TB 989,(1949) USDA TECHNICAL BULLETINS UPDATA

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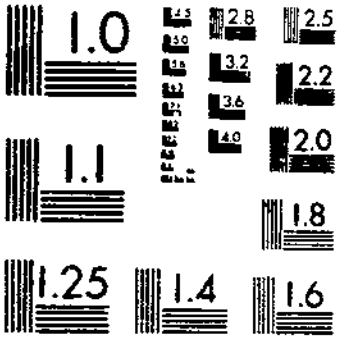

MICROCOPY RESOLUTION TEST CHART
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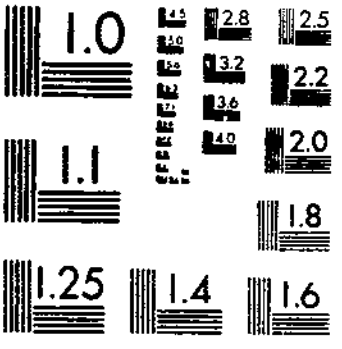

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Technical Bulletin No. 989 • September 1949

UNITED STATES
DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

Weight and Capacity of the Dairy Cow Udder in Relation to Producing Ability, Age, and Stage of Lactation[1]

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INTRODUCTION

The bovine udder, as the organ of milk secretion, justifiably deserves considerable attention in any attempt to estimate a cow's producing ability by her form or type, or in any study of the possible relationships between her producing ability and her type and anatomy. Score cards for judging dairy cattle give considerable importance to the size, shape, and other characteristics of the udder. Yet relatively little research has been done to determine the relationships between these characteristics and producing ability.

Swett[2] found significant correlations between producing ability and udder weight and udder capacity in a group of 11 cows of various breeds.

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[1] Submitted for publication March 22, 1949.

[2] SWETT, W. W., MILLER, E. W., GRAVES, R. R., and CREECH, G. T. QUALITY, SIZE, CAPACITY, GROSS ANATOMY, AND HISTOLOGY OF COW UDDERS IN RELATION TO MILK PRODUCTION. Jour. Agr. Res. 45: 577–607, illus. 1932.

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The purpose of this publication is to report the results of studies conducted by the Bureau of Dairy Industry to determine the relationships between udder weight or capacity and producing ability as affected by age, stage of lactation or dry period, and breed.

SOURCE OF DATA

Most of the udders used in this study were obtained from Holstein, grade Holstein, and Jersey cows that were slaughtered over a 20-year period at Beltsville, Md., in connection with other research on the dairy cow's anatomy. Additional udder specimens were obtained from autopsy cases and from some other cows not used in the anatomical research.

Altogether, 473 udder specimens that were suitable for use in this study had been obtained from these sources by March 1, 1946. Data on weight, capacity, and producing ability were complete for 442 udders. No production records were available for the other 31 udders, since they were from cows that died or were killed during the first lactation period, but these udders were included in the study of the effect of age on udder weight and capacity.

Before the cows were slaughtered, most udders were examined thoroughly for size, shape, and handling qualities. The results were recorded as grades for study in comparison with the internal structure of the udder.

Each cow was milked just before slaughter so that the weight of the excised udder would be its empty weight. The udder was removed from the carcass with enough hide from adjacent areas of the body to allow it to be suspended from a specially designed "udder board" in a nearly normal position. Strings were attached to the septum between the halves of the udder to hold up the middle part.

The excised udder was filled through the teats with a 5- or 10-percent formalin solution to fix or preserve the tissues for future studies and to obtain a measure of capacity. The larger veins and arteries extending beyond the boundaries of the udder were tied off to prevent the escape of the filling fluid as it seeped into the vascular system from the milk ducts.

The earliest udders obtained for this study were filled by means of a hand pump. Filling was continued until the udder appeared firmly distended or maintained a pressure of several pounds, on the gage at the pump, between strokes of the pump. Later specimens were filled by a gravity system, which delivered fluid at a pressure of 10 pounds. Filling was continued for 5 minutes, or occasionally longer for large udders.

Still later, over a period of 12 years, the udders were filled by using 10 pounds of air pressure to force fluid from tanks into each quarter of the udder. The tanks were weighed at regular intervals during the filling process in order to measure the rate of flow into each quarter. The basic filling time was 5 minutes; but if the fluid was flowing at a rapid rate at the end of the 5-minute period, filling was continued until the rate of flow was definitely slower. Frequently, 7.5 to 10 minutes was required to fill large lactating udders. The filling pressure, which was standardized at 10 pounds, was several times the pressure ever developed in a living lactating udder, but the

udders could be filled more rapidly with this pressure than with lower pressures.

At times, when an udder was needed for histological studies, one side was removed and only the two quarters on the other side were filled with fluid. The capacity of the udder was calculated from twice the fill in the two quarters.

Figure 1 shows an udder suspended from an udder board being filled with fluid by means of the air-pressure apparatus. The filling process was practically completed when this photograph was taken. A metal teat plug, with a turned shoulder which was pushed in past the sphincter muscle, was inserted in each teat to prevent the escape of the fluid.

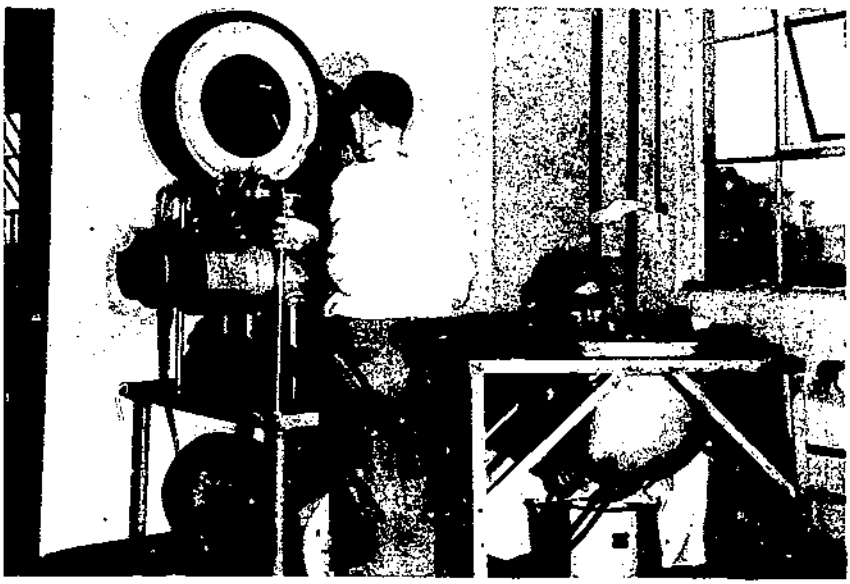

FIGURE 1.—Filling an udder with the air-pressure apparatus to measure capacity and the rate of flow into each quarter.

METHODS OF MAKING CALCULATIONS AND ANALYSES

This study involved three measurable characteristics of the excised udders and five factors that appeared to have some effect on these characteristics. The measurable characteristics were empty weight, capacity, and the ratio of capacity to weight $\left(\text{ratio}=\frac{\text{capacity}}{\text{weight}}\right)$. The factors that may influence these characteristics of an udder are: The breed, age, stage of lactation, length of dry period, and producing ability of the cow.

