amount of ash supplied in the feed must always be larger than the quantity actually stored in the body, in order to cover the continuous excretion thereof from the body which occurs even in the case of a deficient supply.

Kellner (93) concludes that the ration of the growing animals should contain three times as much of the mineral constituents as the animals are storing daily in the body. On this basis lambs should receive 10 grams of lime and 11 grams of phosphoric acid daily for each 100 pounds of live weight.

The body of even a very young animal contains a large stock of the minerals which can be drawn upon to a certain extent to meet any temporary deficiency in the feed. On the other hand it would appear from Forbe's (94) report that, under favorable conditions, ash may be stored in the bones in excess of the actual requirements for growth and constitute a reserve of mineral matter in the body. An animal appears far less sensitive to fluctuations of its daily supply of ash than those of the organic nutrients because it has relatively a much larger reserve to draw upon.

In dairy cattle and especially swine there is abundant evidence of the evil effects of an insufficient supply of ash.

With beef cattle and sheep a deficiency of calcium is not usually to be feared, since roughages, especially legume hays, are usually rich in this element. Since the common feeding stuffs which are rich in protein are likewise high in phosphorous, the phosphorous supply will usually be ample as balanced according to feeding standards. (89)

Vitamines.

Recent investigations have shown that food furnishing sufficient amounts of proteins, fats, carbohydrates and minerals may not always prove permanently adequate. Hopkins, McCollum and Davis, Hopkins and Nevill, and Osborne and Mendel (95) found in testing the efficiency of various pure proteins and inorganic salts in promoting the growth of young white rats, that artificial diets containing good quality protein, some inorganic salts, starch, and lard nourished animals for a time, but that sooner or latter they ceased to grow, so that they seldom attained more than two-thirds of the weight normal for rats of their age. Some food materials which go to make up a complete ration must have properties beyond those which had up to that time been considered.

The vitamine hypothesis was first advanced by Funk(96) who obtained a crystalline substance from the rice husk in which was carbon, hydrogen and nitrogen and was basic. This substance served as a cure when injected into beri-beri pigeons, and because it was apparently necessary for life Funk gave it the name vitamine.

There are three known vitamines, two of which are absolutely essential for growth. The third is probably not necessary for growth, but the necessity of its presence in the ration for the prevention of scurvy is accepted by most authorities. (97)

No doubt is expressed by any of the most reliable authorities as to the necessity of the fat-soluble A, and water-soluble B, for the promotion of growth in any animal.

In regard to the minimum requirements of these substances for maintenance and growth, McCollum and Simmonds (98) write as follows: "Our results indicate that there is no low plane of intake of either of these substances which can be said to maintain an animal without the loss of vitality. When the minimal amount necessary for the prevention of loss of weight is approached the life of the animal is jeopardized if the diet is persisted in." "Within certain limits growth is proportional to the supply of the fat-soluble A, and water-soluble-B in the diet, all other factors being properly adjusted."

Numerous experiments indicate that it is a dangerous policy to attempt to fast individuals selectively from one or both of these dietary essentials.

Butter and egg-yolk fat were the first known sources of the fat-soluble A vitamine and are probably the richest sources of this accessory food substance. It is known now to be present in many oils derived from the animal kingdom, but in very few oils from plant sources. The primary sources of fat-soluble A are present in green leaves of plants and the embryos of some seeds. (99)

The plant kingdom also provides the primary source of water-soluble B. It is present in wheat (100), corn (101), wheat germ (102) and alfalfa leaves (103).

From a brief discussion we find that in order for an animal to grow there must be present in its ration besides a sufficient amount of protein of good quality, carbohydrates, and minerals, two other factors, the fat-soluble A and the water-soluble B vitamines, and perhaps the third or the anti-scorbutic vitamine.

THE SALT CONSUMPTION OF LAMBS.

The hunger of herbivorous animals for common salt is well known, but practical men have differed as to the necessity or advantage of adding it to the ration. It was at one time believed that salt increased the digestibility of the ration. Kellner (93b) states that besides the physiological action of salt, it serves as a spice which whets the appetite and increases the palatability of many foods. "It also stimulates the secretion of the digestive fluids, hastens the circulation of the fluids of the body, and prevents digestive disturbances. Excessive salt consumption will greatly increase the amount of water excreted in the urine. Abnormal consumption of water as a consequent result will impair digestion and lead to other disturbances. Animals allowed free access to salt or supplied with it at frequent intervals will consume only enough to meet the needs of the body.

Babcock (104) points out that the salt consumption will vary greatly in different localities. Soils containing large quantities of salt produce feeding stuffs more complete in this ingredient. The water of streams and wells will also vary greatly in the salt content. This accounts for the disagreement among experimenters in different parts of the world as to the importance and value of salt.

According to the Farmer's Cyclopedia (105) of Livestock, western sheep raisers never salt their sheep but allow them to eat alkalia, which is safe if it contains 80 per cent salt.

In an experiment in France (93c) in which three lots of sheep were fed the same ration of hay, straw, potatoes, and beans, those receiving a daily allowance of .5 ounce of salt with their feed gained 4.5 pound more per head than those fed no salt, and 1.25 pounds more than those fed .75 ounce per head daily. These results indicate that sheep may be fed too much salt as well as too little salt. The fleeces of the salt-fed sheep were better and heavier than those fed no salt.

THE WATER CONSUMPTION OF LAMBS.

The opinions as to the amount of water necessary for sheep vary more than with any other domestic animal. In countries with heavy dews and large amounts of succulent feeds in the summer, and where roots are largely used in the winter, it may be possible to deny sheep water, but ordinarily water is very essential.

The following table presents data gathered at the Michigan and Colorado Stations (106--109) on the amount of water consumed by fattening lambs, averaging 80 pounds at the beginning of the trials.

Table 11 Water Consumed by Lambs on Various Rations during Fattening.

Ration	Av. daily gain	Water consumed	Water consumed per 100 gain	No. of trials
Michigan	lb.	lb.	lb.	
Grain, clover, open yard	.22	1.4	599	1
Grain and clover	.28	2.8	979	8
Grain, roots, clover	.36	1.9	540	3
Clover hay and sugar beets	.13	.3	314	1
Colorado				
Grain and alfalfa hay	.36	5.1	1,423	2

Adding roots to the ration greatly decreased the water consumption, the lambs fed clover hay and unlimited sugar beets drinking .3 pound daily. Lambs fed in an open yard required less water than those in confinement, due to the lower temperature outside.

Gray and Ridgeway (110) of the Alabama Station found that in late summer ewes in confinement consumed 2.5 pounds of water each while on green sorghum forage, and 6.1 pounds when feed cottonseed meal and hulls.

Coffey (111) found that lambs receiving a large quantity of corn in proportion to alfalfa consumed more water than those receiving less corn and more alfalfa. According to his results the water consumption decreased with the large protein consumption. Table III gives the amounts of water consumed under different conditions.

Table III Water Consumed per Lamb per Day.

