III. SOME FACTORS AFFECTING THE COMPOSITION OF ROUGHAGE

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Research in chemistry has a broad and varied field. In fact many of the outstanding pieces of research have been along the lines of chemistry known as "pure science," in which the investigator had no practical application for his findings. Such was the case when one man discovered that the double bond in the oleic radical found in cottonseed oil could be broken by the use of a catalytic agent and hydrogen. By this process, he found that the melting point and body of the oil could be changed. It remained for another person to make practical application of this discovery in the commercial field—and to produce the trade compound "Crisco."

In the past two decades investigators in the field of chemistry have looked further into the border-lands of the practical realm, into problems which affect the life of plants, the nutrition of man and of domestic animals. Such a problem is now under discussion—the question of factors which cause variations in the composition of plants. Certain of these variations which occur naturally in the composition of plants, are of economic importance in the livestock industry.

Statement of Problem.

Whitson (1904) has stated that there are two sets of factors which determine the composition of plants in general. First among these are the inherited characteristics or those which depend upon species or variety; and second, those which are produced by the environmental conditions under which the individual plant is grown. Among the environmental factors which cause natural variations in the composition of crops, are:

1. Soil.
2. Application of fertilizing elements.
3. Seasonal rainfall, or water supply.
4. Stage of development of the plant at time of harvest.
5. Leaching, caused by rain or dew.

A brief and fragmentary review of the literature on these five factors will be made. This will be followed by a brief presentation of data accumulated by the author and associates under the direction of Dr. C. H. Eckles at the University of Minnesota.

Review of Literature

1. Soil, a Factor Affecting Composition of Roughages.

As early as 1879, Dircks found that hays grown on an in-fertile soil contained only one-third as much phosphorus as did similar hays grown on a fertile soil. Headden (1897) of Colorado observed in 1894 that fertile soils tend to increase the percentages of protein, crude fiber and ash in alfalfa. Guthrie and associates (1914) found in New South Wales that soils measurably lower in nitrogen, lime, potash and phosphorus, produced grasses the ash of which likewise contained smaller percentages of lime, phosphorus and potash.

	Total ash in dry matter	Composition of ash		
		P_2O_5	Lime	Potash
	%	%	%	%
Average of 8 grasses from poor soils	9.83	0.98	3.08	
Average of 3 grasses from fertile soils	9.93	2.76	9.11	
Average of 17 poor soils		0.047	0.168	0.087
Average 17 fertile soils		0.184	0.465	0.143

Theiler (1924) attributes the low phosphorous content of grasses grown in a part of the Union of South Africa to a poverty of phosphorus in the soil. Tuff (1923) found the same relationship to hold in the case of vegetation grown on a phosphorus-deficient soil in southern Norway. Elliott and co-workers (1925) found that sheep preferred to graze in those parts of a meadow where the grasses were more rich in calcium, phosphorus, sodium and potassium, altho the energy value of those grasses were closely similar to that from less palatable areas. They attribute the difference in the mineral content of these grasses in the Falkland Islands, and of Aberdeenshire, Scotland, to fertility of the soil on which they grew.

2. Application of Fertilizing Element.

Ames (1910) of the Ohio experiment station, applied various phosphate fertilizers to wheat, and found a greater influence on the phosphorus content of the straw than of the grain. He (1912) also found that the phosphorus content of alfalfa was increased thru applications of phosphates. Lawes and Gilbert (1884) concluded from 20 years' work with wheat on fertilized plots at the Rothamsted station, that the amounts of ash in the total plant were increased, but that the portion stored in the grain was influenced very little by the amount which the plant took from the soil. Chaven (1908) in Switzerland, found that the phosphorus content of mixed grasses could be increased from 0.11 to 0.24 percent by application of phosphate fertilizers.

