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To the Graduate Council:

I am submitting to you a thesis written by Frank D. Hinton entitled "Rumen Inoculation of Dairy Calves, its Relation to Feeding of Roughage and Growth of Calves." I recommend that it be accepted for nine quarter hours credit in partial fulfillment of the requirements for the degree of Master of Science, with a Major in Dairying.

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RUMEN INOCULATION OF DAIRY CALVES, ITS RELATION TO FEEDING OF ROUGHAGE AND GROWTH OF CALVES

A THESIS

Submitted to
The Graduate Council
of
The University of Tennessee
in
Partial Fulfillment of the Requirements
for the degree of
Master of Science

---

by

Frank D. Hinton

June 1952

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--F.D.H.

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CHAPTER I

OBJECTIVES

The object of this study is to determine the value of rumen inoculation in the digestion of roughage by the young calf and the effect of rumen inoculation on the growth of calves from birth to six months of age.

It has been postulated that starting the young calf's rumen to functioning as early as possible would increase the efficiency of roughage utilization, as well as providing other beneficial factors resulting from proper rumen fermentation. In the normal, mature cow, rumen fermentation provides most of the B complex vitamins used by the cow and aids in the digestion of cellulose and other complex foods.

It may be that consumption of roughage would lower the amount of concentrates consumed (due to a small rumen capacity) at a time when the calf needs a high TDN intake for mantainance and growth.

While rumen organisms are primarily associated with roughage consumption, they may possibly play a part in the digestion of concentrates or may provide benefits in some other manner.

Groups of calves have been included to test the value of each of the above assumptions.

CHAPTER II

REVIEW OF LITERATURE

The age at which a calf begins rumination may vary greatly. Williams and Knodt (25) found that ten Holstein males began rumination at the average age of 35 days. Mead and Goss (13) reported that Holstein heifers 18 months of age and maintained on a no roughage diet, did not have regular ruminations. Pounden and Hibbs (15) showed that normal rumen organisms were present in only five out of fifteen calves at 30 days of age and were not present in two out of seventeen at 90 days of age.

Factors other than age may also influence the time at which rumen organisms become established. Pounden and Hibbs (16) found characteristic organisms could be established before calves were one week old, provided the calves were receiving good quality hay and no grain. They (17) later reported a marked reduction in numbers of protozoa in the rumen when the calf was on a ration which exceeded three parts of grain to two parts of hay. A ration of grain alone practically eliminated all protozoa from the rumen. Pounden and Hibbs (18) also studied calves which were being pastured and concluded that from several weeks to several months are required for all calves to develop normal rumen organisms. By placing small amounts of cud

material from healthy cows in the mouths of young calves on the 5th, 10th, 15th and 21st days of age, Pounden and Hibbs (16) were able to establish normal rumen organisms in most calves by three weeks of age.

Proper function of the rumen will depend partly on its size. Hastings (6) concluded that the size of the rumen increased under the stimulus of solid feed. Marshall, Arnold and Becker (10) have shown that while the abomasum is the largest stomach at birth, the rumen usually surpasses it in size between seven and thirty days of age. Wise and co-workers (27) reported in their work with a calf which had its rumen removed, that no rumination occured and the calf was quite unhealthy until administration of ruminal fluids from other animals stimulated the appetite and eventually aided in the partial regeneration of the rumen.

The value of rumen inoculation with cud material is still open to question. Pounden and Hibbs (16) emphasized that no significant difference, at the 5% level of probability, was noted between the weight of inoculated and non-inoculated calves. They (20) also concluded that although calves without characteristic rumen organisms developed rough hair coats and appeared unthrifty, there was no significant difference between their rate of gain and that of a control group. Hibbs and Pounden (7) found that inoculation of the rumen will increase the plasma

ascorbic acid levels but does not affect the plasma carotenoids, plasma vitamin A or blood carotenoid levels. Conrad and co-workers (3) reported that inoculated calves on a ration of whole milk and alfalfa hay digested 4.81% more cellulose and 3.84% more dry matter than uninoculated calves on the same ration. A calf freed of characteristic organisms by heavy grain feed showed a decreased ability (11.26%) to digest cellulose, in contrast to a calf in which characteristic organisms had reappeared.