Lot	Proportion of corn to alfalfa	Moisture in feed lb.	Water in pails lb.	Total water in feed and pails lb.
1	1 : .99	.21	4.02	4.23
2	1 : 1.36	.22	3.89	4.11
3	1 : 2.42	.19	3.87	4.06
4	1 : 3.45	.18	3.85	4.03

THE NATURE AND RATE OF GROWTH IN LAMBS DURING THE FIRST YEAR.

Growth from a purely practical point of view presents two rather striking peculiarities. One of these is the uniformity with which the framework or skeleton keeps on enlarging even when the supply of food is not very constant. This is shown by some degree of indifference towards food deficiency for relatively long periods as well as by a lack of response toward efforts to force growth by abundance or excess of food.

The other is the extremely sensitive reaction of fleshy tissue to increase or decrease in proportion to the variation in the food supply.

The farm animals show a remarkable uniformity in their tendency to become fleshy and plump during the early stages of growth, provided their natural food (milk) for this period is abundant. With the transition from a suckling diet to one containing some roughage the plumpness of flesh disappears and it is more difficult as well as more expensive to reestablish a similiar state of flesh after the digestive tract has become more dependent on the use of coarser feed with more bulk.

The natural plumpness of the suckling period forms a necessary reserve which assists the young to meet the adjustment to coarser feed without injury to health or too severe a check to development. While a high state of flesh seems to be a necessity during the early stages of growth, it ceases to be essential for the well being of an animal as it approaches maturity.

In the case of lambs that are to be grown to maturity nature does not demand, and practical conditions do not warrant, the prodigal use of grain merely to keep them in a high state of flesh. It has, in fact, been well established that such procedure may be harmful physically as long periods of heavy feeding tend finally to cause digestive disorders.

In the case of lambs that are grown for early slaughter, plumpness is essential, and a rapid increase of flesh is of even greater importance than a rapid growth of frame.

In dealing with the nature and rate of growth in lambs from the purely commercial point of view, the two phases of growth of frame and that of flesh have quite a distinctive significance because of their unlike demands for feed and their unlike response to variation in its quantity and quality.

Table IV shows the results of measurements and weights taken by Ritzman (112) of 62 lambs when 14 and when 280 days old.

Table IV Measurements and Weights of 62 lambs When 14 and When 280 Days Old.

		1	2	3	4
Item		Average at 14 days	Average at 280 days	Enlarged scale height	Increase per cent
Weight	pounds	15.2	68.7		352.0
Height, shoulder	mm	390	575	575	47.5
Head length	mm	115	175	170	52.5
Head width	mm	80	115	120	43.8
Neck length	mm	175	285	260	62.9
Trunk length	mm	320	525	470	64.1
Chest depth	mm	140	260	205	85.7
Chest width	mm	100	170	150	70.0

Table IV--continued.

Item		1 Av. at 14 days	2 Av. at 280 days	3 Enlarged scale Ht.	4 Increase %
Loin width	mm	70	120	105	71.4
Croup length	mm	80	135	120	68.8
Foreleg length	mm	270	395	400	46.3
Hindleg length	mm	305	445	450	45.9

Column 1 shows the animals at 14 days of age; column 2, at 280 days of age; column 3 shows what their proportions would be at 280 days if the growth of all parts were proportional; and column 4 shows tha actual percentage of increase made by the different parts in 266 days.

The percentage of increase shows a wide variation in the rate of growth of the different parts of the body. The head width, head length, and length of legs increased only 45 per cent, while chest depth increased 85 per cent, and body width dimensions about 70 per cent.

Table V shows periodical weighs and measurements (112)

Table V Average Measurements of 52 Lambs by Periods.

Item		Age 2 wk.	Age 4 wk.	Age 8 wk	Age 12 wk	Age 24 wk	Age 40 wk	Age 52 wk.
Weight	pounds	15.5	21.5	37.5	450	53.5	66	67
Height	mm	385	415	475	505	545	575	585
Head length	mm	110	120	135	145	160	175	185
Head width	mm	80	85	95	100	105	115	115
Neck length	mm	175	190	205	220	265	280	280
Trunk length	mm	320	365	440	475	500	520	546
Chest depth	mm	145	160	195	210	235	260	265
Chest width	mm	100	115	130	140	155	170	175
Loin width	mm	75	80	95	100	110	120	120

Table V illustrates that the greatest growth occurs during the earlier stages of life, decreasing with advancing age, as would be expected. There is an exceedingly rapid growth during the first three months. This period produces 50 per cent of the total years' growth. During the second three months there is a considerable slowing up due to the going on pasture at first and latter to weaning. About 20 per cent of the years' growth can be expected during this period, according to Ritzman (112). There is about an equal increase during the fall period of the year and not over 5 per cent during the winter period.

Maturity is probably attained during the end of the second year under normal conditions, the time varying somewhat with different breeds and with care and environment.

Ritzman (112) states "75 per cent of the total growth is completed at the end of one year, in all characters except chest width and loin width, which have attained, respectively, only 55 and 65 per cent of their adult state." This exception is quite in harmony with general observed facts that widening continues after height or length stature has been completed.

In the production of market lambs a rapid growth of frame would have little value unless growth of flesh keeps pace with it. In lambs that are to be slaughtered young, it is important mainly because it increases the capacity for carrying flesh in proportion, for the larger the frame the greater will the weight be in well fleshed lambs. If the lambs are to be grown to maturity they need only to be kept in a thrifty vigorous growing condition. We may distinguish between two types of growth, namely, growing for the market and normal growth.

According to Ritzman's results over 75 per cent of the whole year's weight increase is obtained during the first six months, and the greater part of this, or 67 per c ent of the whole year's weight, is produced during the fir st three months.

The weight increases shown in table V were made under normal conditions of feeding. The lambs had been dropped between the middle of February and the first of April, were grained after the second week and until about two or three weeks after they had been on pasture. After that they received no more grain, the feed during the following winter consisting of roots with one-half native hay and one-half clover or alfalfa.

Chapter IV

METHODS OF EXPERIMENTATION AND CARE OF ANIMALS.

In order to gain as much information as possible, and to make observations upon growing lambs through their first winter an original feeding trial was planned during the fall of 1921 and conducted during the winter of 1921-22 by the writer. This trial was made possible through the assigning to the writer for this purpose, of a group of lambs of the 1921 produce of the University Breeding Flocks.