Pember and McLean (1925) observed with pot cultures of wheat, oats and barley at the Rhode Island station, that the amount of phosphorus added to the culture usually closely approximated the amount in the harvested plants. The straw varied more widely in percentage of phosphorus, depending more directly upon the amounts supplied during the growing season. Duley and Miller (1921) found similar results concerning the use of nitrogen and potash by the corn plant. Their data confirmed the results obtained by Parrozzani (1907) in Italy. Woods (1889) noted that the protein content of corn and stover were greater when nitrogen carriers were applied to the growing crop. Theiler and co-workers (1924) found that applications of phosphate carriers to a deficient South African soil improved the feeding qualities of the grasses due to an increase in the phosphorus content of this forage.

3. Seasonal Rainfall, or Water Supply.

Water, of course, is essential to the life of the plant. The amount of water available for use of the plant during the growing season also influences the amount of soluble plant food derived from the soil and stored within the plant. It was noticed in parts of Germany that years of drouth were accompanied by a mineral deficiency disease of livestock, caused by the lack of certain mineral elements in the forage grown under these conditions. The same occurrance has been observed in many parts of the world, and reported by such men as Guthrie (1914) of Australia, Theiler (1924) of South Africa, Tuff (1923) of Norway, and Kellner (1894) of Germany, as well as many others.

Von Seelhorst and associates (1900) noted that the phosphorus content of meadow fescue and clover was directly affected by the amount of irrigation water applied during the growing season. Widtsoe and others (1897, 1901, 1912) at the Utah station, worked with such crops as the cereal grains, alfalfa, brome, orchard and Italian rye grasses as well as root crops and cabbages. They found, considering the plant as a whole, that there is undoubtedly an increase in the percentages of ash as the quantity of irrigation water is increased. In cereal grains, protein decreased in percentage as the irrigation water was increased. The percentage of protein in the straw also decreased slightly, as well as in the forage crops, alfalfa, timothy, brome, orchard and Italian rye grasses. The ether extract content varied irregularly. In cereal grains the crude fiber remained practically constant, while in the straw crude fiber increased with the amount of irrigation water. With the other forage crops the same tendency was noted. Root crops varied little in content of crude fiber.

Working with oats in pot culture, Forbes (1910) found a relationship between the amount of water applied and the phosphorus content of the plants. He also noted that the use of irrigation water on alfalfa, bermuda and blue grasses increased the phosphorus content of these plants. Miller and Duley (1925) found that the moisture supply of the corn plant varied inversely with its nitrogen and mineral content. They used a fertile soil in all lots, rather than a limited food supply to the experimental plants.

4. Stage of Development of the Plant at Time of Harvest.

Many studies have been made on the corn plant and others, which show that in general the dry matter and crude fiber content of the plants increases with advancing maturity. Perhaps the largest number of these investigations have been conducted on the corn plant. As early as 1882, Horneberger (1882) made studies of the chemical changes occuring during the growth of maize. Further extensive studies have been made under widely varying soil and climatic conditions at the Missouri (Duley and Miller, 1921; Miller and Duley, 1924; Schweitzer, 1889) Kansas (Failyer and Willard, 1889) Geneva, New York (Babcock, 1883; Ladd, 1890), Michigan (Smith, 1898), Indiana (Jones and Huston, 1914), North Dakota (Hopper, 1925; Ince, 1916) and Nebraska (Kiesselbach, 1922) agricultural experimental stations. In general it was found that the dry matter, ether extract and nitrogen-free extracts increase with age of the plant, while the crude protein and ash decrease in percentage during the same period. In the stalk and leaves the percentage during the same period of growth, but when the grain is taken into consideration, the percentage of crude fiber in the total plant decreases from the tassel stage to maturity. Nine flint varieties of corn grown in North Dakota (Hopper, 1925) contained a larger percentage of crude protein, ether extract and ash but less crude fiber than nine varities of dent corn.

Average Composition of Dent and Flint Corn at Different Stages of Maturity (N. Dak. Bul. 192, p. 14).