The value of organisms in the rumen has been demonstrated. Baker and Harriss (1) concluded that not only cellulose but also other complex starches are largely digested by the aid of organisms. These organisms utilize the more complex compounds in building their bodies. They then die and are broken down and digested by the host animal. Pounden, Hibbs and Ferguson (19) showed that most microorganisms undergo breakdown before leaving the digestive tract. They also confirm that most protozoa are destroyed in the abomasum fluids.

Few workers have been able to successfully grow calves on no roughage diets over a long period of time. McCandlish (14) found that a diet of milk alone increased appetites up to 100 days but caused fits at three and one-half to four months of age. However, Knoop and co-workers

(9) observed no ill effects of feeding whole milk only to 150 days of age. Davenport (5) noted that calves did well on milk and grain for four to six months and then died with convulsions. By supplementing the diet with cod liver oil and alfalfa ash or copper and iron, Mead and Regan (12) were able to grow calves to 19 months of age on a no roughage diet. Although no deficiencies appeared in these animals before seven to nine months of age, some symptoms were observed before the end of the period.

Investigators disagree on the effect on no roughage diets on gain in weight with calves. Sanborn (23) reported that a steer made more efficient gains on grain alone than on grain and hay rations. Bender and Bartlett (2) concluded that animals made faster gains when receiving alfalfa hay and a medium protein grain, than when on a ration with no hay and a high protien grain. Mead and Goss (13) showed that animals on digestion trials without roughage had approximately the same digestion coefficients for fat, proteins, etc. as animals with roughage included in the ration. The only exception was crude fiber which was 32% lower for animals receiving no roughage.

CHAPTER III

EXPERIMENTAL PROCEDURE

This study to determine the value of rumen inoculation, its relation to roughage digestion and rate of gain of dairy calves was conducted at the Tennessee Experiment Station at Knoxville, and was begun in December, 1950. All Jersey and Holstein calves born in the University herd were divided into four groups at birth.

Group I

The seven Jersey calves and six Holstein calves in this group were allowed to remain with their dams for four days after birth. They were then fed from pails with the Jerseys receiving six pounds of whole milk daily and the Holsteins ten pounds daily for seven weeks. Hay and grain feeding was begun on the fourth day.

Group II

The six Jersey calves and five Holstein calves in this group were handled in the same manner as the calves in Group I except that no hay was fed until the calves were 90 days of age. Grain feeding was begun at four days of age.

Group III

The seven Jersey calves and six Holstein calves in this group were fed milk, hay and grain exactly as in Group I. In addition, these calves were rumen inoculated by placing fresh pieces of cud in their mouths and forcing them to swallow it. This was done on the seventh day after birth and repeated on the fourteenth and twenty-first days.

Group IV

The six Jersey calves and the five Holstein calves in this group were handled in the same manner as those in Group II except that these were inoculated in the same manner as those in Group III. Grain was fed beginning at four days and hay beginning at ninety days.

Feed

All calves were fed the same grain ration. It consisted of 200 pounds of cracked yellow corn, 200 pounds of crushed oats, 150 pounds of wheat bran, 150 pounds of cottonseed meal, 300 pounds of skimmilk powder, 10 pounds of salt and 20 pounds of bone meal. Medium quality Korean lespedza was used as a roughage. Milk from the Holstein herd at the University Farm was used to feed the calves.

The Jerseys were fed a total of 300 pounds and the Holsteins 500 pounds of milk.

Housing

The calves were left with their dams for four days and then were placed in individual calf pens until they were four months old. They were then divided into inoculated and non-inoculated groups and placed in two large pens until they were six months old. Individual feed weights were kept while the calves were kept in the individual pens. Wood shavings were used for bedding.

Handling

The calves were fed hay, grain and milk twice daily. Water was provided in small pails and was changed at each feeding. The calves were weighed and measured for height at the withers and heart girth each week.

Digestion Trials

Six Holstein and three Jersey males were used in digestion trials. Trials were run at 90, 120, 150, and 180 days of age. The calves were kept in a small pen for four days preceding the collection period. They were then placed

in a digestion crate and their feces collected for four days. It was weighed, mixed and sampled at 24 hour intervals and kept at 40° F until the end of the period. It was then dried, weighed, ground and sampled for analysis. The Crampton and Maynard (4) method was used to analyze for cellulose.