The size (empty weight) of each udder was determined by weighing the excised udder, which in most cases had been milked out just before the cow was slaughtered. Milking was not possible with udders from autopsy cases, but a prolonged illness usually checked milk secretion before death occurred and the udder was nearly empty

when weighed. Empty weight was not always directly proportional to the amount of glandular tissue present, since greater amounts of fat were included in the empty weight of some udders than others.

The capacity of each udder was calculated from the quantity of fluid retained by each quarter during the total filling time, whether it was 5 minutes or longer. The quantity that seeped out of the udder tissues during the filling process was subtracted from the quantity injected to determine the quantity retained. The quantity of fluid retained (in liters) was converted to its milk equivalent in pounds by multiplying the liters by the factor 2.2725, which represents milk weighing 8.6024 pounds per gallon. This method of expressing udder capacity was favored for convenience in comparing capacity with empty weight and with records of milk production. Actually the capacities of the lactating udders, as determined in this way, far exceeded the largest amount of milk recorded for a single milking from any of these cows.

These measures of capacity were to some extent approximate values, because fluid under pressure of 10 pounds would continue to flow into a quarter of a large udder at a low rate (200 to 500 gm. per minute) for an indefinite length of time. For example, if the flow into each quarter of a large udder was at the rate of 400 gm. per minute when the filling process was terminated, an additional minute of filling at the same rate would have added 3.64 pounds to the value for the capacity of that udder. Nevertheless, inexactly as the actual capacity of an udder might be measured, these techniques gave good relative measures for comparing the capacity of one udder with another.

The ratio of capacity to weight was calculated by dividing the milk-equivalent capacity by the empty weight and expressing the result as a percentage. It was expected that such a ratio might measure differences in udder porosity and therefore in the "quality of the udder," as indicated by its degree of looseness after milking. A higher ratio, indicating greater capacity in relation to weight, thus would represent a higher quality udder.

Differences in the weights and capacities of udders from cows of different breeds were soon apparent. Comparing the group averages was the only way to measure these differences, and some separate breed studies were made on udder data from 367 cows (Holsteins, grade Holsteins, and Jerseys) in the Bureau's experimental breeding herds. These studies were handicapped by a lack of numbers in various age groups and in stage of lactation or dry-period groups. Also, there were 106 udders from other breed groups, but not enough in any one group for a statistical analysis of breed differences. For these reasons all breed data were combined for this study, on the assumption that, until demonstrated otherwise, the udder weights and capacities of all breeds were affected in the same manner by differences in age, stage of lactation or dry period, and producing ability.

Age was expressed in these studies as the number of months from birth to the time of last calving. Age at last calving was preferred to the age at death because it corresponds to the customary basis for stating the age at which production records are made. The confusion from using two measures of age thus was avoided. Furthermore,

while it is generally observed that older cows have larger udders, it is also apparent that udders do not increase in size after the first month or so following parturition.

The stage of lactation was expressed as the number of days from the date of last calving to the date of death. The length of the dry period was calculated from the date that the cow was last milked regularly to the date of her death, with the exception that lactating cows dying after a short illness were still classified as lactating cows. Undoubtedly, the secreting cells of most udders were still active for several days during the early part of a dry period defined in this manner, but there was no way of knowing when the physiological process of lactation had ceased.

The basic measure of producing ability was each cow's best yearly record of milk and butterfat production when all records were converted to a uniform basis of a 365-day, three-milkings-a-day, mature-equivalent record. Records made at 6 years of age or over were considered as mature-age production, but the standard age-correction factors were used on all others. Most records were made in a 365-day lactation period on three milkings a day; the 365-day records that were made on twice-a-day milking were converted to three milkings a day by multiplying by 1.20. Several 305-day records were made on three milkings a day, and they were converted to a 365-day basis by multiplying by 1.15; a few 305-day records were made on two milkings a day, and they were converted by using the factor 1.38.

For this study, the best yearly records of milk and butterfat production were converted to a milk energy basis by using the formula $FCM=0.4M+15F$, in which FCM is the milk energy yield in pounds, M is the pounds of milk, and F is the pounds of butterfat. The use of milk energy yield as a measure of producing ability in a study involving several breeds of cows in the same groups had several advantages over the use of milk and butterfat records. Producing ability was measured by one value instead of two, thereby simplifying the calculations and the interpretations therefrom.

It might have been expected that udder capacity would have been more closely related to milk records than to butterfat records, and that the weights of the udders—as organs secreting the energy constituents of milk—would have been more closely related to butterfat records than to milk records. However, butterfat records are not directly proportional to the energy value of milk. For example, if one group of data included a Holstein record of 20,000 pounds of 3.5-percent milk and a Jersey record of 12,500 pounds of 5.6-percent milk, the Holstein record would have been 60 percent better on a milk-record basis, just equal to the Jersey record on a butterfat-record basis, but actually 19.35 percent better on a milk-energy-yield basis.

One of the greatest problems in analyzing these data for a study of the relationships between producing ability and udder weight and capacity came from the lack of control over the conditions under which the udders were obtained. Cows were slaughtered at any time policies in the management of the herd directed their removal. As a result, udders were obtained from cows at all ages and at all stages of lactation or dryness. For these reasons, a plan of using numerous group

averages and simple and multiple correlations was adopted in an attempt to measure also the effects of these uncontrolled environmental factors.

The data were not sorted into breed groups, except for the one study of typical breed characteristics. The first step in sorting was to separate the data for lactating udders from the data for dry udders, with two groups under each. Since it is commonly observed that udders are noticeably larger during the first few weeks of a lactation than later on, the data for udders lactating 2 months or less were placed in one group and those for udders lactating more than 2 months were placed in a second group. Since it is questionable whether an udder ceases to be a lactating udder as soon as the cow is no longer milked, the data for dry udders obtained 1 month or less after the cow was last milked were placed in one group and the data for udders that were dry more than a month were included in another group.

Data in each of the two lactating-udder groups and in each of the two dry-udder groups were subdivided into five groups according to age. The first age group included the data from cows slaughtered or dying during their first lactations or during the dry periods immediately following them. The second age group included the data from cows in their second lactations or in the dry periods following them. The third age group included data from all cows past their second lactations but under 6 years of age at the time of last calving. Data from cows 6 to 9 years old at the time of last calving were placed in a fourth group to represent the characteristics of mature udders, and data from cows over 9 years old were included in a fifth group to determine whether there were any characteristics peculiar to old age.

EFFECT OF AGE ON UDDER WEIGHT AND CAPACITY

Average Udder Weights and Capacities at Different Ages

As the udder specimens were acquired, it was easily recognized that the age of the cow had considerable effect on the empty weight and capacity of the udder. Furthermore, it appeared that some way to measure or to compensate for the effect of age should be considered in a study of the relationships between producing ability and udder weight and capacity.

