T H E S I S

ON

THE SIGNIFICANCE OF THE TERM QUALITY

AS APPLIED TO THE UDDER OF THE DAIRY COW

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Introduction

In our text books and many bulletins describing the udder of the dairy cow there are found such statements as the following: "When the milk is removed from the udder that organ should be soft and pliable, showing much shrinkage. The gland tissue should be fine and plastic rather than fatty or coarse and hard. It is desirable to have udders of pliable handling quality. Common defects of the udder are small teats etc., meaty udders , which reduce but little with milking and yield a comparatively small flow."

The foregoing statements are only a few of the many similar statements, but they are sufficient to show the cause of a suspicion of their foundation especially when no reasons are given for their accuracy; furthermore, such statements are vague and meaningless to the student who wants to know the causes of conditions as they are found.

It seemed advisable at this time to begin a project involving the investigation of the accuracy of the idea set before us in such statements as previously mentioned. The factors influencing the udder and production of milk are so many and varied that it is not feasible to give a complete analysis of the project in so short a time and space. Therefore, this paper will deal only with a review of literature published previous to 1918 and with a tentative plan to approach the problem.

Methods

As one studies the literature covering so many and varied factors as presented in this project it soon becomes evident that much of the previous work is of little value in forming a basis for the prosecution of the solution of the problem in question. It is also evident that only a comparatively few workers have given data sufficient to make the statements they do. Still fewer give their technique of procedure in adequate detail. One is led to believe that such articles are unreliable until proved otherwise.

As a result we find a large mass of confusion, contradiction, and mutual animosity. Out of this chaotic mass the following pages are written. In order to eliminate the personalities of the various authors to a minimum and prevent myself from becoming partial to any one writer I have adhered closely to the following method; References were obtained from the Experiment Station Record, Agricultural Index, Veterinary and Medical publications, and the Articles reviewed. Each reference was given a number, the author's name and subject being laid aside. All transfers of any parts of an article were made by numbers. An attempt has been made to arrange this in logical form bearing in mind the truths of the following statements by an unknown author:

When you've got a thing to say,
Say it! Don't take half a day,
When your tale's got little in it,
Crowd the whole thing in a minute!
Life is short--a fleeting vapor--
Don't fill the whole blame paper
With a tale, which, at a pinch,
Could be cornered in an inch!
Boil her down until she simmers;
Polish her until she glimmers,
When you've got a thing to say
Say it! Don't take half a day!

Anatomy

In order to consider the factors involved in the condition presented by the term quality, in describing the udder of the dairy cow, it is necessary to make a comprehensive study of the macroscopical and the microscopical anatomy of the mammary glands of the cow. The following description of the mammary glands will demonstrate clearly the structure with which we have to deal and will present a foundation for studying the changes which may occur to cause the condition described by the term quality. So far very little has been published concerning the chemical composition of the mammary glands. Gross or macroscopical anatomy (124). The mammary glands, normally two in number, are popularly termed the udder. The body of each is somewhat ellipsodial in form, but flattened transversely. They are located in the inguinal region. The base of each gland is slightly concave and slopes obliquely downward and forward in adaptation to the abdominal wall, to which it is adherent; it is in relation posteriorly to the large supramammary lymph glands and a quantity of fat. The medial surface is flat, and is separated from the other gland by a well-developed double septum. The lateral surface is convex. Four well-developed teats are present; they average about three inches in length.

It is customary to consider the udder to consist of four "quarters"; there is no septum nor visible division between the two quarters of the same side, but, on the other hand, injections of fluids of different colors into the two teats of the gland demonstrate that the cavities drained by them do not communicate.

Each teat has a single duct which widens superiorly and opens freely into a roomy lactiferous sinus popularly known as the milk cistern. The lactiferous duct or teat canal is lined by a glandless mucous membrane which is covered with stratified squamous epithelium; the lower part of the canal is narrow, and is closed by a sphincter of unstriped muscle. The mucous membrane of the sinus forms numerous folds which render the cavity multilocular.

The external pudic artery in the cow is usually termed the mammary and is very large, especially during lactation. Each divides at the base of the mammary gland into two branches which are distributed to the anterior and posterior parts of the gland.

The veins of the mammary glands converge to a venous circle at the base of the udder, which is drained chiefly by two pairs of veins. The subcutaneous abdominal vein (milk vein) is very large in animals of the dairy breed, and its course along the ventral wall of the abdomen is easily followed. It is usually flexuous. It emerges at the anterior border of the udder about two or three inches from the linea alba, runs forward, dips under the cutaneous, passes through a foramen in the abdominal wall about a handbreadth from the median plane, and joins the internal thoracic vein. The two veins are connected by a transverse anastomosis at at the anterior border of the base of the udder, and each anastomosis behind with a branch of the external pudic vein. The external pudic vein ascends in the inguinal canal as a satellite of the artery and joins the external iliac vein. The right and left veins are connected at the posterior border of the base of the udder by a large transverse branch. From the latter arises the perineal vein which runs medially upward and backward to the perineum, turns around the ischial arch, and joins the internal pudic vein.

The lymph vessels are numerous, and pass to the supramammary lymph glands chiefly. These glands are situated above the posterior border of the base of the mammary glands. Usually two are present or there may be two on either side. Exceptionally a third gland may be present or there may be only one on one side. The large glands are usually two to four inches long, the smaller ones a fourth to one-half as large. The afferent vessels come from the udder, the external genital organs, and part of the skin of the thigh and leg. The efferant vessels converge to two or three large trunks which go to the deep inguinal glands at the side of the pelvic inlet.

The nerves are derived from the inguinal and the posterior mesentric plexus of the sympathetic.

Histology or microscopical anatomy (3). The mammary gland is a compound alveolar gland. It consists of lobes, each of which is subdivided into lobules. The gland is surrounded by a layer of connective tissue containing more or or less fat. From this periglandular connective tissue broad septa extend into the gland, separating the lobes (interlobar septa). From the latter finer connective-tissue bands pass in between the lobules (interlobular septa). From the interlobular septa strands of connective-tissue extend into the lobule where they act as support for the glandular structures proper. An excretory duct passes to each lobe where it divides into a number of smaller ducts (lobular ducts), one of which runs to each lobule. Within the latter the lobular duct breaks up into a number of terminal ducts, which in turn open into groups of alveoli. The main excretory duct passes thru the nipple and opens on its surface. The main duct presents a sac-like dilitation at the base of the nipple (The Ampulla), which apappears to act as a reservoir for the storage of milk.

The inactive mammary gland consists mainly of connective tissue and a few scattered groups of excretory ducts. Around the end of some of the ducts are small groups of collapsed alveoli. Both ducts and alveoli are lined with a low columnar, often flat epithelium. In some cases the flat layers are two or three layers thick, forming a thin stratified squamous epithelium. The relative amount of fat and connective tissue varies greatly, some inactive mammary glands consisting almost wholly of fat tissue.