Records Kept

The following records were kept:

1. Breed of calves
2. Weekly weights of calves
3. Weekly height of calves
4. Weekly heart girth of calves
5. Grain consumed daily up to four months of age
6. Hay consumed daily up to four months of age

CHAPTER IV

RESULTS

Weight

The average weekly weights of each group are shown in Figures 1 and 2. Jersey calves' weights are shown in Figure 1 and Holstein calves' weights are shown in Figure 2. Individual weekly weights are given by breed and groups in Figures 3-10. These gains are somewhat under those reported by Maynard and Norris (11) and Ragsdale (21) for animals at the same age. However, the animals in this experiment were limited to four pounds of grain per calf per day to encourage the consumption of more roughage.

Birth weight, weight at six months and average daily gain are shown in Table I. The Holstein calves in Group I gained an average of 1.43 $\pm$ 0.11 pounds per day while those in Group II gained an average of 1.41 $\pm$ 0.21 pounds per day for the six months period. The Holstein calves in Group III gained an average of 1.15 $\pm$ 0.19 pounds per day and those in Group IV gained an average of 1.27 $\pm$ 0.066 pounds per day for the six months period. As some of the calves have not yet reached six months of age, they are not included in these averages.

The Jersey calves in Group I gained an average of 0.83 $\pm$ 0.15 pounds per day while those in Group II gained

TABLE I

GROUP AVERAGE WEIGHT AND AVERAGE GAIN IN WEIGHT

Group	Breed	Number Calves	Birth Weight	Weight at six months	Daily Gain	S. D.
I	J	7	54#	199#	.83#	.15#
II	J	6	55	163	.61	.17
III	J	7**	48	163	.65	.15
IV	J	6*	55	187	.71	.073
I	H	6*	87	336	1.43	.11
II	H	5	83	328	1.41	.21
III	H	6*	89	289	1.15	.19
IV	H	5**	92	303	1.27	.066

* One calf not yet six months old and not included in the last three columns.
** Two calves not yet six months old.
Weights, daily gain and S. D. are given in pounds.
S. D. Standard Deviation.

an average of 0.61 ± 0.17 pounds per day for the six months period. The Jersey calves in Group III gained an average of 0.65 ± 0.15 pounds per day and those in Group IV gained an average of 0.71 ± 0.073 pounds per day for the six months period.

Height

The average height at birth, the height at six months and the average daily gain in height are shown in Table II.

Feed Consumption

The amount of hay, grain and milk consumed by individual calves is shown in Tables III and IV. The pounds of TDN required to produce one pound of gain is also shown in these tables. The average pounds of TDN required to produce one pound of gain for Group I Holsteins was 1.91, for Group II 1.82, for Group III 2.25 and for Group IV 1.72 pounds.

The average pounds of TDN required to produce one pound of gain for Group I Jerseys was 2.19, for Group II 2.45, for Group III 2.25 and for Group IV 2.17 pounds.

When milk is included in calculating TDN, none of these gains are as effecient as those reported by Ragsdale (22).

TABLE II

GROUP AVERAGE HEIGHT AND AVERAGE GAIN IN HEIGHT

Group	Breed	Number Calves	Height at Birth	Height at Six Months	Average Daily Gain in Height
I	J	7	25.72 in.	36.79 in.	.061 in.
II	J	6	25.25	33.66	.047
III	J	7**	24.24	31.60	.041
IV	J	6*	24.79	32.90	.045
I	H	6*	27.96	37.41	.052
II	H	5	27.65	37.75	.056
III	H	6*	28.08	37.08	.050
IV	H	5**	28.60	36.75	.045

* One calf not yet six months old and not included in averages.
** Two calves not yet six months old.