1. Objects of the Experiment.

1. To determine the comparative efficiency of several rations for producing gains in weight on growing lambs.

2. To determine the comparative effect of these several rations upon the health, thrift and growth made by the lambs.

3. To determine the correlation between growth and gain in weight as affected by the several rations.

4. To determine the relative economy and relative cost of the several rations.

5. To determine the effect of the several rations upon salt consumption.

6. To determine the effect of the several rations upon water consumption.

The object in mind in the selection of the rations was to use rations that had been fairly successful for lamb-feeding, also to use feeds that could be readily grown on

Minnesota farms or would at least be readily available in Minnesota. It will be noticed that all the feeds used are either crops grown in Minnesota or by-products from the manufacture of parts of crops in Minnesota into some other form. The rations used were:

Lot I		Lot II		Lot III	
Clover hay		Clover hay		Clover hay	
Corn silage		Corn silage		Corn silage	
Oats		Oats	35%	Oats	40%
		Corn	35%	Corn	40%
		Bran	20%	Bran	20%
		Linseed meal	10%		

Lot IV		Lot V	
Clover hay		Clover hay	
Corn silage		Corn silage	
Corn		Oats	50%
		Corn	50%

II. <u>The Lambs Used.</u>

The lambs used in this trial were selected from the University flocks. They had been bred and reared under much the same conditions as would prevail in any well managed flock of pure bred sheep. They were born in the late March and April of 1921. They ran with their mothers about the sheep barn and lots until grass became good enough to sustain the ewes. As soon as they were old enough to eat they had access to a creep where they received both grain and hay fed liberally until the ewes were turned to pasture when the feeding of lambs was discontinued until they were weaned. During this period ewes and lambs ran on blue grass pasture. The lambs were weaned when three and one-half months to four months old after which they were again fed grain and pastured on rape until fall when hay feeding was begun. The grain received by the lambs up to the beginning of the trial consisted chiefly of corn, oats, bran, and oilmeal and the hay fed was alfalfa. At the beginning of the feeding trial the lambs were in moderate condition but appeared healthy. Due to the fact that several different breeds were represented there was considerable variation in type and weight but this was taken care of in a satisfactory manner in the grouping of the lots into the several lots.

III. Grouping and Weighing.

Thirty of the most uniform lambs available were divided into five separate lots. They were divided according weight, condition, sex and breed.

Individual weights were taken for three consecutive days at the beginning and at the end of the trial, and also every thirtieth day during the experiment. The monthly weighings made it possible to trace the good feeding and poor feeding of individual lambs and also to ascertain their relative progress during each monthly period of the experiment. The average of the three consecutive weights at the beginning and at the end of the trial was used as the initial and final weights. All the weights were taken at two o'clock in the afternoon.

The lambs ranged in weight from 62 pounds to 100.3

pounds, having an average weight of 81.1 pounds. Because of this variation in weights there were placed 2 heavy, 2 medium, and 2 light lambs in each lot. The average initial weight of each lot was 487.5 pounds.

In the allotment careful attention was paid to condition and quality. Previous to the grouping the lambs were graded in one of the following classes: good, fair, and poor. Each lot was made up of 2 good, 2 fair and 2 rather poor lambs.

Because there were not enough ewe lambs available it was necessary to use 2 wether lambs for each of four lots and three wether lambs for lot III.

The lots were also grouped according to breed. Lambs of purebred Shropshire, Hampshire, Oxford and Southdown breeding were used. There were lambs of at least three of the above breeds in each lot, and in no case were there more than three lambs of the same breed grouped together.

IV. Taking Growth Measurements.

In determining the growth of the lambs, weight is used as a fairly accurate measure of the increase in tissue structures and skeletal measurements are used to indicate changes in the skeleton as nearly as possible. A combination of the two gives a practical measure of total growth.

In attempting to get the skeletal growth, the following measurements were taken:

1. Height at withers.

2. Height at hooks.

3. Height from the floor to the body at the heart-girth.

4. Depth at chest.

5. Length of body.

6. Circumference of body.

7. Width between hip points.

In taking these skeletal measurements the lambs were on a wooden floor and were held in a normal position. All the measurements were taken at three different normal positions and the average figure of these three results is used as the initial stage of growth at the beginning of the feeding trial. Similiar measurements were again taken at the end of the experiment. The heavy fleece was parted so as to get the actual measurements as accurate as possible at the beginning of the test. The final measurements were more easily taken as the lambs were sheared the previous day. All the skeletal measurements were taken in centimeters.

The height at the withers and hooks was measured with a standard having a level attachment on a sliding bar, which could be adjusted according to the height of the animal. The height at the withers was taken at a point midway between the the shoulder blades and in line with the back bone. The height at the hooks was taken at a point midway between the two hook bones and in straight line with the back bone. The height from the floor to the underline at the heart-girth was measured with the standard.

The depth of body was taken at the chest and was measured with a pair of calipers.

The length of body was measured with the standard from the point of the shoulder to the ischium.

The circumference of the body seemed quite well represented by taking a measurement of the heart-girth.

The width of the body was determined by measurements with calipers of the width between the hip points.

V. Shelter and Exercising Yards.

The lambs were fed in the south side of the Station sheep barn, the stable part of which was 9 feet high. The numerous windows and doors in the sides provided a good circulation of air. Exclusive of racks, there were approximately 12 square feet of floor space to each lamb inside the barn and 50 square feet in the lots outside. In fair weather the lambs had access to the outside lots during the day. Each pen had a combination hay and feed rack on one side, which provided 14 inches of rack space per lamb.

VI. Method of Feeding, Watering and Salting.

The lambs had been used to a full grain ration previous to the trial, so they were placed on their respective rations immediately on the first day of weighing and accurate feed records were kept from the second weigh day at which time the experiment actually began.

They were on the desired amount of feed in a short time, except with silage which had to be increased slowly, because no silage had been fed previous to the trial.

The lambs were fed twice daily throughout the trial, at 7 a.m. and 4 p.m. All feed was placed in combination grain and hay racks inside the sheep barn, except the morning feed of hay was fed outside in the yards when the weather was fair.

Just before feeding time, the troughs were carefully swept. Grain was fed first in the morning, followed by hay. Silage with grain scattered over it was fed first in the evening, followed by hay again. The hay was not fed before the grain and silage had been cleaned up. It was a part of the method of feeding to have all edible feed consumed. When any such feed was left, some adjustment was made to prevent a repetition of the occurence. All the lots were fed the same amount of grain with the exception of lot IV, which was on corn. It was necessary to feed less corn than any other single or mixture of feeds because of the high energy content. When warm days appeared the lambs on the corn ration showed a tendency to scour and due to the rather mild winter it was necessary to keep the corn fed lot about 16 per cent below the other lots in the amount of grain consumed.

The lambs had free access to clean, fresh water and salt at all times.

An accurate record was kept of all the feed, salt and water consumed.

Rye straw was used for keeping the pens well bedded.

VII. Composition of Feeds.

The corn fed in this experiment was of good quality, grading No. 3 yellow. The oats was of fair quality, grading No. 4. The bran came from the Northwestern Consolidated Milling Co. It was of choice grade, guaranteed to contain 13 per cent crude protein, 4 per cent fat, 50 per cent carbohydrates and not over 13 per cent crude fiber. The linseed meal was of

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choice grade and old processed ground linseed oilcake, guaranteed to contain 34 per cent protein, 6 per cent fat, 40.5 per cent nitrogen-free-extract and 10 per cent crude fiber. The clover hay was of an inferior quality, containing a mixture of other hay, perhaps about 20 per cent. The corn silage was of good quality, but contained a rather low percentage of corn. The chemical composition of the feeds is shown in table VI.

Table VI Analysis of Feeds by C. H. Bailey, Assoc. Agr. Biochemist, University of Minnesota.

Feed	percent water	percent ash	percent protein	percent fat	percent fiber	percent N-free Ex
Silage	78.63	1.12	1.37	.69	5.66	12.53
Clover	19.39	3.41	6.79	4.16	23.92	42.33
Corn	14.21	1.03	9.31	4.41	1.26	69.78
Oats	9.90	3.91	12.62	4.85	10.09	58.63

The number of pounds of digestible nutrients in a hundred pounds of feed are given in table VII. These amounts were calculated by using the average digestibility given in Henry and Morrison's Feeds and Feeding (Table II--p 647.)