Table 1 shows the average values for weight, capacity, and the ratio of capacity to weight for the data from all breeds of cows grouped according to age. Data on udders from 31 first-lactation cows without yearly production records were included in this study of the effect of age in order to have first-lactation data for cows lactating 2 months or less and to have additional data for cows lactating more than 2 months.

Most comparisons show increases in average udder weight and capacity from one age group to the next older one. The increases were greater between groups of young cows than between groups of older cows, even though differences in average age were less for the young cow groups.

TABLE 1.—*Average udder weights, capacities, and ratios of capacity to weight for lactating and dry cows in different age groups*

Age group	Udders studied	Age of cow at last calving	Empty udder weight	Udder capacity	Ratio of capacity to weight
	Number	*Months*	*Pounds*	*Pounds*	*Percent*
Cows lactating 2 months or less:					
First lactation	16	27.0±0.9	28.4±1.9	33.1±2.8	120±11
Second lactation	11	42.0±1.0	46.3±4.2	59.5±6.8	131±13
Third lactation to 6 years	17	59.5±1.7	54.4±7.7	74.4±6.5	149±10
6 to 9 years	28	92.3±1.6	49.9±3.4	79.1±5.1	171±12
Over 9 years	16	135.0±5.7	55.0±6.1	81.3±8.4	154±13
Cows lactating over 2 months:					
First lactation	27	25.8± .4	26.7±1.2	41.7±2.4	161± 9
Second lactation	21	42.7±1.2	32.3±2.4	46.5±4.3	149±11
Third lactation to 6 years	45	69.9±1.1	37.2±1.8	53.5±2.8	151± 8
6 to 9 years	55	89.2±1.4	41.3±1.6	54.5±2.3	137± 6
Over 9 years	21	126.9±2.7	37.4±2.4	56.6±4.7	151± 9
Cows dry 1 month or less:					
First lactation	18	25.7± .6	23.1±1.6	34.3±2.9	150±11
Second lactation	15	40.5± .8	30.2±3.5	44.8±4.5	157±14
Third lactation to 6 years	11	59.3±3.2	28.5±2.3	37.8±3.6	135±10
6 to 9 years	6	89.2±4.0	32.0±3.4	48.0±7.5	156±31
Over 9 years	5	142.2±6.8	42.4±2.5	54.0±9.7	132±30
Cows dry over 1 month:					
First lactation	29	27.3± .6	18.9± .9	21.8±1.9	116± 9
Second lactation	48	41.8± .6	22.4±1.0	27.4±1.9	125± 8
Third lactation to 6 years	31	62.0±1.2	24.3±1.3	28.8±1.9	125± 9
6 to 9 years	36	89.8±1.7	27.6±1.2	37.4±2.9	136±10
Over 9 years	17	124.9±3.2	27.5±1.6	37.0±4.3	138±13

One feature of these results was the tremendous increase in both udder weight and capacity between first- and second-lactation groups of udders from cows lactating 2 months or less. Second-lactation weights and capacities for cows lactating 2 months or less were 63 and 80 percent greater, respectively, than those for the first-lactation groups. Increases between corresponding groups of udders from cows lactating over 2 months were only 21 and 12 percent, respectively. The corresponding figures for cows dry 1 month or less are 31 and 31 percent, and for cows dry over 1 month, 19 and 26 percent.

Changes in ratio of capacity to weight from one age group to another were variable. In the groups for cows lactating 2 months or less, the ratios were generally greater for the udders from older cows. Also, for cows dry over 1 month, the ratios were greater for the older cows. On the other hand, in the group for cows lactating over 2 months the ratios tended to be somewhat lower for older cows than for the younger cows.

Some of the variations from the general trends toward increases in udder weight and capacity with advancing age may be attributed to differences in the proportions of Holsteins and Jerseys in the various groups under consideration (table 1). Of the five different age groups for cows lactating 2 months or less, the third group (third lactation to 6 years) included a relatively higher proportion of Holsteins than the groups preceding or following it. Of the five age groups for cows lactating over 2 months, the second group (second lactation) included a low proportion of Jerseys and the fourth and fifth groups (over 6 years) included a high proportion of Jerseys. Of the five groups that were dry 1 month or less, the fifth group (over 9 years) contained only Holsteins, which probably explains the higher average udder weight and capacity of this group. Of the five groups that were dry over 1 month, the first group (first lactation) contained a lower proportion of Jerseys and a higher proportion of Holsteins than any other group.

Breed Differences in Udder Weight and Capacity

From the previous study, breed characteristics appeared to be a considerable factor in determining udder size. A measure of the differences between breeds in udder weight and capacity is shown by the data in table 2. This table gives the average values for udders from lactating and dry cows in one herd of registered Holsteins, one herd of registered Jerseys, and a herd of grade Holsteins with a high proportion of inbred cows. A lack of numbers in some cases made it inadvisable to show all age groups as in table 1. Average data for all the lactating and dry cows that were included in table 1 are presented in table 2 for comparison with the breed averages.

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TABLE 2.—*Average udder weights, capacities, and ratios of capacity to weight for lactating and dry cows in different breed groups*

Breed group	Cows in each group	Age at last calving	Stage of lactation or length of dry period	Net energy milk yield	Empty udder weight	Udder capacity	Ratio of udder capacity to weight
Lactating cows:	*Number*	*Months*	*Days*	*Pounds*	*Pounds*	*Pounds*	*Percent*
Holstein	78	74. 2±3. 6	174±16	18, 304±425	49. 4±2. 6	67. 9±2. 7	156±9
Grade Holstein	29	64. 1±6. 0	211±23	16, 314±486	31. 5±2. 2	46. 7±3. 2	148±5
Jersey	86	84. 4±3. 3	136±14	15, 526±297	38. 0±1. 2	55. 0±2. 4	147±6
All lactating cows [1]	226	78. 5±2. 1	158± 9	16, 454±230	41. 7±1. 2	59. 7±1. 6	150±3
Dry cows:							
Holstein	69	62. 3±4. 2	143±26	17, 278±488	27. 0±1. 0	37. 4±2. 1	142±7
Grade Holstein	39	58. 4±5. 6	84±14	15, 764±479	25. 0±1. 3	35. 4±2. 5	145±9
Jersey	66	66. 5±4. 0	165±21	15, 056±405	24. 3± . 8	28. 8±1. 7	120±6
All dry cows [1]	216	60. 4±2. 2	131±11	15, 477±290	25. 1± . 6	32. 8±1. 1	133±4

[1] Average data for all cows with production records that were included in table 1.

Data on average age of cows at last calving, stage of lactation or length of dry period, and producing ability are also shown in table 2, because there were some differences between breed groups in these respects. In both the lactating and dry groups, grade Holstein cows were younger than the Holsteins or Jerseys; the lactating cows were further along in lactation, and the dry cows had been dry for a shorter period of time. Both lactating and dry Jersey groups were a few months older in average age than the Holstein groups. In producing ability, as measured by net energy milk yields, Holstein cows exceeded the Jersey cows by 15 percent for the lactating groups and by 18 percent for the dry groups. Grade Holstein cows exceeded Jersey cows in net energy milk yields by 5 percent for both lactating and dry groups.