TABLE III

FEED CONSUMPTION AND GAIN IN WEIGHT TO FOUR MONTHS OF AGE BY JERSEY CALVES

Calf No.	Group	Pounds				
		Milk fed	Grain fed	Hay fed	Weight Gain	Pounds of TDN* per Pound Gain
T321	I	300	215	110	97	2.19
T323	I	300	241	104	94	2.39
T329	I	300	187	26	79	1.91
T335	I	300	199	32	82	2.00
T339	I	300	284	58	79	3.00
T344	I	300	222	88	101	1.80
T345	I	300	249	78	110	2.02
Average		300	228	83	90	2.19
T318	II	300	230	65	95	2.10
T320	II	300	184	43	64	2.46
T328	II	300	183	28	53	2.83
T330	II	300	170	32	47	3.03
T336	II	300	215	29	86	2.03
T340	II	300	125	20	56	2.28
Average		300	183	36	77	2.45
T322	III	300	230	54	100	1.97
T326	III	300	189	59	66	2.55
T332	III	300	226	71	80	2.53
T334	III	300	193	86	86	2.14
T341	III	300	196	34	64	2.14
T347	III	300	210	88	100	1.98
T348	III	300	139	73	69	2.01
Average		300	198	66	81	2.25
T327	IV	300	238	51	94	2.14
T333	IV	300	241	180	95	2.77
T338	IV	300	245	23	90	2.15
T342	IV	300	234	29	78	2.41
T342	IV	300	76	36	55	1.36
Average		300	207	64	80	2.17

* Does not include milk fed.

TABLE IV

FEED CONSUMPTION AND GAIN IN WEIGHT TO FOUR MONTHS OF AGE BY HOLSTEIN CALVES

Calf No.	Group	Milk Fed (lbs.)	Grain Fed (lbs.)	Hay Fed (lbs.)	Weight Gain (lbs.)	Pounds of TDN* per Pound Gain
602	I	500	309	134	148	2.13
603	I	500	328	209	183	1.99
611	I	500	214	84	100	1.99
618	I	500	287	208	150	2.09
619	I	500	249	200	165	1.70
626	I	500	287	143	157	1.81
Average		500	279	163	149	1.91
601	II	500	291	95	155	1.69
604	II	500	208	90	115	1.72
614	II	500	265	43	109	2.00
617	II	500	244	107	125	1.87
620	II	500	284	84	137	1.84
Average		500	258	86	128	1.82
605	III	500	295	225	149	2.20
607	III	500	318	237	145	3.34
612	III	500	222	52	107	1.78
615	III	500	275	140	144	1.89
621	III	500	196	94	94	1.84
622	III	500	243	240	133	2.23
Average		500	258	158	128	2.04
606	IV	500	260	97	130	1.76
608	IV	500	238	44	105	1.78
616	IV	500	181	65	121	1.75
623	IV	500	305	109	158	1.76
624	IV	500	316	110	175	1.66
Average		500	260	83	138	1.72

* Does not include milk fed.

Feed Efficiency

Table V gives the relative efficiency with which sample animals in each group digested cellulose at three, four, five and six months of age. Digestion of cellulose was more efficient in older calves than in young calves but no great differences were observed between groups.

TABLE V

APPARENT DIGESTION OF CELLULOSE BY ALL GROUPS OF CALVES AT FOUR DIFFERENT AGES

Calf No.	Group	AGE 90 Days	120 Days	150 Days	180 Days	Calf Averages
611	I	*	*	*	79.6%	-
619	I	63.2%	48.0%	81.8%	59.4	63.1%
T334	I	*	*	*	76.3	-
T345	I	63.7	36.4	64.5	62.9	57.4
Average	I	63.5	42.2	74.2	72.0	62.9
620	II	64.3	66.7	71.7	58.0	65.1
Average	II	-	-	-	-	-
622	III	59.5	52.6	69.0	70.9	63.0
Average	III	-	-	-	-	-
624	IV	56.5	60.3	68.8	*	60.9
T342	IV	*	*	49.3	57.8	53.5
Average	IV	-	-	50.9	-	-
Average by Age		61.6	52.8	67.5	66.9	

% Figures gives are per cent of cellulose digested.
* Trials were not in progress when calves were at these ages.
- No average is given when only one calf is included.

CHAPTER V

DISCUSSION

The failure of the inoculated calves to gain faster than the uninoculated calves agrees with Pounden and Hibbs (17) who reported that inoculated calves did not make faster gains than uninoculated calves.

The Holstein calves at 180 days had gained 1.43 ± 0.11 pounds per day for Group I, 1.41 ± 0.21 pounds per day for Group II, 1.15 ± 0.19 pounds per day for Group III and 1.27 ± 0.066 pounds per day for Group IV. Snedecor's (24) method for calculating the significant difference between groups was applied to the total gain for the six months period. At the 5% level of probability, the gain of the Holstein calves in Group I was barely significantly higher than the gain of Holstein calves in Group III. There was no significant difference between the gain of the other groups.