Table VII Digestible Nutrients in 100 pounds of Feed.

Feed	Crude Protein	Carbohydrates	Fat	Total Digestible nutrients.
	Pounds	Pounds	Pounds	Pounds
Silage	.6987	12.575	.5658	13.97
Clover	4.0061	51.6126	2.3712	59.953
Corn	6.8894	66.3114	4.1013	82.4287
Oats	9.8436	51.0218	4.2195	70.3592

VIII. Price of Feed.

The average price of each feed was determined by taking the "Farm Value Estimates" for Minnesota as reported monthly by the Monthly Crop Reporter(113) and Weather Crops and Markets (114), and averaging these and getting a general average price during the period of the trial. The price charged for corn silage was based on the price of corn at silo filling time plus the cost of filling the silo as estimated by Mr. Pond of the Farm Management Division of the University of Minnesota. The prices of feed are shown in table VIII.

Table VIII. Feed Prices.

Feed	First 30 days	Second 30 days	Third 30 days	Fourth 30 days	Fifth 30 days	Average
Corn, per bu.	$ .32	$ .36	$ .43	$ .45	$ .45	$ .40
Oats, per bu.	.24	.26	.30	.28	.28	.27
Linseed M. per ton	42.00	43.50	43.25	50.50	50.75	46.00
Bran, per ton	19.00	22.00	27.00	27.50	26.50	24.40
Clover, per ton	10.90	10.90	11.80	11.20	11.20	11.20
Silage, per ton	3.00	3.00	3.00	3.00	3.00	3.00
Salt, per ton	23.52	23.52	23.52	23.52	23.52	23.52

IX. Length of Feeding Trial.

The feeding trial continued from November 19, 1921 until April 18, 1922, for a period of 150 days.

X. Valuing Lambs at end of trial.

The value of the lambs was determined by the gain in weight, growth and general appearance as to health and thrift.

Chapter V

DISCUSSION OF RESULTS

Consumption of Feed.

As previously mentioned all the lots were fed the same amounts of feed, with the exception of lot IV which received corn as the sole grain. The lambs fed on corn alone as a concentrate were at times difficult to keep on feed. On warm days they were more likely to go "off feed" than the other lambs. These lambs at all times lacked the appetite of the lambs of the other lots. Lots II and III receiving corn 35%, oats 35%, bran 20% and oilmeal 10%; and corn 40%, oats 40% and bran 20%, respectively, were easily kept on feed at all times and had a good appetite during the whole trial. They would have consumed more feed if it had been given to them, this was especially noticeable of lot II. Lots I and V showed about the same desire for feed, cleaning up their feed much more rapidly than lot IV (corn), but not as quickly as lots II (oats, corn, bran and oilmeal) and III (Oats, corn and bran). Table IX shows the average daily consumption of feed during the entire trial for the various lots.

Table IX Feed Consumed per Lamb per Day.

Lot	I Pounds	II Pounds	III Pounds	IV Pounds	V Pounds
Clover	1.123	1.123	1.124	1.123	1.123
Silage	.896	.896	.896	.896	.896
Total Roughage	2.019	2.019	2.019	2.019	2.019
Corn		.52	.594	1.325	.7425
Oats	1.485	.52	.594		.7425

Table IX (continued)

Lot	I	II	III	IV	V
Bran Oilmeal		.297 .148	.297		
Total grain	1.485	1.485	1.485	1.325	1.485
Total Feed	3.504	3.504	3.504	3.344	3.504

Rate of Gain.

A study of table X will bring out the fact that the feeding of corn as the sole concentrate produces very good gains for the first two months, but after that the gains decline a a great deal, and in this case after four or five months of corn feeding gains practically ceased. One lamb in the corn fed lot made average gains for the first three months and during the fourth and fifth month declined in weight so that she weighed 10 pounds less than she did at the beginning of the feeding trial. This lamb and another in the same lot died from enteritis or inflammation of the intestines during the latter part of April. This inflammation may have been due to the feeding of corn as the sole concentrate, but the fact that a lamb in lot III (corn, oats and bran) died from the same intestinal trouble in February detracts from the correctness of this conclusion. The lamb in lot III, that died from enteritis, was in a poor condition at the beginning of the experiment. This lamb also showed the presence of a few stomach worms on post mortem examination.

Table X shows that the lambs fed on corn as the sole concentrate made the lowest gains for the entire period and required the most feed per pound of gain. The lambs fed on oats as the sole concentrate made slightly higher gains than the lot fed corn, making an average daily gain of .1324 pounds as compared with .1271 pounds for the lot on corn. The monthly gains were more uniform in lot I (oats) than in lot IV(corn), however, there was also a tendency for the former to decrease during the last two months. The lot fed oats alone as the grain ration required 1.63 pounds less of roughage per pound of gain than the lot receiving corn alone, but .8 of a pound more grain, which is probably due to a larger amount of total digestible nutrients in a pound of corn than in a pound of oats.

Lot V (corn and oats) ranked third in the gains made and the amount of feed required per pound of gain. The daily gains were .0142 pounds more daily than those of the lambs fed oats. Lot V required 1.082 pounds of grain and .494 pounds of roughage less per pound of gain in weight than the lot fed oats.

Supplementing 20 per cent of the corn and oats mixture with bran (lot III) gave only .0055 pounds more daily gain pr lamb or only 2 pounds more for the lot during the five month trial. This shows that the addition of 20 per cent bran to an equal mixture of corn and oats was not of any great value in producing additional gains. It's use should depend almost entirely upon the comparative prices of oats and bran.

The standard ration of corn 35%, oats 35%, bran 20% and oilmeal 10% as shown in table X gave the largest gains and required the least feed for each pound of gain. Lot II receiving this ration made a total gain of 38.8 pounds more than lot III, receiving the next best ration of corn 40%, oats 40% and bran 20%. The average daily gain of lot II was .1904 pounds as compared with .1521 pounds for lot III. The amount of feed required per pound of gain was 10.53 pounds of roughage and 7.69 pounds of grain as compared with 12.64 pounds and 9.28 pounds respectively for lot III.

Table X. Rate of Gain and the Amount of Feed Required per 100 pounds of Gain.

Lot	I	II	III	IV	V
	Pounds	Pounds	Pounds	Pounds	Pounds
Average initial weight	81.025	81.11	81.115	81.108	81.05
Initial weight by lot	486.15	486:66	486.81	486.65	486.31
Monthly gains per lot:					
1st 30 days	27.83	33.82	22.68	34.00	15.33
2nd 30 days	27.22	35.02	36.01	39.85	43.36
3rd 30 days	29.80	34.00	14.50	19.10	18.00
4th 30 days	20.50	30.00	35.25*	13.50	25.75
5th 30 days	13.82	39.90	25.60*	9.00	29.60
Total gains	119.17	172.74	134.04	114.45	132.04
Final weight per lot	605.32	659.40	620.85	601.10	618.35
Average final weight per 1 Lamb	100.88	109.90	106.11	100.68	103.06
Average gain per lamb	19.86	28.79	23.76	19.07	22.00
Average daily gain per lamb	.1324	.1904	.1521	.1271	.1466
Pounds of Feed required per pound of gain					
Clover	8.492	5.858	7.087	8.842	7.656
Silage	6.766	4.668	5.554	7.046	6.108

* 1 lamb in lot III died at the end of third month.