The lactating Holstein udders weighed 30 percent more than lactating Jersey udders, and the average capacity was 23 percent greater. Dry Holstein udders weighed 11 percent more than dry Jersey udders, and the average capacity was 30 percent greater. The ratios of capacity to weight were higher for Holstein udders than for Jersey udders—by 6 percent for lactating udders and by 18 percent for dry udders. For some reason, lactating grade Holstein udders were below lactating Jersey udders in weight and capacity.

With actual milk and butterfat records adjusted to age at last calving, both the lactating and dry Holstein groups produced 46 percent more milk than lactating and dry Jerseys. Lactating and dry grade Holsteins produced 28 and 34 percent more milk, respectively, than lactating and dry Jerseys. However, the butterfat records for lactating and dry Holstein cows were 1 and 3 percent lower, respectively, than those of the Jersey cows. The corresponding butterfat records for grade Holstein cows were 15 and 17 percent lower than the Jersey records.

From these age-adjusted milk records, it was calculated that for each pound of milk obtained at an average milking, lactating Holstein, grade Holstein, and Jersey udders had average weights of 2.96, 2.17, and 3.33 pounds, respectively, and average capacities of 4.08, 3.21, and 4.82 pounds. Corresponding values calculated from net energy milk yields adjusted to age at last calving were 3.12, 2.31, and 2.76 pounds for udder weights and 4.29, 3.43, and 3.99 pounds for capacities.

Dry Holstein, grade Holstein, and Jersey udders had average weights of 1.80, 1.81, and 2.36 pounds, respectively, for each pound of milk obtained at an average milking, or average weights of 1.89, 1.97, and 1.91 pounds for each pound of net energy milk yield at a milking. Corresponding capacities of dry udders were 2.50, 2.57, and 2.80 pounds for each pound of milk, or 2.62, 2.79, and 2.27 pounds for each pound of net energy milk yield.

From these values it appears that it took a larger, more capacious Jersey udder to produce as much milk as a Holstein udder, but that a smaller Jersey udder with less capacity might produce as much milk energy as a Holstein udder. To some extent this was true of dry udders as well as lactating udders. The lactating grade Holstein udders were remarkably efficient producers for their size in respect to both milk production and net energy milk yields.

However, individuals within the same breed differed considerably in the proportions between udder size and producing ability. Small individual differences in this proportion within a breed group would have been associated with high correlation coefficients between udder size and producing ability. Actually, a value of only 0.365 was obtained as the average of 6 correlation coefficients for the relationship between udder weight and net energy milk yields in data from 367 udders sorted into groups for lactating and dry grade Holstein, Holstein, and Jersey cows.

Correlations Between Age and Udder Weight and Capacity

The results of correlation studies on the effect of age on udder weight, capacity, and the ratio of capacity to weight are shown in table 3. In this table data from the five age groups listed in table 1

TABLE 3.—*Correlation coefficients between age of cow at last calving and udder weight, capacity, and the ratio of capacity to weight*

Age group	Udders studied	Correlation coefficients [1] between age and—		
		Weight	Capacity	Ratio of capacity to weight
	Number			
Cows lactating 2 months or less:				
First and second lactations	27	0.6484**	0.5927**	0.0334
Up to 6 years	44	.5362**	.6735**	.2642"
Up to 9 years	72	.3073**	.5463**	.3733**
All ages	88	.2875**	.4199**	.2056*
Over 6 years	44	.0394	−.0971	−.1996'
Cows lactating over 2 months:				
First and second lactations	48	.2361'	.1368	−.0739
Up to 6 years	93	.4152**	.3128**	−.0657
Up to 9 years	148	.3985**	.2312**	−.1930*
All ages	169	.2931**	.2201**	−.1160'
Over 6 years	76	−.2199"	−.0485	.0553
Cows dry 1 month or less:				
First and second lactations	33	.3888*	.3273"	.0204
Up to 6 years	44	.2624"	.1304	−.1382
Up to 9 years	50	.2645"	.2056'	−.0458
All ages	55	.4715**	.3252**	−.0921
Over 6 years	11	.5021'	.1670	−.1277
Cows dry over 1 month:				
First and second lactations	77	.2635*	.2357*	.1033
Up to 6 years	108	.2616**	.1954*	.0792
Up to 9 years	144	.3668**	.3650**	.1127'
All ages	161	.3955**	.3553**	.1243'
Over 6 years	53	.0724	.0398	−.0111
All lactating cows [2]	257	.2903**	.3232**	.0211
All dry cows [2]	216	.3726**	.2917**	.0470

[1] Correlation coefficients at the $P=0.01$ level or better (highly significant) are indicated by 2 asterisks; those from $P=0.05$ to $P=0.01$ level (significant) are indicated by 1 asterisk; those from $P=0.10$ to $P=0.05$ level are indicated by quotation marks; and those from $P=0.20$ to $P=0.10$ level are indicated by an apostrophe.

[2] Refers to all cows included in table 1.

were combined in different ways in order to have ranges of age great enough for the effect of age to be recognized and at the same time to illustrate the differences between young and old cows in the relationships between age and udder weight and capacity. Data from first- and second-lactation udders were combined to illustrate the changes in this period when increases were most rapid. Correlation studies on udder data from cows up to 6 or 9 years of age were made in an attempt to measure the changes occurring during the growing period of a cow's life. Correlations on the groups for all cows over 6 years of age were designed to study whatever changes in udder weight or capacity occur in mature cows.

Many groups showed highly significant correlations between age at last calving and udder weight and capacity. However, the correlations were not significant between age and udder weight and capacity for the group of first- and second-lactation udders from cows lactating over 2 months. The reason cannot be explained fully by the greater proportion of Jersey udders in the second-lactation group or by the peculiar distribution of specimens in the second-lactation group, by which the cows with an older age at last calving tended to be more advanced in lactation than the younger cows when slaughtered.

Fewer correlations were significant in the groups of udders from cows dry 1 month or less. Possibly the number of udders was smaller and the unmeasured environmental factors were more numerous in these groups than in some others. Also, there was considerable variation in the relative proportions of Holstein, grade Holstein, and Jersey udders in the individual age groups.

None of the groups of udders from lactating or dry cows over 6 years of age showed significant correlations between age and udder weight and capacity. The high but not significant correlation between age and udder weight for cows dry 1 month or less may be explained by the absence of Jersey udder from cows over 9 years of age.

The negative correlation coefficient between age and udder weight for udders from cows over 6 years old and lactating over 2 months is not explained by a study of corresponding relationships with breed, stage of lactation, or producing ability. Table 1 showed that udders from cows over 9 years of age weighed slightly less than udders from cows 6 to 9 years old. Furthermore, the correlation coefficients between age and udder weight were negative both in the groups 6 to 9 years of age and in the groups over 9 years of age.

Very few of the age groups included in the data in table 3 show significant correlation coefficients between age and the ratio of capacity to weight. There was a significant negative correlation for the group of udders from cows up to 9 years of age and lactating over 2 months. On the other hand, udder data from cows lactating 2 months or less in age groups up to 9 years and all ages showed significant positive correlations.