Fodder (entire plant)

	Dry matter	Ash	Crude protein	Ether extract	Crude Fiber Ear	Crude Fiber Stover	Crude Fiber Fodder	N-F-E
	%	%	%	%	%	%	%	%
Tassel	13.48	8.53	11.65	1.68			27.66	50.48
Milk	1847	6.49	8.95	1.57	1886	28.04	26.08	56.91
Dough	25.02	5.51	8.22	2.20	11.83	29.77	22.52	61.55
Glazed	32.72	5.38	8.33	2.67	9.57	33.53	21.42	62.20
Ripe	43.01	5.00	8.19	2.94	8.59	34.37	20.29	63.58

With sudan grass, Gaessler and McCandlish (1918), and Piper (1913) found a decrease in the percentages of crude protein, ether extract and ash, while an increase was noted in the percentage of nitrogen-free extract, crude fiber and total dry matter, with maturity. Waters (1915) observed that the protein, ether extract and ash decrease in timothy with growth, while the nitrogen-free extract increases. Little variation in the content of crude fiber was noted after the heads formed.

Elliot and associates (1925) found that the mineral content of native grasses varied thruout the season in Aberdeenshire, Scotland. Chlorine increased in amount as the grasses matured, while the percentage of lime and phosphorus appeared to decrease after mid-summer. The energy value of the dry matter varied slightly from month to month. Theiler (1924) also noted a wide range in the phosphorus content of grasses grown on a deficient soil, this being especially low at the close of the growing season.

5. Leaching Caused by Rain and Dew.

Headden (1904) observed that a single rainfall of 1.76 inches washed out a large amount of the soluble food compounds from a cutting of alfalfa hay. The protein content was decreased one-third, while the nitrogen-free extract decreased five percent in amount. Due to the losses of soluble matter, the crude fiber was nearly one-third higher in the remaining leached sample.

	Crude fiber %	Crude protein %
Sample not rained on	26.46	18.71
Hay rained on (1.76 inches)	38.83	11.01

Ames (1912) observed that about three-fourths of the phosphorous could be dissolved out of alfalfa hay with water. LeClerc and Breazeale (1908) sprinkled samples of forage with distilled water and found that the water removed rather large amounts of soluble mineral matter from the plants. Jones and Huston (1914) of Indiana, noted that heavy rains in October made marked reduction in the potassium content of corn stalks and ears. Losses due to exposure to the weather for 35 days, with corn in the shock, amounted to 21.5 percent of the total dry matter, 31.3 percent of the potash (K_2O), 15.6 percent of the phosphoric acid (P_2O_5), and 25.9 percent of the nitrogen. Losses were greater from the leaves than from the ears.

Presentation of Data.

Cattle were suffering from what appeared to be malnutrition in a part of Minnesota. In the years prior to 1923, numbers of letters were received by the Minnesota experiment station staff relative to troubles occurring among cattle, many mentioning that they suspected the feeds to be the source of the trouble. These complains were more numerous during late winter and early spring. The commission men at the South St. Paul stock-yards also complained that the poorest quality of cattle as regards size and fatness, came from these same parts of the state.

Beginning in the summer of 1923, members of the Minnesota experiment station staff, including the author, began to make a thoro study of the condition, under the direction of Dr. C. H. Eckles. Field surveys were made, including personal visits to over 100 farms, collecting samples of feed and other data. The feeds were secured from affected farms and also from unaffected soil areas near by, where cattlemen had had no particular dificulty. A large number of hay samples were secured in 1923, and again in 1924, which were analyzed especially for their content of mineral elements—calcium, magnesium and phosphorus. These particular elements were selected because the survey led those in charge to suspect one or more of these to be concerned in the cause of the trouble.

These feed samples, secured thru cooperation of the division of Dairy Husbandry and Agricultural Biochemistry, were analyzed by Dr. J. R. Haag and F. R. Davison, while a number of feeding trials using feeds and cattle from the area involved, were carried out by the Division of Dairy Husbandry.