The Jersey calves gained an average of 0.83 ± 0.15 pounds per day for Group I, 0.61 ± 0.17 pounds per day for Group II, 0.65 ± 0.15 pounds per day for Group III and 0.71 ± 0.073 pounds per day for Group IV. At the 5% level of probability, the gain of the Jersey calves in Group I barely significantly higher than the gain of the calves in Groups II and III. There was no significant difference

between the gains of the other groups.

The average daily gain in skeletal growth, as measured by height at the withers, is shown in Table II. The average gain by Jerseys in Group I was 0.061, for Group II 0.047, for Group III 0.041 and for Group IV 0.045 inches per day. Group I was significantly higher than Group III at the 5% level. No other differences of gain in height were significant for the Jersey calves.

The Holsteins in Group I gained an average of 0.052 inches per day while those in Group II gained an average of 0.056 inches per day. The calves in Group III gained an average of 0.050 inches per day while those in Group IV gained an average of 0.045 inches per day. None of the differences are significant at the 5% level of probability.

The Jersey calves at four months of age had required an average of 2.19 $\pm$ 0.38 pounds of TDN per pound of gain for Group I, 2.45 $\pm$ 0.36 pounds of TDN per pound of gain for Group II, 2.25 $\pm$ 0.07 pounds of TDN per pound of gain for Group III and 2.04 $\pm$ 0.21 pounds of TDN per pound of gain for Group IV. At the 5% level of probability, no differences were statistically significant.

The Holstein calves at four months of age had required an average of 1.91 $\pm$ 0.33 pounds of TDN per pound of gain for Group I, 1.82 $\pm$ 0.30 pounds of TDN per pound

of gain for Group II, 2.04 ± 0.21 pounds of TDN per pound of gain for Group III and 1.72 ± 0.04 pounds of TDN per pound of gain for Group IV. At the 5% level of probability, none of these differences are significant.

The results of the digestion trials are too widely scattered to draw many conclusions from them. It does seem apparent that the ability of the calves to digest cellulose increases with age. These trials did not show the results obtained by Conrad, Pounden and Hibbs (3) who found that inoculated animals were able to digest cellulose more efficiently than uninoculated animals. It should be noted that at most of the ages and in most groups only one or two calves were on the digestion trials. There was also some difficulty encountered in keeping the calves eating the same amount of feed while in the digestion crate as they were eating on preliminary feedings.

CHAPTER VI

SUMMARY

Twenty-six Jersey and twenty-two Holstein calves were used in this experiment. The growth and feed utilization of these calves was compared with standards and between groups.

Group I was the control group, receiving grain and hay beginning at four days of age. Group II received grain at four days and hay beginning at 90 days of age. Group III was inoculated and received grain and hay starting at four days of age. Group IV was inoculated and received grain beginning at four days and hay at 90 days of age.

Calves in Group I of both breeds had significantly higher gains in weight than calves in Group III. Jersey calves in Group I also had significantly higher gains than Jersey calves in Group II.

The Jersey calves in Group I had a significantly higher gain in height at the withers than Jersey calves in Group III. There were no significant differences between the Holstein groups.

No significant differences were found in the pounds of TDN required per pound of gain in any group of either breed.

The limited number of animals on the cellulose digestion trials and the difficulties encountered in conducting the trials greatly limit the conclusions which can be drawn from these data.

Observations of the limited number of animals for this experiment suggest that rumen inoculation does not greatly affect the digestion of roughage by the young calf and does not have a stimulating effect on growth.

BIBLIOGRAPHY

BIBLIOGRAPHY

1. Baker, F. and Harriss, S. T. "Microbial Digestion in the Rumen (and Caecum) with Special Reference to the Decomposition of Structural Cellulose," Nutritional Abstracts and Reviews, 17-1; 3-11, 1946.

2. Bender, C. B. and Bartlett, J. W. "A Study of the Factors Affecting the Growth of Dairy Heifers," Journal of Dairy Science, 12: 37-49,1929.

3. Conrad, H. R., Hibbs, J. W., Pounden, W. D. and Sutton T. S. "The Effect of Rumen Inoculation on the Digestibility of Roughage in Young Dairy Calves," Journal of Dairy Science, 33: 585-592, 1950.

4. Crampton, E. W. and Maynard, L. A. "The Relation of Cellulose and Lignin Content to the Nutritive Value of Animal Feeds," Journal of Dairy Nutrition, 15: 383-395, 1938.