Insignificant correlations between age and the ratio of capacity to weight reflect the high degree of relationship between udder weight and udder capacity. The correlation coefficients between weight and capacity for all cows in each group were 0.6383 for cows lactating 2 months or less, 0.5523 for cows lactating over 2 months, 0.5023 for cows dry 1 month or less, and 0.5416 for cows dry over 1 month.

When the data from all lactating cows were combined into one group, and the data from all dry cows were combined into another group, there were highly significant correlations between age and udder weight and capacity. The coefficients with capacity were slightly higher for lactating cows than for dry cows, and the coefficients with weight were higher for dry cows than for lactating cows. The correlation coefficients for age with the ratio of capacity to weight were not significant.

Increases in Udder Weight and Capacity With Age

A measure of the increases in udder weight and capacity and the changes in the ratio of capacity to weight for each year added to a cow's age are shown in table 4. Naturally, these estimates could not

Table 4.—*Increases in udder weight and capacity and changes in the ratio of capacity to weight for each additional year of age at last calving* [1]

Age group	Udders studied	Empty weight	Capacity	Ratio of capacity to weight
	Number	*Pounds*	*Pounds*	*Percent*
Cows lactating 2 months or less:				
First and second lactations	27	12. 85**	17. 96**	2. 1
Up to 6 years	44	10. 22**	14. 72**	9. 3"
Up to 9 years	72	2. 97**	7. 10**	9. 1**
All ages	88	2. 02**	4. 01**	3. 5*
Over 6 years	17	. 38	−1. 33	−5. 7'
Cows lactating over 2 months:				
First and second lactations	48	2. 75'	2. 81	−4. 6
Up to 6 years	93	3. 42**	4. 13**	−2. 4
Up to 9 years	148	2. 30**	1. 96**	−4. 4*
All ages	169	1. 31**	1. 51**	−2. 0'
Over 6 years	76	−1. 53"	−. 52	1. 4
Cows dry 1 month or less:				
First and second lactations	33	6. 36*	7. 68"	1. 5
Up to 6 years	44	2. 18"	1. 57	−5. 2
Up to 9 years	50	1. 47"	1. 74'	−1. 3
All ages	55	1. 70**	1. 79"	−1. 6
Over 6 years	11	1. 76'	1. 27	−3. 6
Cows dry over 1 month:				
First and second lactations	77	2. 51*	4. 34*	8. 0
Up to 6 years	108	1. 53**	1. 99*	3. 5
Up to 9 years	144	1. 45**	2. 61**	3. 1'
All ages	161	1. 10**	2. 01**	2. 6'
Over 6 years	53	. 31	. 42	−. 4
All lactating cows [2]	257	1. 74**	2. 76**	. 4
All dry cows [2]	216	1. 17**	1. 71**	. 9

[1] See footnote 1, table 3, for explanation of symbols indicating different levels of significance.

[2] Refers to all cows included in table 1.

be calculated from a series of observations on the same individual. They are based on the regression equations calculated from the correlation coefficients between age and udder weight and capacity presented in table 3. The data are grouped in the same manner as in

table 3. As regression coefficients were calculated for all groups regardless of the significance of the correlation coefficient, the same symbols are used in table 4 to show the level of significance of the correlation from which the regression coefficient was calculated.

The data in table 4 demonstrate that increases per year in udder weight and capacity were greater for young cows than for older ones. With the exception of the group of udders from cows lactating over 2 months, the greatest increases in udder weight and capacity were in the period covered by the first and second lactations. As the groups were extended to include udders from older cows, the increases per year became smaller. When the groups of udders from cows over 6 years old were separated from the rest, only one group showed appreciable increases per year in udder weight and capacity. This was the group of udders from cows dry 1 month or less in which the older cows were all Holsteins or grade Holsteins.

The changes in the ratio of capacity to weight with the various groups are presented in table 4, but most of them were calculated from correlation coefficients that were not significant. Nearly all of them were smaller than the standard error of the mean in the respective groups.

As might have been expected, the increases in udder weight or capacity that were calculated from the regression coefficients differed from those that might have been calculated by the subtraction of group averages in table 1. Because the original age groups were combined in various ways in calculating the data for table 4, udder data from cows in their first or second lactations furnished the only nearly direct comparisons. For these groups increases per year in udder weight and capacity calculated from regression equations were 90 and 85 percent as high, respectively, as those calculated from first- and second-lactation group averages for cows lactating 2 months or less, 69 and 83 percent as high for cows lactating over 2 months, 1.10 and 0.91 percent as high for cows dry 1 month or less, and 87 and 94 percent as high for cows dry over 1 month.

Two characteristics of the effect of age on udder weight and capacity complicate the problem of measuring its effect through multiple correlation methods in a study of the relationships between producing ability and udder weight and capacity. The effect of age on udder weight and capacity is curvilinear by reason of more rapid increases in udder weight and capacity in younger cows. Also, age has little effect after the sixth year. Since both of these are characteristics of the standard age-correction factors for the milk-production records that were used, it seemed possible that a practical means of accounting for the effect of age could be accomplished by adjusting the net energy milk yield to the age of the cow at her last calving.

A test of this possibility was made on udder data from cows up to 9 years of age within each of the lactating and dry-period groups. Three sets of correlations were calculated on these data: (1) The simple correlation between the net energy milk yield converted to maturity and udder weight and capacity; (2) the simple correlation between the net energy milk yield adjusted to the age of the cow at last calving and udder weight and capacity; and (3) the partial correlation between net energy milk yield converted to maturity and

udder weight and capacity, independent of the age of the cow. These comparisons showed lower standard errors of estimate for both sets, taking into account the effects of age, with slight advantage to the set using the partial correlation coefficients. However, since this advantage was slight in proportion to the amount of unmeasured variance, it provided little reason for not using net energy milk yield adjusted to age at last calving as a simpler way of accounting for the effect of age in studies of the relationships between producing ability and udder weight and capacity.

EFFECT OF STAGE OF LACTATION AND LENGTH OF DRY PERIOD ON UDDER WEIGHT AND CAPACITY

Partial Correlation Coefficients

In studying the effect of the stage of lactation in days or the number of days dry on udder weight and capacity and the ratio of capacity to weight, multiple correlation studies were used to eliminate the effect of producing ability. No attempt was made to eliminate the effect of age. However, it did not appear that this would have made much difference, because there were significant or nearly significant correlations between age and the stage of lactation or length of dry period in only two of the groups listed in table 5. There were highly significant negative correlations (−0.2282 and −0.2502) between age and stage of lactation in the group of udders from cows lactating over 2 months and in the group of udders from all lactating cows. These correlations showed that more older cows were killed early in lactation than younger cows. But this relationship was demonstrated principally by data from cows over 6 years of age, when age had little effect on udder weight and capacity.