The data of most interest to us, are those dealing with the forage samples. The analysis of 68 hay samples will be presented according to soil area where grown, and later according to the year they were collected. It was observed during the survey that the trouble with mineral deficiency occurred on rather sharply defined soil areas, hence the hays were grouped for comparison according to these areas.

Comparison of Hays from Affected and Unaffected Soil Areas

Variety	Area	Number of samples	CaO %	P_2O_5 %	MgO %
Alfalfa hay	affected	14	2.65	0.43	0.71
	unaffected	9	2.46	0.59	0.66
Prairie hay	affected	30	0.58	0.23	0.36
	unaffected	10	0.67	0.25	0.51
Timothy hay	affected	4	0.55	0.25	0.32
	unaffected	1	0.57	0.31	0.35

It will be noted above that in every case the phosphorus content of hays grown on the "affected" soil area is lower in amount. It will also be noted that there is no uniformity in the relationship of calcium and magnesium to the particular condition under investigation. Feeding experiments conducted corrobated the above conclusions.

From three United States Weather Bureau observation stations located near these soil areas, the rainfall data were obtained for the years in which the forage samples were collected. Rainfall in 1923 was 17.29 inches, as against 21.98 inches in 1924. Rainfall is usually more general in nature in this northern country, than in our own state (Oklahoma), so that these figures are of greater significance.

Effect of Rainfall on the Mineral Constituents of Hays Collected.

Variety	Year	Number of samples	CaO %	P_2O_5 %	MgO %
Alfalfa hay	1923	7	2.58	0.46	0.79
	1924	16	2.63	0.51	0.65
Prairie hay	1923	16	0.57	0.17	0.38
	1924	24	0.62	0.28	0.41
Timothy hay	1923	3	0.62	0.25	0.38
	1924*	2	0.45	0.27	0.25

*Both of these samples were from the affected area.

The above data indicates that the plants took calcium and phosphorus from the soil in proportion to the rainfall during the year, and that rainfall is a factor in the mineral content of forage crops on a given soil area.

Prairie hay is more often stacked in the open fields, unprotected and subject to exposure to rain and weather. This was also pointed out as a possible contributing factor, due to leaching out of the soluble mineral elements. However no specific analyses were made covering this particular point, in the Minnesota work. A review of the literature indicates that leaching probably occurs under these conditions.

Discussion of Data

What application has this problem to conditions existing in Oklahoma?

Parts of the state are subject to drouth during some years. It is probable that following such years, cows in milk and growing cattle may suffer to some extent from a lack of mineral matter in the farm-grown feeds. Information from Beckham county, and others, leads me to believe that such has been the case in the past. It is well that we be aware of the factors affecting the composition of feeds, and of the symptoms presented by cattle in the early stages of mineral deficiencies, so as to meet the situation. Additional mineral matter needed under these conditions, can then be most economically supplied as finely ground feeding bonemeal. In areas where the local forage crops are deficient in average seasons, due to soil deficiency, this deficiency can be remedied thru fertilizing the land and thus feeding the growing crops, or by feeding the cattle directly.

Conclusions.

1. Soil affects the percentage of nutrients present in the forage crops grown on it.

2. Applications of fertilizing elements affect the percentage of these present in the vegetative parts of plants more than in the seeds.

3. Seasonal rainfall, or amount of irrigation water supplied to plants during the growing season, may affect the content of nitrogen in both the seed and plant, as well as the mineral elements taken by the plant from the soil.

4. Stage of development of the plant at time of harvest affects considerably the protein, crude fiber, ether extract, ash and nitrogen-free extract content of the plant.

5. Rain and dew may leach out a considerable proportion of the soluble mineral, protein and nitrogen-free extract, and cause an apparent increase in the percentage of crude fiber in plant tissues subject to their action.

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