The microscopical appearance of the active gland differs greatly from that of the inactive. There is a marked reduction in the connective tissue of the gland, its place being taken by newly developed ducts and alveoli. The alveoli are spheroidal, oval, or irregular in shape, and vary considerably in size. The alveoli are lined by a single layer of low columnar or cuboidal epithelial cells which rest upon a homogeneous basement membrane. The appearance of the cells differs according to the secretory conditions. The resting cell is cuboidal and its protoplasm granular. With the onset of secretion the cell elongates, and a number of minute flat droplets appear. These untie at the free end of the cell. The fat is next discharged into the lumen of the alveolus, and regeneration of the cell takes place from the unchanged basal portion. Active secretion does not as a rule take place in all the alveoli of a lobule at the same time. Each lobule thus contains both active and inactive alveoli. The smallest ducts are lined with a low columnar or cuboidal epithelium. This increases in height with increase in the diameter of the duct until in the largest ducts the epithelium is of columnar type.

Pfaundler (56) distinguishes four typical glandular tissue conditions, which, however, are always closely connected, and are to be taken as occurring in succession in the actively secreting udder.

(a) The alveoli are open, the epithelial cells are cubical and contain clear round nuclei with one or two nucleoli. Mitosis is constantly present in the epithelium; the protoplasm of the cells shows fine granulation and vacuoles. The cells appear indefinite, their outline and limiting surfaces, indistinct. There is a marked infiltration of the alveoli with leucocytes (many eosinophile), which are found in such great numbers in the interstitial tissue and the epithelial layer and lumina of the alveoli; that the remaining structure is only recognized with difficulty.

(b) The alveoli have very narrow lumina and the epithelium is cubical, the nuclei of which seem shrunken. Mitosis is constantly present. The protoplasm of the cells contains coarse granules and fat drops, and the cell outline is indistinct. The interstitial tissue is rich in leucocytes, but less so than in (a). In the lumen of the alveolus leucocytes, colloidal masses and colostrum bodies are present.

(c) The alveoli have very narrow lumina and long, cylindrical, or pyramidal epithelial cells, clearly marked off from one another, some resting flat on the alveolar wall and some suspended by a narrow process. Each cell contains from to three nuclei, and at the free margin of the cell fat drops are often seen. Many of the cells which hang by a tongue of protoplasm into the alveolar space appear as if torn.

(d) The alveoli are dilated. The epithelial cells are flat, and in profile appear as ring-shaped narrow protoplasmic borders with spindle-shaped nuclei; and contain very few fat globules. Mitosis is rarely seen.

(3) The arteries finally terminate in capillary net works among the alveoli and ducts. From the capillaries arise veins which accompany the arteries.

The lymph capillaries form net works among the alveoli and terminal ducts.

The nerve terminals break up into plexuses which surround the alveoli just outside their basement membranes. From these plexuses, delicate fibrils have been described passing through the basement membrane and ending between the secreting cells.

Chemical Composition of the Mammary Glands

(123) The chemical composition of the mammary glands has not been studied in detail. We know, however, that the protoplasm of the functionally active glands is rich in albumins, and it appears that a very complex nucleo-glucoproteid is here present, and is probably intimately concerned in the formation of two of the most important constituents of the milk, viz., the casein and lactose. On boiling with dilute acids the substance is decomposed into albumin, phosphoric acid, and a reducing substance of unknown composition.

The substance is decomposed by boiling the gland with water. A coagulable albumin and a nucleo-gluco-proteid, which is somewhat less complex than the original substance, thus results. Like its mother-substance, it also yields a reducing substance on hydrolytic decomposition.

Of other constituents of the gland, we find various xanthin-bases, and in the functionally active organ also a certain amount of fat which is present in the form of globules of variable size, in the bodies of the cells.

Milk

When speaking of a dairy cow as a good producer the thing in question from a commercial stand point is the quality and quantity of milk secreted.

In order to study the changes that may occur in the mammary glands it is necessary to utilize the knowledge at hand of the specific substance, (milk), which is secreted by these glands.

The specific substance which is secreted by the mammary glands is termed milk, It is the natural food of all mammals during their early extra-uterine existence. It contains all those compounds (proteins, carbohydrates, and fats) which are necessary for their maintenance. The compounds in question are more or less specific of milk and are not found elsewhere in the body as such. They are produced in the gland itself from the common constituents of the blood.

Fresh milk is an opaque, white, yellowish-white, or bluish-white liquid, transparent only when in very thin layers, somewhat sweet in taste and of an insipid odor, peculiar to the particular animal from which the milk has been obtained. The opacity is largely due to the presence of dicalcium caseigogen.

Milk of most herbivorous animals, owing to the presence of diacid and monacid phosphates in association with the calcium of caseinogen, is alkaline to lacmoid and acid to phenolphthalein.

Fat is present in a state of fine emulsion in a feebly alkaline media. On microscopical examination it is found in innumerable small globules. As a result of molecular attraction each globule is surrounded by a delicate layer of albumen. This layer of albumen does not constitute a true membrane. Our present knowledge is incomplete regarding the structure of this particular albumen.

On microscopical examination of milk innumerable granules of Calcium phosphate (probably a mixture of diphosphates and triphosphates) are found. Casein is obtained in the form of a thin jelly-like material when milk is passed through a Chamberlain filter. Casein which is found in combination with lime is not present in solution. Cells are also found in milk.

A resume' of the foregoing will show that cells and calcium phosphate are in suspension in milk. Casein is either in suspension or colloidal state. Fat is in the form of an emulsion. All the other components of milk are present in a state of actual solution. (8) Casein exists in milk in a semi-colloidal condition.

(8) Colostrum differs from milk in that it contains a higher percent of total solids, of albumenoid character; also in the abundance of mineral salts. It

is the result of resting cells, and not a special product. The following table is an example.

(136)	Evening before calving	Immediately after calving I	II	III	IV	Five days after calving
"Extract" at 95°C (solids?)	27.615	24.49	27.356	22.470	24.17	14.37
Fat	1.300	6.32	3.840	1.360	2.42	5.18
Milk sugar	1.520	2.17	2.366	1.023	2.86	4.07
Soluble ash	.278	.25	.220	.271	.19	.26
Insoluble ash	.809	.84	.830	.791	1.02	.51
Calcium phosphate	.622	.63	.660	.605	.87	.38
Proteids	23.705	14.91	20.100	19.025	17.68	4.35
Acidity per liter (P_2O_5)	3.480	2.72	3.360	2.640	2.80	1.60

In order to have a comprehensive understanding of the physiology of the mammary glands it is advisable to consider in some detail the various constituents of milk. They will be considered in the following order: General idea of the composition by tables of analysis; Variations, protein, fat, carbohydrate, inorganic components, and salts, gases and cells.