Table X (continued)

Lot	I	II	III	IV	V
Total roughage	14.258	10.526	12.641	15.888	13.764
Corn		2.709	3.712	10.41	5.064
Oats	11.21	2.709	3.712		5.064
Bran		1.548	1.856		
Linseed meal		.724			
Total concent.	11.21	7.69	9.28	10.41	10.128
Total feed consumed	25.468	18.216	21.921	26.298	23.892

Digestible Nutrients Required.

Table XI shows the average amount of digestible nutrients consumed per lamb on the different rations. In looking through the table it may be observed that the highest gaining lot (II) consumed the largest amount of protein and the second to the lowest amount of carbohydrates, thus having the narrowest nutritive ratio which was 1 : 7.9. The second highest gaining lot (III) also received a narrower nutritive ratio than the third most rapid gaining lot (V), but the ration of this lot was wider than the ration of lot I which ranked fourth. Corn, oats and bran formed a ration with a wider nutritive ratio than oats alone, but nevertheless the gains were larger with the former ration. This mixture probably supplies a more complete source of proteins necessary for proper growth than oats as the sole concentrate.

Lot IV, fed on corn, received a ration with a very wide nutritive ratio of 1 : 11.89 and the gains produced were comparatively low. The failure to make proper growth was not only due to a lack of a proper quantity of protein but probably due to a lack of the proper kinds, except for the variety supplied in the roughage which was not sufficient.

Table XI. Digestible Nutrients per day per lamb.

Average daily ration		Protein	Carbohydrates	Fat	Total Dig. Nutr.
Lot I	Pounds	Pounds	Pounds	Pounds	Pounds
Hay	1.123	.04990	.56961	.02662	.67327
Silage	.896	.00626	.11267	.00507	.12517
Oats	1.485	.14618	.75767	.06266	1.04483
Total		.20234	1.43995	.09435	1.84327
			Nutritive Ratio 1 : 8.16		
		Lot II.			
Hay	1.123	.04990	.56961	.02662	.67327
Silage	.896	.00626	.11267	.00507	.12517
Corn	.5205	.03586	.33415	.02135	.42904
Oats	.5205	.05124	.26557	.02196	.36622
Bran	.296	.03700	.12314	.00888	.18026
Linseed M.	.148	.04470	.04825	.00992	.11449
Total		.22496	1.45339	.09380	1.88845
			Nutritive Ratio 1 : 7.39		
		Lot III.			
Hay	1.124	.04996	.57027	.02666	.67409
Silage	.896	.00626	.11267	.00507	.12517
Corn	.5942	.04094	.39403	.02242	.48979
Oats	.5942	.05849	.30317	.02513	.41807
Bran	.2971	.03714	.12360	.00891	.18093
Total		.19279	1.50374	.09019	1.88805
			Nutritive Ratio 1 : 8.85		

Table XI (continued)

Average daily ration		Protein	Carbohydrates	Fat	Total Dig. Nut.
		Lot IV.			
Hay	11123	.04990	.56961	.02662	.67327
Silage	.896	.00626	.11267	.00507	.12517
Corn	1.325	.09128	.87863	.05434	1.09217
Total		.14744	1.56091	.08603	1.89061
			Nutritive	Ratio	1 : 11.89
		Lot V.			
Hay	1.123	.04990	.56961	.02662	.67327
Silage	.896	.00626	.11267	.00507	.12517
Corn	.7425	.05105	.49236	.03045	.61203
Oats	.7425	.07309	.37883	.03133	.52241
Total		.18030	1.55347	.09347	1.93288
			Nutritive	Ratio	1 : 9.78
According to the Wolff-Lehmann Feeding Standard (per lamb of 100 pounds weight.)					
		.30000	1.43000	.05000	
			Nutritive	Ratio	1 : 5.2

As previously mentioned in selecting the combinations of feeds used in the several rations the aim was to use feeds readily available in Minnesota and feeds known to be at least fairly satisfactory for lamb feeding. A comparison of the nutritive ratio prescribed by the Wolff-Lehmann feeding standard reveals a somewhat wider nutritive ratio for all the rations than that prescribed in the standard ration.

Possibly rations with a narrower nutritive ratio would have given better results but it must be remembered that narrowing the nutritive ration would in every case have increased the cost of the ration.

Growth Produced by the Different Rations.

Table XII shows that in the amount of increase in skeletal growth of all the parts measured, with one exception, the lots rank as follows: corn, oats, bran, and oilmeal,(lot II) first; corn, bran and oats, (lot III) second; corn and oats, (lot V) third; oats, (lot I) fourth and corn, (lot IV) fifth. In the increase in height from the floor to the body at the chest, the average increase of lot IV slightly exceeded that of lot I. This exception will be considered again in discussing the percentage increase as expressed in table XIII.

Table XII The Average Increase per Lamb of Several Skeletal parts as affected by the different Rations.

Measurement	I	II	III	IV	V
	Cm.	Cm.	Cm.	Cm.	Cm.
Height--withers	3.07	4.558	3.706	2.98	3.46
Height--hooks	3.06	4.454	3.670	2.952	3.425
Heart-girth	5.485	7.745	6.462	5.238	6.181
Length	4.883	7.271	5.922	4.733	5.558
Width--hips	1.238	1.808	1.468	1.161	1.418
Depth--chest	1.39	1.955	1.622	1.28	1.548
Height--floor to body	1.53	2.29	1.858	1.66	1.738

Table XIII shows the same order or rank of the rations as table XII. It will be noticed that the exception noted in the preceding paragraph has disappeared, when the increase in skeletal growth is calculated to a percentage basis.

In this case another exception is noted in the average percentage increase in the depth of chest of lot III, which ranks below lot V and barely equal to lot I in this respect, while it is above both of these lots in gains in weight and percentage increase of the other skeletal parts measured. Just how to account for this specific variation is difficult. The difference is so small, however, that it may be due entirely to experimental error.

Table XIII The Average Percentage Increase per Lamb of the Skeletal parts as Affected by the Different Rations.

Measurement	I	II	III	IV	V
	Percent	Percent	Percent	Percent	Percent
Height--withers	5.60	8.38	6.83	5.50	6.25
Height--hooks	5.45	7.91	6.56	5.26	6.00
Heart-girth	7.56	10.26	8.88	6.99	8.32
Length	8.17	12.35	9.95	7.35	9.48
Width--hips	7.94	11.59	9.31	7.38	8.93
Depth of chest	5.93	8.43	5.92	5.37	6.33
Height--floor to chest	4.409	6.98	5.32	4.29	5.12

Correlation Between Growth and Gains in Weight as Affected by the Several Rations.