The partial correlation coefficients between stage of lactation or length of dry period and udder weight, capacity, and the ratio of capacity to weight are shown in table 5. These coefficients are

TABLE 5.—*Partial correlation coefficients between the stage of lactation, or length of dry period, and udder weight, capacity, and the ratio of capacity to weight, independent of net energy milk yields*

Group	Udders studied	Partial correlation coefficients [1]		
		Weight	Capacity	Ratio of capacity to weight
	Number			
Cows lactating 2 months or less	72	−0.2808*	0.0057	0.2599*
Cows lactating over 2 months	154	−.3561**	−.1568*	.2151**
Cows dry 1 month or less	55	−.0099	−.1564	−.0941
Cows dry over 1 month	161	−.1674*	−.1290'	−.0398
All lactating cows [2]	226	−.4096**	−.3427**	.0896'
All dry cows [2]	216	−.2543**	−.2586**	−.1048'

[1] See footnote 1, table 3, for explanation of symbols indicating different levels of significance.

[2] Average data for all cows with production records that were included in table 1.

independent of the effect of producing ability as measured by net energy milk yields adjusted to age at last calving.

There were highly significant negative partial correlations between advance in lactation and udder weight and capacity for all lactating cows and between length of dry period and udder weight and capacity for all dry cows. The group of udders from cows dry 1 month or less covered too short a range of time to expect significant correlations. The same result to a lesser degree might have been expected from the group of udders lactating 2 months or less, but there was a significant negative correlation between stage of lactation and udder weight. In most groups the correlations with weight were higher than those with capacity.

Partial correlations between the stage of lactation and the ratio of capacity to weight were significant and positive for udders from cows lactating 2 months or less and for udders from cows lactating over 2 months, although they were not significant when these two groups were combined. These coefficients with the ratio of capacity to weight indicate that the swelling or increase in udder size occurring at calving time is not accompanied by an equivalent increase in udder capacity.

The question arose as to whether the decline in udder weight and capacity with advance in lactation or length of dry period was as characteristic for young cows, when udders are developing, as it was for older cows. The data for all lactating cows were sorted into one group for cows under 6 years of age and another group for older cows. Udder data from dry cows were sorted in the same way.

The simple correlation coefficients between advance in the stage of lactation and udder weight and capacity were -0.2952^{**}[3] and $-0.1573'$ for 137 young lactating cows, and -0.3641^{**} and -0.3122^{**} for 120 older cows. Data in table 1 on cows in their first lactations showed that udder weights were only slightly higher in the first 2 months of lactation than later on, and that capacities were considerably less in the first 2 months. By omitting data from the first-lactation cows, the correlations between advance in lactation and udder weight and capacity were -0.3475^{**} and -0.2421^{*} for 94 young lactating cows. The simple correlation coefficients between length of dry period and udder weight and capacity, respectively, were -0.2489^{**} and -0.2924^{**} for 152 young dry cows and -0.2677^{*} and $-0.1747'$ for 64 older ones.

Changes in Udder Weight and Capacity With Advance in Lactation or Length of Dry Period

The changes in udder weight, capacity, and the ratio of capacity to weight accompanying each 30-day month of advance in lactation or length of dry period are shown in table 6. These values were calculated from the multiple regression equations for the same groups of udders that were included in the data given in table 5. The same symbols are used to indicate the significance of the corresponding partial correlation coefficients.

[3] See footnote 1, table 3, for explanation of symbols indicating different levels of significance.

TABLE 6.—*Changes in udder weight, capacity, and ratio of capacity to weight for each 30-day month of advance in lactation or dry period* [1]

Group	Udders studied	Empty weight	Capacity	Ratio of capacity to weight
	Number	*Pounds*	*Pounds*	*Percent*
Cows lactating 2 months or less	72	−10. 97*	0. 25	25. 6*
Cows lactating over 2 months	154	−1. 01**	−. 61*	2. 3**
Cows dry 1 month or less	55	−2. 91	−6. 58	−15. 0
Cows dry over 1 month	161	−. 21*	−. 32*	−. 3
All lactating cows [2]	226	−1. 47**	−1. 66**	. 9'
All dry cows [2]	216	−. 36**	−. 67**	−1. 0'

[1] See footnote 1, table 3, for explanation of symbols indicating different levels of significance.

[2] Average data for all cows with production records that were included in table 1.

Decreases is udder weight were most rapid during the first 2 months of lactation, being nearly 11 pounds a month. After 2 months, the decrease was only 1 pound for each 30-day month. Capacity did not decrease with advance in lactation during the first 2 months, although there was a decrease after 2 months of 0.6 pound for each month of advance in lactation. The ratios of capacity to weight increased with advance in lactation, particularly for udders from cows lactating 2 months or less. Probably the swollen condition of fresh udders caused weights to be proportionally higher early in lactation, but it did not have a similar effect on capacity.

Udder weight and capacity decreased with increases in the length of dry period. Decreases were greatest for udders obtained within 1 month or less after the cow turned dry, but the correlation coefficients on this group of udders were not significant. For all dry cows there was a monthly decrease of 0.4 pound in weight and 0.7 pound in capacity. Changes in the ratio of capacity to weight were not significant.

EFFECT OF PRODUCING ABILITY ON UDDER WEIGHT AND CAPACITY

PARTIAL CORRELATION COEFFICIENTS

In studying the effect of producing ability on udder weight, capacity, and the ratio of capacity to weight, due consideration was given to the possible effect of age by using net energy milk yields adjusted to the age of the cow at her last calving. Multiple correlation studies were used to account for the effects of advance in the stage of lactation or in the length of the dry period. The partial correlation coefficients from these calculations on six groups of udders are shown in table 7.

TABLE 7.—*Partial correlation coefficients between net energy milk yields adjusted for age at last calving and udder weight, capacity, and ratio of capacity to weight*

Group	Udders studied	Partial correlation coefficients [1]		
		Weight	Capacity	Ratio of capacity to weight
	Number			
Cows lactating 2 months or less	72	0. 2998*	0. 4846**	0. 1777'
Cows lactating over 2 months	154	. 3800**	. 4097**	. 0319
Cows dry 1 month or less	55	. 4980**	. 5975**	. 2287''
Cows dry over 1 month	161	. 4131**	. 4618**	. 2579**
All lactating cows [2]	226	. 2672**	. 3709**	. 0890'
All dry cows [2]	216	. 4162**	. 4677**	. 2329**

[1] See footnote 1, table 3, for explanation of symbols indicating different levels of significance.

[2] Average data for all cows with production records that were included in table 1.

All of the partial correlation coefficients between net energy milk yields and udder weight and capacity in table 7 were highly significant except one, and that one was close to that level of significance. The coefficients were a little higher for udders from dry cows than for udders from lactating cows. Thus it would appear that the size of the udder in dry cows is as reliable an estimate of producing ability as the size of the udder in lactating cows.

The partial correlation coefficients between net energy milk yields and the ratio of weight to capacity were highly significant for cows dry over 1 month and for the group of all dry cows, but they were not significant for any group of lactating cows. If the effect of producing ability on udder capacity was closely parallel to its effect on udder weight, it is only natural that the correlations between producing ability and the ratio of weight to capacity would be low. The simple correlation coefficients between udder weight and capacity were 0.5514 for cows lactating 2 months or less, 0.5436 for cows lactating over 2 months, and 0.6216 for all lactating cows. Similar coefficients for udders from dry cows were 0.5023 for cows dry 1 month or less, 0.5416 for cows dry over 1 month, and 0.5605 for all dry cows.