(123) Cow's Milk

Water	842.8	860.0
Solids	140.0	157.2
Albumins (total)	33.0	43.2
Albumin (proper)	1.2	2.8
Casein	30.2	42.0
Fats	40.0	64.7
Lactose	43.4	50.0
Salts	6.3	7.1

(99) The average composition 197 samples of milk from consecutive milkings of one cow was:

	Total solids	fat	solids not fat
Morning milk	12.59	3.71	8.88
Evening milk	13.09	4.26	8.83

	No. of samples	Specific Gravity	Total Solid	Fat	Solids not Fat
(100) 1903		1.0322	12.78	3.83	8.95
(101) 1904	15,910	1.0322	12.68	3.74	8.94
(102) 1906	14,828	1.0323	12.70	3.73	8.97
(103) 1907	13,513	1.0322	12.64	3.71	8.93
(104) 1908	14,967	1.0322	12.69	3.75	8.94
(105) 1909	18,519	1.0321	12.66	3.74	8.92
(106) 1910	19,282	1.0320	12.62	3.73	8.89
(107) 1912	19,646	1.0319	12.54	3.68	8.86

(17) Month of Lactation

	1	2	3	4	5	6	7	8	9	10	Avr.
Number of cows	11	11	11	10	10	9	8	6	6	5	
Milk I period	559.9	584.6	562.6	535.1	486.3	504.5	464.4	485.9	401.6	347.8	497.3
Milk 2 period	780.9	725.0	663.4	603.8	577.5	553.8	511.9	369.9	243.7	112.3	514.2
Percent	130.0	124.0	118.0	113.0	119.0	110.0	110.0	76.0	61.0	32.0	103.4
Tot. Solids % I per.	13.07	13.04	13.33	13.50	13.75	13.74	13.93	14.22	14.34	14.48	13.72
Tot. Solids % 2 per.	13.32	13.32	13.59	13.74	14.05	14.05	14.33	14.42	15.04	15.01	14.09
Percent	102.0	102.0	102.0	102.0	102.0	102.0	103.0	103.0	105.0	102.0	102.0
Tot. Solids % I per.	13.07	13.04	13.33	13.55	13.75	13.74	13.93	14.22	14.34	14.48	13.72
Tot. Solids % 2 per.	13.32	13.32	13.59	13.74	14.05	14.05	14.43	14.42	15.04	15.01	14.09
Percent	102.0	102.0	102.0	102.0	102.0	102.0	103.0	103.0	105.0	104.0	102.7
Tot. Solids Ilb I "	78.2	75.9	74.4	71.9	66.3	68.5	64.0	67.5	57.5	49.7	67.4
Tot. Solids Ilb 2 "	102.9	95.4	89.0	81.9	79.8	76.4	71.9	53.1	37.1	17.5	70.5
Percents	132.0	126.0	120.0	114.0	120.0	111.0	112.0	79.0	65.0	35.0	104.6
Fat % I period	4.07	4.05	4.17	4.11	4.20	4.19	4.39	4.46	4.62	4.44	4.27
Fat % 2 period	3.91	3.85	3.97	4.01	4.24	4.23	4.23	4.14	4.53	4.62	4.17
Percent	96.0	95.0	95.0	98.0	101.0	101.0	96.0	93.0	98.0	104.0	97.7

Fat lbs I period	24.4	23.5	23.0	21.8	20.0	20.7	19.6	21.1	18.5	15.2	20.8
Fat lbs 2 period	29.9	27.2	25.5	23 6	23.6	22.5	20.4	15.1	11.6	5.8	20.5
Percent	123.0	117.0	111.0	108.0	118.0	109.0	103.0	72.0	63.0	38.0	98.7
Casein % I period	3.10	3.29	3.36	3.33	3.51	3.51	3.56	3.73	3.74	4.13	3.53
Casein % 2 period	2.96	3.12	3.11	3.52	3.60	3.59	3.80	3.83	4.13	4.59	3.63
Percent	95.0	95.0	93.0	106.0	103.0	102.0	107.0	103.0	110.0	111.0	102.8
Casein lbs I period	18.6	19.0	18.7	17.9	17.0	17.3	16.2	17.9	15.0	13.9	17.2
Casein lbs 2 period	22.8	22.3	21.6	20.7	20.4	19.4	19.1	14.1	9.8	4.6	17.5
Percent	123.0	117.0	115.0	116.0	120.0	112.0	118.0	79.0	66.0	33.0	101.9
Sugar % I period	5.18	5.00	5.11	5.35	5.31	5.35	5.33	5.30	5.27	5.17	5.23
Sugar % 2 period	5.75	5.69	5.68	5.55	5.51	5.56	5.58	5.75	5.71	5.03	5.58
Percent	111.0	114.0	111.0	104.0	104.0	104.0	107.0	108.0	108.0	97.0	106.8
Sugar lbs I period	31.1	29.2	28.7	28.5	25.8	27.1	24.6	25.3	21.1	16.2	25.8
Sugar lbs 2 period	44.8	41.1	37.8	33.6	31.7	30.8	28.8	21.4	14.1	6.4	29.1
Percent	144.0	141.0	132.0	118.0	123.0	114.0	116.0	85.0	67.0	39.0	112.8

Variations

(18) Most cows give about the same quality of milk year after year, beginning with this quality at the first calving.

(27) The total protein was found to be abnormally high following parturition, reached the minimum at 3 or 4 weeks, then remained fairly constant until near end of the lactation period, when it rose rapidly and reached the maximum at the end of the period. No relation was found between the protein and the sugar.

The percentage of fat on the average declined during the first three months, followed by a period of 4 or 5 months with but little change. From this point a rapid increase was found to the end of the lactation period. The variations in the fat and protein were on the whole quite similar. The total solids show the same variations as the fat and protein.

(121) The seasonal variation was greater, both in actual figures and in proportion to the amount present, in the case of protein than in the case of fat.

(93) The average range of fat variation in the guernsey, ayrshire, and holstein breeds was as follows:

Guernseys	1.99%
Ayrshires	1.56%
Holstein	.46%

The following table shows the variation, in amount of milk and the percentage of fat, in comparing cows of different ages for a period of six months.

Age of Cow Years (20)	No. of cows reported on	Average yield for six months gallons	Average % of fat in milk
2	30	362	3.83
3	147	377	3.87
4	164	403	3.76
5	137	421	3.66
6	110	438	3.63
7	88	465	3.63
8	80	468	3.69
9	50	461	3.63
10	36.	457	3.64
11	28	464	3.60
12	16	493	3.48
13	10	428	3.42

The seasonal variations as shown in the following table closely resembles the results of other investigators.

(20) Percentage of Fat

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1903	3.90	3.65	3.85	3.75	3.65	3.75	3.80	3.75	3.9	4.35	4.40	4.75
No. of Herds	4	4	4	5	3	5	6	4	4	3	3	2
1904	3.85	4.10	4.15	4.00	3.75	3.50	3.60	3.60	3.85	4.10	4.30	4.40
No. of Herds	1	1	1	1	1	1	2	2	2	2	2	2

Percentage of Solids-not-Fats

Year 1903	9.05	9.00	8.85	8.85	8.85	8.85	8.70	8.65	8.75	8.80	8.85
No. of Herds	4	4	4	4	3	5	5	3	3	2	2
1904						9.12	8.99	8.80	8.65		
No. of Herds						1	1	1	1		

Protein

(89) It remains an open question whether milk contains only one proteid in different stages of solution or whether a great number of distinct proteids is met with. Duclaux thought that milk contained nothing but casein, of which part was suspended, the majority in the colloidal condition and part dissolved. Danilewsky and Radenhausen profess to have found seven proteids in milk, viz., caseo-albumen, protalbin, albumen, orroprotein, whey protein, lacto-syntoprotalbin and lacto symtogene; further, peptones like peptone, pseudopeptone, syntogene.

Caseinogen and lactalbumin are found in milk, and it is possible that other protein substances may occur in milk. Caseinogen is the most abundant and the most important.

Fat

On microscopical examination of milk the fat is found in the form of small globules of various dimensions, as will be seen later. There is every reason to believe that all the fat globules have the same chemical composition. (120) It is impossible by any known process to separate completely the large and small fat globules. The best is two creams, one large and one small. There is very little difference between fat from the two and little or no variation in color. All are within limits of legitimate experimental error.