The number of pounds of gain for each centimeter increase in height at the withers, length of body, width of hips and depth of chest has been tabulated in table XIV.

The uniformity between the number of pounds of gain compared with each centimeter of growth is quite marked and indicates a close correlation between skeletal growth and rate of gain in in body weight of lambs in a normal growing condition , however, lambs that are in an abnormal condition of health, due to feed or other causes, do not show such a marked correlation. This is especially noted in the case of lamb 1718 of lot IV. This lamb lost 10 pounds in weight but made a slight skeletal growth.

Table XIV. Correlation between skeletal growth and Increase in Bodily Weight.

No. of lamb	Pounds of gain	Increase at withers	No. of lb. of gain for each Cm. increase	Increase at length	No. of lb of gain for each Cm. increase
		Cm.		Cm.	
1706	63.16	9.79	6.45	15.68	4.02
1708	18.50	2.89	6.40	4.64	3.98
1760	6.84	1.03	6.64	1.65	4.14
1750	19.34	2.99	6.46	4.71	4.53
1744	4.00	.59	6.78	.86	4.65
1712	7.33	1.16	6.32	1.76	4.16
Total lot I	119.17	18.45	6.46	29.30	4.06
1748	23.87	3.67	6.58	5.92	4.03
1747	32.17	5.6	5.74	8.91	3.61
1733	34.	5.47	6.21	8.64	3.93
1735	41.5	6.36	6.52	10.24	4.05
1746	26.6	4.15	6.40	6.56	4.05
1720	14.6	2.10	6.95	3.36	4.34
Total lot II	172.42	27.35	6.30	43.63	3.95
1725	36.80	5.58	6.59	8.96	4.10
1716	13.67	2.12	6.44	3.40	4.02
1715	18.17	2.66	6.83	4.16	4.36
1740	24.59	4.10	5.99	6.61	3.72
1738	25.27	4.07	6.24	6.47	3.90

Table XIV. (continued)

No. of lamb	Pounds of gain	Increase at withers	No. of lb. of gain for 1 Cm.	Increase at length	No. of lb. of gain for 1 Cm.
Total lot III	118.50	18.53	6.39	29.60	4.00
1709	36.67	5.49	6.67	8.63	4.24
1704	10.44	1.40	7.45	2.24	4.66
1756	33.17	4.28	7.45	6.76	4.90
1718	-10.	.10	.00	.18	.00
1751	24.00	3.66	6.55	5.91	4.06
1742	20.67	2.98	6.93	4.68	4.41
Total lot IV	114.45	17.91	6.39	28.40	4.03
1702	16.34	2.53	6.45	4.01	4.07
1736	32.25	4.98	6.48	7.92	4.07
1734	30.67	5.08	6.03	8.03	3.81
1732	29.67	4.60	6.45	7.79	3.82
1749	9.47	1.62	5.84	2.56	3.69
1764	13.67	1.97	6.94	3.04	4.49
Total Lot V	132.07	20.78	6.35	33.35	3.96

No. of lamb	Pounds of gain	Increase in width of hips	No. of lb of gain for 1 cm.	Increase in depth of chest	No. of lb. of gain for 1 cm.
		Cm.		Cm.	
1706	63.16	3.92	16.11	4.38	14.42
1708	18.50	1.16	15.94	1.30	14.23
1760	6.84	.45	15.20	.46	14.87
1750	19.34	1.21	15.98	1.38	14.01
1744	4.00	.23	17.39	.26	15.38
1712	7.33	.46	15.93	.56	13.08
Total lot I	119.17	7.43	16.03	8.34	14.29

Table XIV (continued)

No. of lambs	Pounds of gain	Increase in width of hips	No. of lb of gain for 1 cm.	Increase in depth of chest	No. of lb. of gain for 1 cm.
		Cm.		Cm.	
1748	23.87	1.43	16.69	1.64	14.55
1747	32.17	2.25	14.29	2.19	14.68
1733	34.00	2.08	16.34	2.22	15.31
1735	41.50	2.56	16.21	2.86	14.51
1746	26.60	1.71	15.55	1.91	13.92
1720	14.60	.82	17.80	.91	16.04
Total lot II	172.74	10.85	15.92	11.73	14.72
1725	36.80	2.13	16.33	2.16	17.03
1716	13.67	.91	15.02	1.01	13.53
1715	18.17	1.03	17.64	1.18	15.48
1740	24.59	1.67	14.72	1.90	12.94
1738	25.27	1.60	15.79	1.86	13.58
Total lot III	118.50	7.34	16.40	8.11	14.61
1709	36.67	2.01	18.44	2.10	17.46
1704	10.44	.56	18.64	.64	16.31
1756	33.17	1.83	18.12	2.00	16.58
1718	-10.00	.00	.00	.00	.00
1751	24.00	1.39	17.26	1.62	14.81
1742	20.67	1.18	17.51	1.32	15.65
Total lot IV	114.45	6.97	16.42	7.68	14.90
1702	16.34	1.09	14.99	1.13	14.46
1736	32.25	2.01	16.04	2.16	14.93
1732	29.67	1.89	15.69	2.13	13.92
1734	30.67	2.10	14.60	2.30	13.33
1749	9.47	.64	14.79	.73	12.79

Table XIV. (continued)

No. of lamb	Pounds of gain	Increase in: width of hips	No. of lb. of gain for 1 cm.	Increase in depth of chest	No. of lb. of gain for 1 cm.
		Cm.		Cm.	
1764	13.67	.78	17.52	.82	16.67
Total lot V	132.07	8.51	15.51	9.27	14.24

Health, Thrift and Condition of Lambs as Affected by The Different Rations.

Table XV brings out the general condition, as represented by covering of flesh, health and thrift, at the beginning and at the end of the trial. In order to get a basis upon which to compare the different lots, 10 points was given to a lamb grading good and 5 points to one grading fair with variations depending on the degree of variation. A lamb grading good plus was given 11 points while one grading good minus was given 9 or 8 points, depending on the degree of difference as ascertained by the eye and hand of the judge.

Table XV. Grades of Lambs at the Beginning and the End of the Experiment.

No. of lamb	Initial Grade	Score	Final Grade	Score	Per cent Increase
1706	fair	5	good	10	
1708	fair	5	fair	5	
1760	fair	5	fair	5	
1750	good	10	good	10	
1744	fair	5	fair-	4	
1712	poor		fair	5	
Lot I----Total		30		39	30.

Table XV. (continued)

No. of Lambs	Initial Grade	Score	Final Grade	Score	Per cent Increase
1748	fair	5	good	10	
1747	good	10	good	10	
1733	fair	5	good	10	
1735	fair--	3	good	10	
1746	poor		good	10	
1720	good	10	good	10	
Lot	II----Total	33		60	81.8
1725	fair	5	good	10	
1716	fair	5	good	10	
1715	poor		poor		
1740	good	10	good	10	
1713	poor	died			
1738	good	10	Very good	12	
Lot	III---Total	30		42	62.6 #
1709	good	10	good -	9	
1704	good	10	good	10	
1756	fair	5	fair--	3	
1718	poor		poor		
1751	poor		fair	5	
1742	fair	5	good	10	
Lot	IV---Total	30		37	23.3
1702	poor		good--	8	
1736	good	10	good	10	
1732	good	10	good	10	
1734	poor		good	10	
1749	fair	5	fair	5	
1764	fair	5	fair	5	
Lot	V---Total	30		48	60

#Calculated on percentage basis

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Table XV credits the largest per cent increase in general condition and health, by far to lot II which received the standard ration of corn 35%, oats 35%, bran 20% and linseed meal 10%. The corn 40%, oats 40% and bran 20% ration (lot III) comes second in its effect on the health of the lambs, although it is followed very closely by the corn and oats ration of lot V. Lot IV, receiving corn, again ranks last in the general appearance of the lambs as affected by this concentrate being used alone.