The reason for highly significant correlations in dry cow groups between producing ability and the ratio of capacity to weight may have been due to a tendency for the weights of dry udders from poor producing cows to include larger percentages of fat in proportion to glandular tissue. The result would be lower ratios for these cows and higher ratios for higher producing cows.

CHANGES IN UDDER WEIGHT AND CAPACITY WITH INCREASES IN PRODUCING ABILITY

The changes in udder weight and capacity that accompanied each 1,000-pound increase in net energy milk yield are shown in table 8.

These values were calculated from the multiple regression equations for the same groups of udders that are listed in table 7. The same symbols are used to indicate the significance of the corresponding partial correlation coefficients for each group.

TABLE 8.—*Increases in udder weight, capacity, and the ratio of capacity to weight for each 1,000-pound increase in net energy milk yield* [1]

Group	Udders studied	Empty weight	Capacity	Ratio of capacity to weight
	Number	*Pounds*	*Pounds*	*Percent*
Cows lactating 2 months or less	72	2. 05*	4. 30**	3. 0'
Cows lactating over 2 months	154	1. 14**	1. 98**	. 4
Cows dry 1 month or less	55	1. 31**	2. 41**	2. 9''
Cows dry over 1 month	161	. 67**	1. 53**	3. 3**
All lactating cows [2]	226	1. 19**	2. 38**	1. 2'
All dry cows [2]	216	. 80**	1. 69**	3. 1**

[1] See footnote 1, table 3, for explanation of symbols indicating different levels of significance.

[2] Average data for all cows with production records that were included in table 1.

The data in table 8 show increases of 1.19 pounds in udder weight and 2.38 pounds in capacity for each 1,000-pound increase in net energy milk yield for all lactating cows. Corresponding increases for all dry cows were 0.80 pound in weight and 1.69 pounds in capacity. Increases in udder weight and capacity for each 1,000-pound increase in net energy milk yield were considerably greater for cows lactating 2 months or less than for cows lactating over 2 months. Also, they were greater in proportion to the average udder weights and capacities of each of these two groups. In like manner, the increases in udder weight and capacity in pounds, or in proportion to the average weight and capacity of each group, were greater for cows dry 1 month or less than they were for cows dry over 1 month.

SELECTED PHOTOGRAPHS USED TO ILLUSTRATE UDDERS OF DIFFERENT SIZES

Having established the relationship between producing ability and udder size as measured by empty weight and capacity, there remained the need for interpreting the data in terms of udder size on the living cow. There is no practical way of measuring the weight or capacity of an udder while it is attached to the cow. The size of an udder must be judged from its appearance. The pictures in plates 1 to 9, inclusive, are presented in order to establish the relationships between the weights of udders of different sizes and their appearance before slaughter.

Most of the 473 udders used in this study were photographed a few days before the cow's death. These photographs were taken soon after milking, by a standardized procedure, to show all udders alike in scale

and position. Pictures were selected from three groups of udders sorted according to age under each of three groups sorted according to the stage of lactation or length of dry period. For each of these nine groups, examples are shown of three Holstein udders and three Jersey udders that were high, medium, or low in weight. No pictures are shown for udders dry 1 month or less, because this was a small group from which to make selections and because of its limited usefulness.

No picture was available for a large udder from a Jersey cow lactating 2 months or less in her first lactation, so a picture from an older cow with an udder of the desired weight was used. Also, because no picture was available of any small Jersey udder in the same group, one from a cow of the same age nearly 6 months in lactation was substituted.

The weight of each udder is shown with each picture. More data on each udder are given in table 9. The three values for each breed group under the column for group weight data are the mean empty weight for the group, the mean plus the standard deviation, and the mean minus the standard deviation. These are data calculated separately for Holstein and for Jersey groups. These values are shown in order to locate the example illustrated in relation to the variation that occurred within each group. The net energy milk yields are all on a mature basis. No attempt was made to select large udders with high production records and small ones with low records. As a result, the examples show much deviation from the general relationship between producing ability and udder size.

TABLE 9.—*Data on udders that were selected to illustrate, by photographs (pls. 1 to 9), the variations in size between the different groups according to age and stage of lactation or length of dry period*

COWS LACTATING 2 MONTHS OR LESS

Age and breed group	Empty udder weight data for each breed group			Data on each udder selected for illustration								
	Mean plus standard deviation	Mean empty weight	Mean minus standard deviation	Udder size group	Cow No.	Age at last calving	Time in milk	Time dry	Net energy milk yield	Empty weight of udder	Capacity of udder	Ante-mortem grade of udder for size
	Pounds	*Pounds*	*Pounds*			*Months*	*Days*	*Days*	*Pounds*	*Pounds*	*Pounds*	
First lactation:												
Holstein	39. 1	31. 8	24. 5	Large	292	27	43			44. 4	46. 4	——
				Medium	1643	27	48			34. 3	40. 9	5—
				Small	1608	23	53			23. 2	30. 8	5 —
Jersey	35. 5	27. 5	19. 5	Large	1483	57	22		12, 947	35. 3	71. 8	7 —
				Medium	1438	24	51			26. 6	43. 7	4+
				Small	1423	26	167			23. 2	58. 0	5+
Second lactation to 6 years:												
Holstein	99. 6	65. 1	30. 5	Large	848	69	5		14, 846	165. 7	111. 7	9 —
				Medium	1611	53	32		22, 710	54. 7	108. 7	6
				Small	1620	49	75		24, 588	34. 6	67. 5	4
Jersey	51. 8	42. 1	32. 4	Large	1476	55	17		18, 175	48. 0	47. 8	6
				Medium	1482	53	31		12, 916	40. 2	49. 1	6
				Small	697	70	37		16, 073	29. 2	65. 6	6
6 years and over:												
Holstein	105. 6	75. 6	45. 5	Large	287	135	6		22, 012	138. 2	170. 8	9
				Medium	802	116	6		16, 431	72. 4	110. 6	8
				Small	255	115	32		13, 596	42. 7	55. 9	5+
Jersey	56. 5—	43. 0	29. 4	Large	1411	83	20		15, 979	61. 4	95. 3	8
				Medium	444	185	27		16, 182	40. 0	63. 5	7
				Small	653	107	40		16, 793	32. 5	66. 0	6

TABLE 9.—*Data on udders that were selected to illustrate, by photographs (pls. 1 to 9), the variations in size between the different groups according to age and stage of lactation or length of dry period*—Continued