(89) Fat is a mixture of the glycerides of the following acids: Formic, acetic, butyric, capronic, caprilic, caprinic, myristic, palmitic, stearic, arachic, and oleic acid. Stearine, palmitine, and olein form 92 to 93 percent of the total milk-fat.

The insoluble fats are olein, stearin, and palmatin.

(69)4% of globules were between.000385&.000275in.in diam.
22% " " " " .000275".000165 " " "
26% " " " " .000165".00011 " " "
28% " " " " .00011 ".000055 " " "
20% " " " less than .000055 in. in diameter.

These measurements of fat globules were taken from milk which had been obtained from jerseys milked nearly four months.

Lactose

We know very little concerning lactose, but we have been shown that (29) none of the types of underfeeding influenced the percentage of lactose in the milk. (123) In the animal body lactose is found only in milk, if we disregard the small amounts that may appear in the urine of nursing females, and which must hence of necessity occur also in the blood. It is formed in the mammary glands. It undergoes a peculiar fermentation with the formation of lactic acid. This is produced by a micro-organism when exposed to air. On inversion lactose is decomposed into glucose and galactose.

Inorganic Components and Salts

The following are quoted as the probable composition of milk-salts: (89)

Chloride of natrium	10.62%	0.07965 percent
Chloride of potassium	9.16%	0.06870 "
Mono-potassium phosphate	12.77%	0.095775 "
Di-potassium phosphate	9.22%	0.06915 "
Potassium citrate	5.47%	0.041025 "
Di-magnesium phosphate	3.71%	0.027825 "
Magnesium citrate	4.05%	0.030375 "
Di-calcium phosphate	7.42%	0.06565 "
Tri-calcium phosphate	8.90%	0.06675 "
Calcium citrate	25.55%	0.176625 "
Calcium oxide combined with casein	5.13%	0.038475 "

Gases

Milk contains a small amount of oxygen and nitrogen and from 5.8 to 7.5 percent of carbon dioxide.

Cells

There are many discrepancies among the results of the various investigators as contributed to the numerous publications; therefore, the cells found in milk may be studied from two stand points, namely: first, the number of cells in a given quantity of milk regardless of the kinds of cells, and, second, the kinds of cells found in milk.

Cow (10)	Age per years	Period of Lactation months	Average No. of cells per c.c.
1	3	8	720,000
2	2	5	400,000
3	6	8	410,000
4	8	8	480,000
5	12	9	495,000
6	6	10	2,720,000
7	7	10	1,040,000
8	4	5	500,000
9	3	4	455,000
10	9	7	50,000
11	2	1	625,000
12	7	9	500,000
13	4	3	1,150,000
14	2	4	930,000
15	2	3	805,000
16	3	8	715,000
17	6	9	910,000
18	6	9	490,000
19	7	8	3,080,000
20	6	8	1,100,000
21	8	9	585,000
22	2	5	650,000
23	7	8	5,340,000
24	6	9	1,600,000
25	2	8	1,305,000
26	6	9	1,340,000
27	8	9	350,000
28	8	8	475,000
29	7	9	370,000
30	8	7	530,000
31			1,125,000
32			230,000
33			1,215,000
34			3,630,000

35	1,730,000
36	3,745,000
37	1,200,000

Average 1,165,000 cells per c. c.

Maximum 5,340,000 cells per c. c.

Minimum 50,000 cells per c. c.

30% of the counts are below 500,000 cells per c.c.

30% of the counts are between 500,000 and 1,000,000 cells per c.c.

40% of the counts are above 1,000,000 cells per c.c.

59 cows under 500,000 cells per c.c. (11)

36 cows between 500,000 and 1,000,000 cells per c.c.

27 cows over 1,000,000 cells per c.c.

122 cows average 868,000 cells per c.c.

(131) The results of 1167 leucocyte counts made from the night and morning milk of two cows from the beginning of lactation:

1 1/5%of total no.of counts below 10,000cells per c.c.

7% " " " " "between 10,000&20,000cells c.c.

61% " " " " " " 20,000&100,000 " " "

29% " " " " " " 100,000&500,000 " " "

1% " " " " "above 500,000 cells per c.c.

(109) Milk from 50 cows varied from 4,000 to 3,576,000 cells per c.c. There was no apparent reason for the difference in the counts.

It may be permissible here to set forth the evidence whether certain factors have any influence upon the number of cells found in milk.

(54) In general in the case of cows which are in calf there is a large increase in these cells at the end of lactation, while in the case of cows which are barren, no such increase usually takes place.

(10) Competent evidence to support the common statement that colostral milk and milk from animals nearly dry contain larger numbers of cells than the milk obtained during other periods of lactation is lacking. It is possible that the munber of cells may be correlated to some degree with the amount of milk secreted, udders which give large amounts discharging fewer cells than where less milk is secreted.

(53) The results of Russell and Hoffman are particularly interesting, in that they attempted to trace the influence of such factors as parturition and lactation of feeding and temperature, etc., on the number of cells appearing in the milk without being able to detect any definite connection, and we also have arrived at similar conclusions.

(11) Changes of a considerable amount in the vacium used to operate cow milkers were found to be entirely without effect on the cell content of the milk.

Kinds of Cells

(115) Roughly three kinds of cells can be distinguished, (a) polymorphonuclear leucocytes, (b) lymphocytes, (c) large leucocytes.

(12) There are two types of cells (a) white blood corpuscles which are largely of the polynuclear and polymorphonuclear type. (b) Epithelial cells, nuclei and cell debris. The cells certainly do not have the significance of pus cells under ordinary conditions.

The following kinds of cells were found in films prepared by a very complete method (54) in which the various cells on the whole are well stained and well differentiated.

1. Cells having a large single nucleus (large uni-nucleated cells).
2. Cells having two or more small nuclei (multi-nucleated cells).
3. Cells with a small single nucleus (small uni-nucleated cells).
4. Cells with eosinophilic granules (eosinophile cells).
5. Vacuolated cells.
6. Cells of indeterminate nature, feeble staining of cytoplasm and nucleus, giving them a hazy appearance.

No cell having any decided resemblance to a polymorphonuclear leucocyte has been detected.

In the case of healthy cows in full milk, which do not give a high cell count, the majority of the cells tend to be of the type termed "large uni-nuclears". At the beginning and the end of lactation, or when the cell count is high, the multi-nuclears tend to be the predominant cells, and this is the case whether the high cell count is without discernible cause, or whether a definite mastitis is present.

A Histological examination of several udders (56) has shown that within the lumina of the alveoli, cells of the 1. large uni-nuclear, 2. small uni-nuclear, 3. multi-nuclear and 4. vacuolated types have been found in some of the specimens, and a study of their appearance confirms our previous views on the nature of these cells, viz. that the large uni-nuclear and vacuolated cells are epithelial cells and that the small uni-nuclears (generally) and the multi-nuclears are cells of the "germinal" layer. None of the eosinophile type have been detected, and their origin, therefore, remains doubtful.

(57) The statement commonly made that the cells of milk stain well and naturally with ordinary blood stains is, in our experience, quite erroneous.