The Cost of Gains.

Without considering the total effects of the several grain rations they rank as follows in the economy of wintering lambs: Corn, first; corn and oats, second; oats, third; corn, oats and bran, fourth; and corn, oats, bran and oilmeal, fifth. In measuring the economy of these rations it is more accurate to consider the cost of producing one pound of gain, especially when we find that there is a rather close correlation between the gain in weight and skeletal growth and also the health and thrift of the lambs.

On the basis of cost per pound of gain the different rations rank as follows: corn (lot IV), first; oats, corn, bran and oilmeal,(lot II), second; corn and oats,(lot V) third; corn, oats and bran (lot III), fourth; and oats (lot I), fifth. Corn is the cheapest per pound of gain, but when we consider that two of the lambs on this ration died several weeks after the completion of the experiment, we realize that this economy is of no real value. The standard ration of corn, oats, bran and oilmeal (lot II) cost only 1 cent more for each pound gained

and all the lambs were in a splendid condition at the end of the trial. The corn and oats ration (lot V) cost 1.43 cents per pound more than the standard ration and did not produce such a thrifty looking lot of lambs. Supplementing corn and oats with bran (lot III) proved rather expensive due to the small additional gains. It added .63 cents to the cost per pound of gain.
Oats as the sole grain (lot I) made the most costly gains, amounting to 16.02 cents per pound as compared with 14.56 cents for the standard ration and 13.93 cents for the corn and oats ration. This is due partly to an 18 per cent higher cost per pound of oats than corn and less total digestible nutrients per pound than is present in corn.

Table XVI shows the relative cost of wintering lambs and the cost per pound of gain for the different rations used.

Table XVI Cost of Wintering per Lamb and Cost per Pound of Gain as Affected by the Rations.

Lot No.	I	II	III	IV	V
Clover	$ .944	$ .944	$ .944	$ .944	$ .944
Silage	.201	.201	.201	.201	.201
Corn		.556	.636	1.420	.795
Oats	1.879	.659	.752		.940
Bran		.543	.543		
Linseed meal		.512			
Salt	.017	.02	.018	.016	.0167
Total per lamb	$ 3.041	$ 3.435	$ 3.094	$ 2.581	$ 2.896
Cost per day	$ .0202	$ .023	$ .0206	$ .0172	$ .0193
Cost per lb.gain	$ .1602	.1246	$ .1456	$ .1140	$ .1393

The feed prices used in this thesis are covered in table VIII on page 63.

The prices of feeds vary from year to year so that a ration that produces cheap gains one year may not do so the next. Feeds that are high priced in one locality may be low priced in another. For these reasons we can draw no definite conclusions with regard to the cost and economy of gains. Each feeder must study out the comparative cost of each feed, based on results, under his special conditions.

The Salt Consumption as Affected by the Different Rations.

The average amount of salt consumed per head daily of all the lots was .1628 ounces, there being a range from .144 ounces in lot IV to .181 ounces in lot II. The detailed amounts are presented in table XVII.

Table XVII. Amounts of Salt Consumed and Relation to Potassium Present in the Grain Ration.

Lot No.	I	II	III	IV:	V
Total salt per lot for 150 da.	8.9 lb	10.2 lb	9.5 lb	8.1 lb	8.5 lb.
Total salt per lamb for 150 da	23.73 oz	27.2 oz	25.33 oz	21.6 oz	24.25 oz
Amount of salt consumed per lamb daily	.158 oz	.181 oz	.169 oz	.144 oz	.162 oz
Amount of salt required per pound of gain	.824 oz	1.425 oz	1.151 oz	1.087 oz	1.014 oz
Total Potassium in grain ration FOR 150 days	6.487 lb	10.90 lb	8.85 lb	4.78 lb	6.412 lb.

Table XVII indicates somewhat of a variation in the amount of salt consumed by each of the five lots. To what is this difference due? According to Smith (115) "the chief salts used by the herbivora are those of potassium." The herbivora require the addition of sodium chloride to the feed because the potassium salts normally withdraw sodium from the body, the latter being replaced with the addition of common salt. This would lead one to be believe that there is a relationship between the potassium content of the feed consumed and the amount of salt necessary for the proper metabolism of the salts. A study of table XVII will bring out a relationship between these two factors. Lot II, which received the most potassium, consumed the most salt. Lot IV, receiving the least amount of potassium, consumed the least salt. In this experiment the salt consumption increased with the amount of potassium consumed in the feed.

The Water Consumption as Affected by the Several Rations.

Table XVIII shows how the different rations affected the consumption of water. The amount of water consumed in the feed averaged 1.095 pounds daily for all the lambs.and was about about the same for all the lots. The average consumption of water from the pails was 4.28 pounds per lamb daily. The daily consumption varied from 3.99 pounds in the slowest gaining lot (IV) to 5.04 pounds in the fastest gaining lot (II). This may lead one to believe that the amount of water consumed is quite closely related to the rate of gain, however, this cannot be concluded. It is very likely though that the processes of mastication, digestion, absorption and assimilation are more efficiently carried on when a rather large amount of water is consumed as compared with a more limited amount. Since all the lambs had free access to water at all times there is no reason why sufficient amounts should not have been consumed for the most effecient functioning of the digestive tract.

The amount of water consumed per pound of gain averaged 28.56 pounds for all the lots, being higher for the slow gaining lots and lower for the more rapid gaining lots.

The average amount of water consumed for each pound of dry matter in all the lots was 1.81 pounds. These amounts did not vary a great deal except with the lot (II),receiving some oilmeal, in which case 2.1 pounds of water was required. This is possibly due to the laxative effect and high protein content of oilmeal, which causes a greater demand for water than a more carbonaceous feeds. Table XVIII shows the nature of the water consumption in detail.

Table XVIII The Nature of the Water Consumption.

Lot No.	I	II	III	IV	V
	Pounds	Pounds	Pounds	Pounds	Pounds
Total water consumed in pails per lot--120 days	2930.4	3628.8	2731.8#	2872.	2937.6
Total consumed in feed per lot 120 days	770.7	786.48	721.57#	800.66	794.04
Daily consumption per lamb from pails	4.07	5.04	4.23	3.99	4.08
Moisture in daily feed	1.070	1.092	1.098	1.112	1.103
Total consumed daily in feed and pails	5.14	6.132	5.328	5.102	5.183
Water consumed from pails per lb gain	31.73	26.12	24.53	35.26	25.17
Water consumed from pails per lb. of dry matter	1.68	2.10	1.77	1.80	1.71

One lamb died in lot III at the end of the third month.