COWS LACTATING OVER 2 MONTHS

Age and breed group	Empty udder weight data for each breed group			Data on each udder selected for illustration								
	Mean plus standard deviation	Mean empty weight	Mean minus standard deviation	Udder size group	Cow No.	Age at last calving	Time in milk	Time dry	Net energy milk yield	Empty weight of udder	Capacity of udder	Antemortem grade of udder for size
First lactation:	*Pounds*	*Pounds*	*Pounds*			*Months*	*Days*	*Days*	*Pounds*	*Pounds*	*Pounds*	
Holstein	34. 7	27. 9	21. 2	Large	1260	26	133			37. 4	41. 3	5—
				Medium	1291	24	371		18, 287	27. 1	50. 1	3
				Small	1218	24	283		13, 312	22. 7	35. 9	2
Jersey	31. 9	27. 0	22. 1	Large	1096	26	205			31. 7	57. 0	6—
				Medium	1035	31	494		18, 145	29. 0	47. 6	6—
				Small	675	25	460		11, 295	17. 9	27. 2	4
Second lactation to 6 years:												
Holstein	52. 3	40. 3	28. 3	Large	844	67	319		18, 255	48. 6	76. 6	6
				Medium	837	65	290		18, 054	35. 8	78. 7	5—
				Small	858	53	138		8, 503	22. 0	59. 8	3
Jersey	42. 2	35. 5	28. 8	Large	1487	57	125		13, 602	49. 3	43. 7	6+
				Medium	687	70	375		16, 358	32. 7	67. 5	6
				Small	643	70	506		18, 469	24. 6	40. 3	5
Six years and over:												
Holstein	57. 0	46. 0	35. 1	Large	843	72	278		18, 095	54. 1	75. 4	7
				Medium	831	88	254		17, 677	45. 4	60. 4	6+
				Small	275	103	373		21, 242	34. 0	52. 6	4
Jersey	45. 7	35. 1	24. 5	Large	1060	78	154		17, 360	49. 5	50. 0	7
				Medium	662	85	220		12, 597	34. 8	44. 2	7—
				Small	426	144	152		13, 620	25. 4	41. 6	7

COWS DRY OVER 1 MONTH [1]

First lactation:												
Holstein	25.0	20.1	15.1	Large	1210	24		63	14,748	21.1	16.4	2—
				Medium	1617	28		225	15.004	18.0	22.6	2—
				Small	1286	23		105	17,484	14.4	21.2	2—
Jersey	26.9	21.8	16.6	Large	1012	27		161	12,345	23.7	21.5	2--
				Medium	1001	39		191	12,782	20.7	17.6	3+
				Small	1003	30		196	14,328	18.5	20.0	2—
Second lactation to 6 years:												
Holstein	31.6	25.3	19.0	Large	1217	57		76	18,432	32.1	29.9	6—
				Medium	1204	39		64	20,112	24.0	37.0	3—
				Small	264	59		470	14,345	19.9	41.5	2
Jersey	30.2	24.4	18.6	Large	1498	38		57	13,204	29.5	40.0	6
				Medium	1412	68		390	17,693	23.7	28.6	4
				Small	1002	36		192	19,157	18.3	15.5	2—
Six years and over:												
Holstein	41.9	34.0	26.0	Large	800	87		72	13,758	47.8	49.2	5—
				Medium	280	89		42	16,180	33.6	46.9	4
				Small	816	82		55	13,743	22.4	60.1	3+
Jersey	31.5	24.9	18.2	Large	440	138		36	19,334	35.0	40.3	6+
				Medium	480	148		77	10,614	24.5	29.0	6—
				Small	416	109		211	14,929	18.6	23.1	3

[1] The three values for empty udder weight of the breed groups are for all dry cows, but none of the selected udders were from cows that were dry less than 1 month.

SUMMARY AND CONCLUSIONS

Data on the udders from 473 cows (Holsteins, grade Holsteins, and Jerseys) were used in numerous group and correlation studies to determine the relationships between udder size and producing ability, and the effect of age, breed, stage of lactation, and length of dry period on the weight and capacity of the udder. Except in a study of breed differences, the data from all breeds were combined to insure a sufficient number of udders in the various age and lactation-cycle groups.

Group averages and correlation studies showed definite increases in udder weight and capacity with age. The increases in weight and capacity were greatest between the first and second lactation, ranging from 12.85 and 17.96 pounds a year, respectively, for cows lactating 2 months or less to 2.51 and 4.31 pounds a year for cows dry over 1 month. Increases were quite definite for all young cows, but they were insignificant for cows over 6 years of age. From the earliest age at first calving up to 6 years of age, yearly increases in udder weight and capacity were 10.22 and 14.72 pounds, respectively, for cows lactating 2 months or less; 3.42 and 4.13 pounds for cows lactating over 2 months; and 1.53 and 1.99 pounds for cows dry over 1 month.

Data from Holstein and Jersey udders were sorted into separate breed groups. The average weight and capacity for lactating udders was 49.4 and 67.9 pounds, respectively, for 78 Holstein cows with an average age of 6 years 2 months, and 38.0 and 55.0 pounds, respectively, for 86 Jersey cows with an average age of 7 years. The average weight and capacity of dry udders was 27.0 and 37.4 pounds, respectively, for 69 Holstein cows with an average age at last calving of 5 years 2 months, and 24.3 and 28.8 pounds, respectively, for 66 Jersey cows with an average age at last calving of 5 years 6 months.

Advance in the stage of lactation was associated with variable but definite decreases in udder weight and less definite decreases in capacity. Increases in the length of dry period were associated to some extent with decreases in udder weight and capacity. When udders from cows dry 1 month or less were included with udders dry over 1 month, there were decreases of 0.36 and 0.67 pound in weight and capacity for each month. Monthly decreases with advance in lactation for all lactating cows combined were 1.47 pounds in weight and 1.66 pounds in capacity, but during the first 2 months of lactation a monthly decrease of 10.97 pounds in weight was observed.

Highly significant correlations between producing ability and udder weight and capacity were found in both groups of lactating cows and in both groups of dry cows. The correlations between producing ability and udder capacity were a little higher than those between producing ability and udder weight. As the coefficients for dry udders were a little higher than those for lactating udders, it would seem that a large dry udder is as good an indication of producing ability as a large lactating udder.

The increases in udder weight and capacity that accompanied each 1,000-pound increase in net energy milk yield were 2.05 and 4.30 pounds, respectively, for cows lactating 2 months or less, 1.14 and 1.98 pounds for cows lactating over 2 months, 1.31 and 2.41 pounds

for cows dry 1 month or less, and 0.67 and 1.53 pounds for cows dry over 1 month.

The ratios calculated by dividing udder capacity by empty weight of udder had no consistent significant relationship within all groups with the effects of age, lactation cycle, or producing ability. However, there were significant positive correlations between this ratio and producing ability in dry cows and between this ratio and advance in lactation for cows lactating 2 months or less and cows lactating over 2 months.

Groups of udder pictures are shown to illustrate variations in size for different age and lactation cycle groups.

Udders of cows lactating 2 months or less in their first lactations.

Udders of cows lactating 2 months or less in their second or later lactations under 6 years of age.

Udders of cows lactating 2 months or less and 6 years of age or over at last calving.

Udders of cows lactating over 2 months in their first lactations.

Udders of cows lactating over 2 months in a second or later lactation under 6 years of age.

Figure 3.—Cows for culling over 2 months and 6 years of age or over at last calving.

Udders of cows dry over 1 month following the first lactation.

Typical cows dry over 1 month before or at second or later lactation under 6 years of age.

Udders of cows dry over 1 month and 6 years of age or over at last calving.

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