We can briefly sum up those facts (53) which support the view that the cells found in milk are for the most part not leucocytes as follows:

(a) The cells present in milk (the so called leucocytes) are very diverse in nature, and, when critically examined, the majority distinctly differ from leucocytes.

(b) However fresh the milk may be, the vast majority of the cells in it never stain like active leucocytes with ordinary blood stains.

(c) Though many multi-nucleated cells are present, the majority of these are distinctly different from polymorpho-nuclear leucocytes.

(d) The cells present in milk, however fresh, are scarcely ever ameboid.

(e) Ingestion of bacteria by the cells present (phagocytosis) is practically absent.

(f) In milk obtained from perfectly healthy cows these cells may occur in vast numbers, and, since the mammary gland in structure resembles other glands, it is against analogy that vast numbers of leucocytes should occur in its secretion.

(g) The cause of the presence of a considerable number of cellular elements at times when there is no obvious reason, such as in quarters of the udder which have a previous history of mastitis etc., but have recovered, is easily explained if these cells are tissue cells and not leucocytes.

Nutrition

Certain processes are prosecuted in the animal body in order to obtain the necessary energy and material for repair expended in the production of milk and other body activities. Briefly they are: First, the apprehension and digestion of the feed; Second, absorption of the feed after it is in assimable form; and Third, utilization of the absorbed material.

Feed is taken into the digestive tract through the process of eating. The function of the digestive tract, breaking down the feed into assimilable form and the expulsion of the undigestable part along with waste, is called digestion. Amino acids are the assimilable forms of proteins. The fatty acids and glycerin are the assimilable forms of fats and the monosaccharides are the assimilable forms of carbohydrates.

Through the activity of the living cells of the intestines absorption takes place. The amino acids are taken up by these cells and made into complex proteins. No amino acids are found in the blood. The fatty acids and glycerin are recombined by these cells and these fats are taken up by the lymph stream, finally getting into the blood stream by way of the thoracic duct. The monosaccharides are not changed but pass into the blood as such. It is very probable that a large portion of the salts are absorbed with water in the large intestines. Some salts are no doubt absorbed in combination with proteins. In all animals the large intestines are the chief seats of absorption of water.

With our limited knowledge and the difficulties attached to experimental inquiry in larger animals we can simply state that there is an interchange of substance between cells and the blood in the process of supplying energy and nutriment to tissues. We know something of the results of these processes with little knowledge of what is happening in the processes themselves.

Briefly some of these results are recorded here that we may in a measure grasp a portion of what has not been accomplished. (108) In crease of phosphorus in the ration increases the phosphorus eliminated; increase of organic phosphorus in the ration causes an increased elimination of inorganic phosphorus, the quantity of outgoing organic phosphorus being but slightly affected by the intake of organic phosphorus. Increased phosphorus elimination is, in the herbivora, mostly by way of the intestines.

A large intake of phosphorus causes a retention of this element. When the phosphorus given is insufficient in quantity the organism uses for its normal functions the phosphorus previously stored in the body, or that which is not serving an immediately vital purpose.

(34) With rations of common practical foods, especially chosen to provide maximum supplies of the mineral nutrients, all calcium, magnesium, and phosphorus balances were negative.

With large increases in the calcium, magnesium, and phosphorus contents of these rations, through increased amounts of food consumed and through the addition to the ration of large amounts of calcium carbonate and bone flour, all calcium balances and all but one magnesium balance remained negative, but the phosphorus balance became positive.

In some cases nearly all the sodium of the excreta was in the urine, while in others it was nearly all in the feces. The same may be said of the chlorine.

The elimination of sodium and chlorine in the urine is increased by high intake of these elements, by constipation and by high water intake.

Potassium in cows is commonly excreted in much larger proportions in the urine than in the feces, but in rations characterized by predominance of acid minerals, potassium was eliminated more largely in the feces.

Calcium is excreted by cows almost wholly in the feces, but a predominance of acid minerals in the rations may cause slight increase in urinary calcium.

Magnesium always exceeds calcium in the urine, but is contained in the feces in amounts usually about four times as great as in the urine.

The excretion of phosphorus is characterized by much the same proportionate distribution as the excretion of calcium, except that urinary phosphorus may be much increased by general physiologic disturbance.

Sulpher is normally excreted in the feces in quantities three or four times as great as in the urine, but with high sulphur intake the urinary sulphur may equal the feces sulphur. (71) The presence of any compound in the feces is not proof that it has not been absorbed into the body cavity.

Concerning the mammary gland we may offer the following:

(28) In none of the experiments did overfeeding exert an influence toward abnormality in the composition of the milk, or the physical and chemical constants of the milk fat.

(80) Different amounts of protein in the daily ration derived from linseed, cotton-seed, soy bean, and corn, gluten meals, do not seem to have any pronounced effect in changing the relative proportions of the several milk ingredients.

In the study of the influence of phosphorus in the ration it was noted that (108) except for the change in the amount of fat, the composition of the milk was not materially altered. The best milk flow, both as to amount and fat content, happened to occur in the period of phosphorus equilibrium.

(67) On the whole the composition of milk is not readily influenced by feeding. (34) There were no noticeable effects of the foodstuffs or the mineral supplements (sodium chloride, calcium carbonate, or bone flour) on the amount or composition of the milk. (142) The quality of milk is something which is inherent in the animal, and is affected by food only within very narrow limits when affected at all.

(70) Favorable effect upon milk secretion of a narrow nutritive ratio is due in part to a stimulative, not wholly to a constructive function of the protein.

(31) Malt sprouts, palm-nut cake, and coconut cake contain substances which exercise a stimulating effect on the mammary glands independent of the form of digestible nutrients contained in the feeding stuff.

(29) Cows subjected to a subnormal plane of nutrition immediately after parturition maintained their milk flow at a nearly constant level under the most adverse conditions. A decline in milk flow accompanies even moderate underfeeding when the lactation period has reached a certain stage. The exact point when this occurs was not determined.

Physiological underfeeding and reduction in the plane of nutrition from a high to a normal plane is invariably accompanied by a marked increase in the percentage of fat in the milk, especially when the cow has a surplus store of fat on her body.

A subnormal plane of nutrition at times affects the percentage of protein in the milk. In some of the experiments conducted there was a decline in the percentage of casein, while in others the total protein only was affected. In the latter cases the percentage of ash in the milk also decreased. None of the types of underfeeding influenced the percentage of lactose in the milk.

All types of underfeeding have marked effects on the physical and chemical constants of the butter fat, which are characterized by a decline in the Reichert-Meissl number and saponification value, and an increase in the iodin value.

Secretion

(88) Toges (Centralblatt fur Physiologie, Bd. 19, S. 233, 1905) found that the development of the mammary gland depended upon the presence of functionally active ovaries, but that the production of milk was dependent on the abrogation of the ovary.

(50) (The fetus through its internal secretions stimulates the hypertrophy and lacteal activity of the mammary gland--Lane and Claypon). (74) So far as our experiments go, they show that the growth of the mammary glands during pregnancy is due to the action of a specific chemical stimulus produced in the fertilized ovum. The amount of this substance increases with the growth of the fetus and is, therefore, largest during the latter half of pregnancy. Lactation is due to the removal of this substance, which must, therefore, be regarded as exerting an inhibitory influence on the gland cells, hindering their secretory activity and furthering their growth.