Economically speaking, the amount of water consumed is of no importance. There is,however,a variation in the amount of water consumed by lambs receiving different kinds of feed, not only as a result of a difference in the moisture content, but probably due somewhat to a difference in the kinds of digestible nutrients consumed.

Individual Gains

No matter how carefully selection is made, it is practically impossible to secure lots of lambs, or any kind of of stock, without including individuals considerably different in their capacity to make gains.

A large variation in the individual gains within each lot is shown in Table XIX. These variations are due to several factors, such as initial weight, condition, health and thrift at the beginning of the trial and breed.

The lambs in lot II, receiving the standard ration of corn 35%, oats 35%, bran 20% and oilmeal 10%, made the most uniform gains of any of the lots. The average variation from the average daily gain was 25.39 per cent. The same variable factors, outside of grain, were present within each lot, so that the lambs within each group all had an equal opportunity to make uniform gains. The fact that the lambs of lot II made the most uniform individual gains is another advantage in favor of the standard ration. The smaller lambs and some less robust were given more of an opportunity to make a headway on this ration.

On the other hand if we compare the individual gains made by the lambs in lot IV (corn) we find a variation of 68.51 per cent. Lambs in this lot who were rather small and secondary in health and thrift were given another setback by being compelled to eat corn as the sole concentrate, while the larger and more robust lambs were better able to withstand the undesirable effects of the corn grain ration.

Table XIX Individual Gains

No. lamb	Breed	Initial Weight	Variation from aver. Initial Wt.	Final Wt.	Total gain	Average daily gain	Variation from Av. daily gain	
Lot I:		Pounds	per cent	Pounds	Pounds	Pounds	Pounds	Percent
1706	Hamp	96.5	19.09	159.66	63.16	.4210	.1562	117.98
1708	Oxfor	87.33	7.78	105.83	18.50	.1233	.0091	6.87
1760	Shrop	81.66	.78	88.50	6.84	.0456	.0868	65.56
1750	So.Do	78.66	2.91	98.	19.34	.1289	.0035	2.64
1744	So.Do	72.50	10.52	76.50	4.00	.0266	.1058	79.90
1712	Shrop	69.50	14.22	76.83	7.33	.0488	.0836	63.14
			9.216					39.34
Lot II								
1748	Hamp	100.33	23.69	124.2	23.87	.1591	.0313	19.67
1747	So.Do	84.33	3.97	116.5	32.17	.2144	.0240	12.60
1733	Hamp	84.	3.56	118.	34	.2266	.0362	19.01
1735	Shrop	79.	2.60	120.	41.5	.2766	.0862	45.26
1746	Shrop	62	23.56	88.6	26.6	.1773	.0131	6.88
1720	Shrop	77	5.06	91.6	14.6	.0973	.0931	48.94
			10.406					25.39
Lot III								
1725	Oxfor	95	17.10	131.18	36.8	.2453	.0932	61.27
1716	Oxfor	82.33	1.497	96.	13.67	.0911	.0610	40.10
1715	Oxfor	72.83	10.21	91.	18.17	.1211	.0310	20.31
1740	Shrop	68.66	15.35	93.25 #	24.89	.1659	.0138	9.07
1713	So.Do	74.76	7.83	90. #	15.24	.1693	.0172	11.3
1738	Hamp	93.33	15.06	118.6	25.27	.1684	.0163	10.71
			11.17					25.46

Table XIX. (continued)

No. lamb	Breed	Initial Weight	Variation from aver initial Wt.	Final Wt.	Total gain	Average daily gain	Variation from average	
		Pounds	Percent	Pounds	Pounds	Pounds	Pounds	Pct.
Lot IV								
1709	Hamp	94.33	16.30	131	36.67	.2444	.1273	100.1
1704	Shrop	91.66	13.00	102.1	10.44	.0696	.0575	45.24
1756	Oxfor	82.83	2.12	116.	33.17	.2211	.0940	74:74
1718	Shrop	77.50	4.44	67.	-10.5		.1971	156.63
1751	Hamp	73.	9.99	97.	24.	.1600	.0328	25.88
1742	So Do	67.33	16.99	88	20.67	.1378	.0107	8.41
			10.47					68.51
Lot V								
1702	Oxfor	96.66	19.26	113	16.34	.1087	.0379	25.85
1736	Shrop	93.5	15.36	125.7	32.25	.2150	.0684	46.65
1732	Hamp	83.33	2.81	113	29.67	.1978	.0512	34.92
1734	Hamp	76.66	5.41	107.3	30.67	.2044	.0578	39.42
1749	Shrop	73.83	8.90	83.3	9.47	.0631	.0640	50.35
1764	Shrop	62.33	23.09	76.	13.67	.0911	.0360	28.24
			12.47					37.57

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SUMMARY OF RESULTS WITH REGARD TO RATIONS.

Lot I, receiving oats as a concentrate, made slightly higher gains and required less roughage per pound of gain than corn; however, this lot required more oats per pound of gain than the lot receiving corn as the sole grain. The lambs receiving oats were more healthy and thrifty than those receiving corn. The oats ration was more expensive than any of the other rations used.

Lot II. receiving oats 35%, corn 35%, bran 20% and linseed meal 10%, made the largest gains and required the least feed per pound of gain. All the lambs in this lot were in a very healthy condition at the end of the experiment. In economy of gains lot II was exceeded only by lot IV, receiving corn as the sole concentrate.

Lot III, receiving corn 40%, oats 40% and bran 20%, made the second highest gains and required the second lowest amount of feed per pound of gain. These lambs were also the second best in health and thrift at the conclusion of the trial. In cost of gain this ration was the second highest priced, being exceeded only by the oats ration in this respect.

Lot IV, receiving corn as the concentrate, ranked the lowest in all the factors considered, except in economy per pound of gain. This last advantage was greatly over-balanced by the disadvantages of low gains, poor health and the death of two lambs after the trial was over.

Lot V, receiving corn and oats, ranked as a close third in rate of gains, amount of feed required per pound of gain, and in the general health and thrift of the lambs at the end of the feeding trial, being exceeded in these respects by lots II and III. In economy of gain, this ration was superior to the ration of lot III.

CONCLUSIONS.

This work is rather limited in scope to allow of the making of definite recommendations but a few points of interest stand out clearly:

1. The grain ration of corn 35%, oats 35%, bran 20% and oilmeal 10% produced the largest gains, the most skeletal growth and maintained the lambs in a more healthy and thrifty condition than any of the other rations used in this trial.
2. There is a rather close correlation between the rate of gain and the skeletal growth of lambs growing under fairly normal conditions.
3. With all the factors considered in this experiment, the standard ration of corn 35%, oats 35%, bran 20% and oilmeal 10% produced the most desirable results with the greatest economy.
4. The average amount of salt consumed per lamb was .16 ounce daily. The larger the potassium content of the ration the larger was the salt consumption.
5. The average amount of water consumed per lamb daily was 5.357 pounds. The amount of water consumed was the greatest with the high gaining lots and the lowest with the slower gaining lots.

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