From histological observations of the mammary glands (88) the animals with placenta implanted showed no development of the mammary tissue. But in all animals with the embryo implanted there was more or less development of the gland. (37) Transfusion of blood from a pregnant goat into a lactating one temporarily inhibits milk secretion. Placental and mammary gland extracts from a pregnant cow have an effect similar to the blood. There is some indication of a subsequent accelerating action in the case of the gland extract.

Other histological evidence shows: (35) At intervals we removed breasts from normal untreated rabbits. It soon became apparent that at different periods a marked increase in size and of functional activity may occur in the breasts of virgin rabbits. At any given period all the breasts are of the same size, but when removed at successive intervals many animals show a progressive increase in size and in the number of ducts and acini. The extreme difference obtained in our----series-----demonstrates that injections do not influence these physiological variations; otherwise some concordance would be noticeàble. Consequently, we feel justified in concluding that the theory of a fetal hormone has no basis of experimental proof.

In the uterus certain well understood changes take place at regular intervals, in order to prepare for pregnancy. These changes are dependent upon the corpus luteum. There is some evidence that similar changes occur in the breast, and probably these, likewise, are effected by the yellow body. What factor after impregnation causes the persistence and exaggerated activity of the corpus luteum is quite unknown. Perhaps it is the fetus; but, if so, its action is indirect, and the necessarily crude method of injecting extract of fetuses offers little promise of solving the problem.

Our knowledge of milk secretion seems to be limited to information gained through experiments with extracts of various body tissues. These experiments, perhaps, throw some light on factors which stimulate and regulate milk secretion but give very little information concerning the manufacturing of milk.

Experiments on the influence of the plane of nutrition on the milk flow (28) indicate that the secretion of milk is regulated by at least two factors. These factors can be designated as first, chemical; second, nervous. Certain facts----appear to admit of interpretation on the basis of such an hypothesis. The relation of these facts to this hypothesis and the evidence upon which they are based may be briefly stated as follows:

(a) The chemical stimulus for milk secretion is the predominating stimulus immediately following parturition, and continues to be so for a period of time, the limit of which is not brought out by the present investigations.

(b) The chemical stimulus for milk secretion is the stimulus that fixes the maximum milk flow for each individual animal. Just what controls the extent of the stimulus for individual animals is not as yet known. Our present knowledge indicates that it is a problem of heredity as well as one of physiology.

(c) The chemical stimulus for milk secretion received at parturition is more or less independent of the plane of nutrition of the cow. It is not possible to increase the chemical stimulus for milk production immediately following parturition by means of an excess food supply.

(d) As the lactation period advances the chemical stimulus for milk secretion is gradually replaced by a stimulus with entirely different characteristics. We have designated this as the nervous stimulus.

(e) The nervous stimulus for milk secretion is entirely dependent upon the plane of nutrition of the cow. (117) We have so far not succeeded in obtaining any positive results from the electrical excitation of the nerves to the glands.

(41) Ott and Scott, in Therapeutic Gazette, p. 761, November, 1912, have drawn up the following table classifying the glands according to the mode of action of their extracts on milk secretion.

Exciting	Inhibitory	Synergistic
pituitary extract	adrenalin	Orchitic extract
corpus luteum extract	iodothyrin	
pineal gland extract	ovary minus corpus luteum	
thymus extract	spleen extract	
mammary gland extract	pancreas extract	

(37) Nursing, milking, and the insertion of a camula in the teat excite a reflex contraction of the gland musculature and expression of milk. There is a latent period of thirty-five to sixty-five seconds.

Milking is a stronger excitant that the canula; nursing is stronger than milking; and the direct action of pituitrin (in some cases) is stronger than nursing. Removal of milk from the gland is dependent upon this reflex, and it may be completely inhibited by anesthesia. The adequate stimulus for the receptor in the reflex arc is the thermal and mechanical effects of nursing; but the strength of the excitation thus aroused is profoundly modified by the psychic state of the mother. Especially striking are anesthesia which greatly weaken it, and recovery of the young after separation which greatly strengthens it.

(117) The extracts which were made with Ringer's solution and were in most cases previously boiled were injected slowly and in small amount (not more than 5cc at a time) into a superficial vein, and the flow of milk, if any, was recorded by one of two methods, or by both methods simultaneously. The simpler method consists in recording the rate of exudation of milk from a small and superficial cut into one of the mammary glands (exudation method). The other method consists in recording the flow of milk led from a cannula tied to a cut nipple (nipple method); in either case the milk is allowed to drop upon an electric recorder, and the drops are marked by an electromagnetic signal upon the paper of a hymograph. On this paper are also recorded at the same time in some of our experiments the blood pressure, the

volume of the kidney, and the rate of excretion of urine. The animals were anesthetised either with chloroform alone or chloroform followed by chloral, the latter being administered either intravenously or subcutaneously; after complete effect of the chloral is established, the chloroform administration is stopped.

The most constant positive results which we have obtained have been those resulting from extracts of the posterior lobe of the pituitary body (of the ox) and of corpus luteum (of the sheep). Of these two materials that contained in the posterior lobe of the pituitary body is the more active. Within twenty seconds of the injection, drops of milk began to fall fast from the tube, the end of which was little, if at all, below the level of the gland with which it was connected, so that the flow was not assisted by suction, but must have been the result of the vis a tergo of the secretion. The effect passed off after three or four minutes, during which time thirty or forty large drops of milk were recorded. The effect of a repeated dose upon the secretion of the mammary gland is much less than produced by the first dose, and in some cases fails to be recorded by the "nipple method", although it can be sometimes observed by the "exudation method", and such repetition produces a smaller result than the previous one.

We find that the galactogogue substance of the pituitary body is not present in the pars anterior, but only in the pars intermedia and pars posterior of the gland. The galactogogue action runs parallel in line with the action of the extract upon the systemic blood vessels, which are contracted by posterior lobe extracts. It is probable, however, that, as in the case of the kidney, the blood vessels of the mammary gland do not share in the general constriction which this extract produces. We have not yet succeeded in definitely determining by a plethysmographic method whether the vessels of the gland dilate during the increased secretion.

The effect of extract of fresh corpus luteum, prepared with Ringer's solution, is quite distinct but less decided than with extract of posterior lobe of the pituitary, for, instead of some thirty to forty drops, not more than five drops of milk were yielded by the nipple method after injection of 5cc of a corpus luteum extract made up in the proportion of one part of the fresh tissue to ten parts of Ringer's solution. Its galactogogue action is unaccompanied by the same general rise of blood pressure as accompanies the pituitary galactogogue action. Indeed, there is usually a fall of a more or less decided character. A repeated dose is usually less effective as compared with the first dose; the amount of milk formed under its influence is often insufficient to cause the secretion to flow from the nipple, although secretion may be apparent when the exudation method is adopted.

Later Dr. Makenzie found that extracts both of involuting uterine mucous membrane and of mammary gland itself are markedly galactagogue, and that with regard to the action of pituitary extract, the source of this extract appears to make no difference to its activity; the extract of the bird's pituitary being quite as active in promoting the mammary secretion as that of the mammalian pituitary.

(41) The flow of milk produced as a result of an injection of pituitary extract varies with the state of nutrition of the injected animal. This variation is not so great as that produced in the case of the morning or the daily yields, indicating that the action of the pituitary extract is on some more stable quantity.

(117) In order to produce the galactagogue effect, it is not necessary to employ a lactating animal. In one instance we obtained a free flow of fluid--of serous appearance--from the incised mamma of a cat, apparently virgin, and not fully grown. Karl Basch (88) used saline extract subcutaneously of human or homologous placenta. These extracts were repeatedly injected. By dogs, cats, rabbits, guinea pigs, and goats he obtained a secretion of milk independent of pregnancy.

Here are two cases of secretion of milk independent of pregnancy and no explanation concerning the cause and effect:

(32) Grade holstein calf born July 4, 1915, having a fully developed mammary gland secreting milk. The udder is about the size of two fists with well developed teats about one inch long and milking from all four quarters. The milk is of good quality; the quantity was about a pint up to the third week and has now increased until it gives a quart night and morning. It began giving milk when it was seven days old.

(16) Percheron mare colt born in July, 1910. When the foal was two or three days of age, the owner noticed that the colt's udder was enlarged. It was found to contain milk, each milking yielding about a pint. This continued for 10 days. Then the colt was given a solution of atropine sulphate and belladonna morning and evening. On the tenth day the secretion ceased entirely, and the foal continued to grow and developed into a fine colt.

(37) Pituitrin has a muscular action on the active mammary gland causing a constriction of the milk ducts and alveoli with a consequent expression of milk. This action holds, also, on the excised gland in the absence of any circulation. The flow of milk produced by pituitrin is dependent on the amount of milk present in the gland. There is no evidence of any true secretory action. The non-lactating gland, up to a late stage of pregnancy, is not sensitive to pituitrin.

(58) There seems to be good evidence in the support of both the glandular and muscular theories of the action of pituitary extract on milk secretion. The

results of my researches would, however, lend themselves more to the support of the former theory.

Comment

In considering the statements set forth in the first paragraph of the introduction one is immediately impressed with the empiricism on which they are based. For example take the following: "The gland tissue should be fine and plastic rather than fatty or coarse and hard." Where is there any evidence that gland tissue is ever fine, coarse, or hard? We will agree that gland cells in the mammary glands of the cow contain some fat normally, but, until we have more evidence we will not agree that these cells are ever fine, coarse, or hard. There no doubt is some difference in the firmness of the gland as as a whole where pathological changes, such as interstitial inflammation, have taken place. In such cases the gland tissue is destroyed and replaced by connective tissue which does not secrete milk.

I believe the statement that the so-called "meaty udders yield a comparatively small flow of milk" is untrue and at present is not based on any experimental evidence to state that it is true. I have seen one holstein cow, giving one hundred pounds of milk a day at the time, with a so-called meaty udder. She was milked four times a day and after each milking the udder was little reduced and the skin nearly as tightly drawn over the tissues as before milking. I had the opportunity to observe this cow only one week. I was later informed by the herdsman that about the eighth month of lactation her udder began to assume a different type. That is, it lost that tense, large proportion and became smaller, reducing more after milking and the skin becoming loose so that it could be picked up with ease. I have observed the same condition in a jersey, the only difference being that the milk flow was less, which occurence is normal. A large portion of this animal's udder seemed to be skin when dry. In the same herd another jersey demonstrated an udder which showed much shrinkage after milking from the beginning of lactation and yielded little more than half as much milk and butter fat. In order that the reader may not be mislead to interpret these personal observations as being influenced by some local environment, it may be stated that the holstein cow was located in the District of Columbia and the jersey cows in the Willamette Valley of Oregon.

Such statements as are given in the first paragraph of the introduction and similar statements elsewhere shall be investigated if we are to make the progress in agriculture that is to be reasonably expected of us by the peoples of the world.

The statements concerning the macroscopical anatomy need no comment. They will stand the closest investigation of the most critical anatomist of the day and stand as they are now. We are in need of a more thorough knowledge of the histology of the udder of the cow. Most of our present knowledge of the microscopical anatomy of mammary glands is based on the histology of the mammary glands of the human being and the small animals. It is obvious that much work needs to be done in determining the chemical composition of the mammary glands before the formation of the various constituents of the milk can be understood.

It is readily noticeable in the general composition of milk by tables of analysis that the majority of the tables give only total solids, fats, and solids, not fat. One table ventures to mention casein and sugar. Shall we continue with so little knowledge of the chemistry of milk?

From the information we have on the variations in milk it would seem possible that some definite unknown physiological factors were responsible for rather regular changes in total protein, fat, and total solids. Is it possible that this may be a so-called hormone which is influenced by a pregnant or non-pregnant uterus? Since we are not in possession of complete information concerning the breeding records of the animals from which this data was taken and owing to the fact that an effort has not been made to control these variations by any so-called hormone, this point is left a question.

Before much of a discussion on the protein of milk can be given it will be necessary to determine more accurately what protein is.

accurately what protein is.

We will have gained a considerable knowledge when we have learned how milk fat and lactose are formed and also how the inorganic components and salts of milk are combined and what their functions may be.

It is unfortunate that there is no record of the types of udders given from which the cell counts were made. The conflicting statements concerning the number of cells at the end of lactation may well be dropped since they are followed by a statement concerning the number of cells in proportion to the amount of milk secreted. The evidence given here seems to be in favor of the cells found in milk being epithelial cells. Furthermore, if room would permit the entire articles to be given here, it would be found that those claiming that the cells are tissue cells have given their technique and complete evidence, and that those claiming that they are leucocytes do not mention their methods but rather expect the reader to take it for granted that they are faultless. It may be found later that both the number and the kind of cells present in milk are correlated with types of udders. In either case one could give theories explaining their influence upon the size and firmness of the udder or so-called pliable and meaty udders.

Since we have noted something of the results of supplying energy and nutriment to the tissues we find only one case in which the milk is affected by controlling some of the factors in supplying the raw material manely underfeeding as carried out in (29). Such experiments, if carried further, might give us some idea as to the origin of fat and protein, even if they do not solve the problem. Why should the percentage of fat increase and the protein decrease while the percentage of lactose remained uninfluenced?

We have presented the hormone theory as the cause of the growth of the mammary glands, and we also find other observations disputing this. Therefore, we are where we started concerning the growth of the mammary glands. The results are practically the same concerning the cause of secretion of milk.

There is mentioned a chemical stimulus, nervous stimulus, nursing, milking, insertion of a cannula in the teat, and the injection of extracts of certain body tissues as stimulating the mammary glands in one way or another, thereby causing a flow of milk. It would seem that the first two are based on some stable quantity limiting the flow of milk at different stages of lactation. This particular work at present has not been carried far enough to ascertain the nature or origin of these stimuli. They may be neither chemical or nervous in character, but, in view of our limited knowledge on this point, we shall accept them as they are until more complete work is done along this line. The others mentioned evidently have only temporary action, either causing the gland cells to unload or, as some authors suggest, cause a contraction of the gland musculature and consequently a flow of milk. The latter does not seem to be consistent with the evidence presented here.

Acknowledgments

Besides my respect and thanks to those of the staff of the Oregon Agricultural College who so patiently gave me instruction, encouragement, and the opportunity to proceed with this thesis, I wish to express my appreciation to those who have worked before and presented to the world in writing the results of their efforts to be torn to pieces as I have done here.

Suggestions for Approaching the Solution of the Problem

The main points in this problem to be brought to our attention may be stated in the following questions: What are the differences between the so-called meaty udder and one which shows much shrinkage after milking? What causes the condition known as meaty udder? Other things being equal, is there any material difference in the milk production of these two types of udders? These questions must be kept in mind as the ultimate aim. An explanation of some of the factors involved may be of more immediate value.

In all the literature bearing on this project there is only one phase of the work established, namely--the macroscopical anatomy of the udder of the cow. However, if some critic doubting this should conduct investigations, I predict that he will add nothing and subtract less from the work done and reported here on the macroscopical anatomy of the udder of the cow. On the other hand it seldom occurs that one can take another's evidence into the field of research and utilize it without some preliminary experimentation.

The following tentative plan is submitted for approaching the solution of this project. This plan will not be an exhausted discussion of the possibilities involved because there are many factors of which we know too little to make any statements. As the work on a problem progresses the factors involved become so variable that it is practically impossible to foresee all of the possibilities. Therefore, only a brief discussion of a plan is given which covers only the outstanding features of the project.

The work relative to this problem should be done on a co-operative basis. One office may be selected to take care of the plans for the project as a whole and give help and encouragement to those working on the various phases of the problem. It should also be a place of exchange, the various stations reporting to this office the progress of their work each pentad (having a definite time for reports). This office should then present all the results of the pentad to all the stations engaged in one phase or another of the problem (have a time limit e. g. 30 days).

The work of this project would naturally come under the properly trained combinations as follows:

Administration, of course, comprises the executive work of the problem. Histologists should apply themselves to the microscopical study of the structures of the udder of the cow. Bacteriologists, physiologists, and histologists should include the work in ascertaining definite information concerning the cells found in milk. Chemists, histologists, and physiologists should reveal to us the information necessary on the chemical composition of the mammary glands of the cow. Chemists and botanists should assist in the work of nutrition, while the chemists and physiologists work out the hidden facts of nutrition and secretion. All work should be done with the idea of finding out the facts in the case in everything attempted and of leaving their application, in so far as is possible, until all the facts are presented for criticism.

At least three stations should be at work on the same phase of the project and they should be separated as widely as possible geographically. For example--station working on histology might be located in Texas, Maine, and Washington; stations working on nutrition, in Pennsylvania, California (west of the mountains), and Minnesota, etc.

The advantages of this system are the co-operation obtained through the prompt delivery of all the results of work done by all engaged in solving the problem. This would also eliminate the local interpretation and influences on any phase of the problem. Each station would act independently and automatically as a check on all the other stations on the same phase of the problem.

It will be necessary to have various men sufficiently trained in the following combinations to carry on the work successfully: Administration; Histology; Bacteriology, Histology, and Physiology; Chemistry, Physiology, and Histology; Chemistry and Botany; Chemistry and Physiology.

The histology will consist of a routine microscopical examination of the tissues of the mammary glands of the cow. These microscopical examinations should be made on glands in the various stages of lactation, dry udders of barren cows and pregnant cows as well as udders from virgin heifers.

For many years some of us have neglected to consider the chemical composition of the mammary glands while others have worked as best they could under the conditions. Much of our trouble will be explained when we have obtained a more complete knowledge of chemistry. This phase of the problem will require much routine work in the chemical examination of the tissues (parenchymatous, fibrous and muscular, each separately) of the udder as mentioned under the suggestions for histology. Much fundamental work will be necessary in physical chemistry before we may expect to satisfactorily explain changes in the mammary gland. The same may be said of the chemical composition of milk. When we once have learned the chemical composition of protein we will be able to give a more explicit program for determining the chemical composition of the udder and milk.

There has been a great amount of work done on the question pertaining to cells in milk. We have gained very little by it, however. The majority of the work has been in connection with the numbers of cells in the milk and their relation to the wholesomeness of the milk. This is very good and the approximate numbers of cells given off in milk may give us an idea of the volume of space occupied by these cells in the udder. On the other hand, without a knowledge of the kind of cells and their origin, we are at a loss as to their application to the present project. It is my opinion, after summarizing the results of work with cells in milk, that, while differential staining of cells is a great aid in discriminating between these cells, it is not wholly reliable. There is more needed to make the results conclusive. It may be suggested that experiments in cutaneous hypersensitiveness be tried as a means of differentiating between these cells. This might be carried out analogous to tuberculosis and tuberculin, etc. More complete experiments in quantative phagocytosis should be carried on before we are in a position to ascertain accurately the kinds and origin of these cells. If these cells are proven to be for the greater part leucocytes there will necessarily have to be a considerable work done with the formation of these cells and the materials needed for their formation.

The work in nutrition needs a fundamental chemical basis before much more can be done which can be applied to this project. When once we understand the chemical composition of the tissues more fully we will be in a position to begin experiments which should reveal the exchange of nutriment and waste materials between the tissues of the mammary glands and the blood and lymph. Of the experiences so far in nutrition we have only recorded the effects from controlling the rations more of less. We do not have knowledge of what is actually occurring in the tissues themselves. This phase of the problem would naturally follow the chemist's results in studying the chemical composition of the various body tissues. There is no means by which one may predict the nature of this phase of the project until the chemists have more nearly completed their work. One may expect much from experiments in physical chemistry.

Most of the efforts in the study of secretion of milk have been directed at the possibility of the presence of specific substances (so-called hormones) as being the cause of the development of the mammary glands and of others acting as causative agents in milk secretion. This work of necessity had to be carried out by rather crude methods. Even though a few of the results disagree, there is evidence that the mammary glands and their activity may be influenced by the secretion of some of the ductless glands (the so-called internal secretions.

It would seem to be a logical plan to learn first all the facts possible concerning the physical status of the udder of the cow. The blood pressure, both arterial and venous, should be ascertained in the various types of udders during their development, lactation when full and when milked; also in the resting udders of both pregnant and barren cows and of virgin heifers. The milk pressure in the various types of udder should be ascertained. It may be necessary to construct a special apparatus to apply to these measurements. Much may be gained by injecting into the milk sinus, arteries, and veins of various types of udders materials of different densities and obtaining X-ray photographs of them.

When we have learned all the facts possible concerning the physical status of the udder of the cow we may again turn to the chemists and obtain their assistance in ascertaining the origin of the various constituents of milk. Of course, this phase of the problem logically follows the work in the study of the chemical composition of the body tissues.

Instead of injecting into the animal body the extracts of various body tissues it would seem just as logical to remove these various body tissues from the animal body and record their effect upon milk secretion.

The phases of this project which may be of more immediate value are: first, determining the kind of cells that are given off in the milk. This, of course, is more immediately valuable because of the idea carried with them as indicating the presence of pus or at least some pathological condition which may be detrimental to the human family. The sooner people are relieved of this superstitious idea the better.

The second phase is the histology of the mammary glands of the cow. This information is needed more immediately because of its direct bearing on diseases of the udder which cause some considerable portion of a dairyman's trouble, and because of its indirect bearing on other problems of importance i.e. abortion.

Third is nutrition. This is of more immediate value because when the factors of utilizing nutritive materials in milk production are under our control the dairymen will be more able to supply the constantly growing demands for dairy products.

It is possible that at the conclusion of the ultimate aim of this project the questions in the first paragraph of these suggestions may be answered by a simple explanation of the presence of different quantities of blood and differences in blood pressure in the various types of udders.

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