5. Davenport, E. Illinois Agricultural Experiment Station Bulletin, 46: 362, 1897.

6. Hastings, E. G. "The Significance of the Bacteria and the Protozoa of the Rumen of the Bovine," Bacteriological Reviews, 8: 235-253, 1944.

7. Hibbs, J. W. and Pounden, W. D. "The Influence of the Ration and Early Rumen Development on the Changes in the Plasma Carotenoids, Vitamin A and Ascorbic Acid of Young Dairy Calves," Journal of Dairy Science, 31: 1055-1061, 1948.

8. _____ and _____. "The Influence of Pasture and Early Rumen Development on the Changes in the Plasma Carotenoids, Vitamin A and Ascorbic Acid and the Liver Storage of Carotenoids and Vitamin A of Young Dairy Calves," Journal of Dairy Science, 32: 1016-1024, 1949.

9. Knoop, C. E., Krauss, W. E. and Washburn, R. G. "The Development of Nutritional Anemia in Dairy Calves," Journal of Dairy Science, 18: 337-347, 1935.

10. Marshall, S. P., Arnold, P. T. D. and Becker, R. B. "Postpartum Development of Bovine Stomach Compartments and Observations on some Characteristics of their Contents," Journal of Dairy Science, 33: 379, 1950.

11. Maynard, L. A. and Norris, L. C. "A System of Rearing Dairy Calves with Limited use of Milk," Journal of Dairy Science, 6: 483-499, 1923.

12. Mead, S. W. and Regan, W. M. "Defeciencies in Rations Devoid of Roughage for Calves," Journal of Dairy Science, 14: 283-293, 1931.

13. _____ and Goss, H. "Ruminant Digestion Without Roughage," Journal of Dairy Science, 18: 163-170, 1935.

14. McCandlish, A. C. "Studies in the Growth and Nutrition of Dairy Calves. V. Milk as the Sole Ration for Calves," Journal of Dairy Science, 6: 54-66, 1923.

15. Pounden, W. D. and Hibbs, J. W. "Some Possible Relationships Between Management, Fore-stomach contents and Diarrhea in the Young Dairy Calf," Journal of Dairy Science, 30: 582-583, 1947.

16. _____ and _____. "The Influence of the Ration and Rumen Inoculation on the Establishment of Certain Microorganisms on the Rumen of Young Calves," Journal of Dairy Science, 31: 1041-1050, 1948.

17. _____ and _____. "The Influence of the Ratio of Grain to Hay in the Ration of Dairy Calves on Certain Rumen Microorganisms," Journal of Dairy Science, 31: 1051-1054, 1948.

18. _____ and _____. "The Influence of Pasture and Rumen Inoculation on the Establishment of Certain Microorganisms in the Rumen of Young Dairy Calves," Journal of Dairy Science, 32: 1025-1031, 1949.

19. _____, _____ and Ferguson, L. C. "The Digestion of Rumen Microorganisms by Host Animals," Journal of Dairy Science, 33: 565-571, 1950.

20. _____ and _____. "The Development of Calves Raised Without Protozoa and Certain Other Characteristic Rumen Microorganisms," Journal of Dairy Science, 33: 639-644, 1950.

21. Ragsdale, A. C. "Growth Standards for Dairy Cattle," Missouri Agricultural Experiment Station Bulletin, 336, 1934.

22. _____. "Feed Consumption of Dairy Cattle During Growth," Missouri Agricultural Experiment Station Bulletin, 338, 1934.

23. Sanborn, J. W. Utah Agricultural Experiment Station Bulletin, 21, 1893.

24. Snedecor, G. W. Statistical Methods. Iowa: The Collegiate Press, Inc., 1946.

25. Williams, J. B. and Knodt, C. B. "The Value of Milk Replacements in the Rations of Dairy Calves," Journal of Dairy Science, 32: 986-992, 1949.

26. Wise, G. H., Gullickson, T. W. and Peterson, W. E. "Value of Various Vitamins and Inorganic Salts for Overcoming Symptoms Manifested in Calves Restricted to a Whole Milk Ration," Journal of Dairy Science, 22: 573-581, 1939.

27. _____, Link, R. P., Thompson, W. W. and Caldwell, M. J. "The Physiological Role of the Rumen of Young Bovine as Indicated by the Growth and Blood Composition of a Rumenectomized Calf," Journal of Dairy Science, 29: 543-544, 1946.

APPENDIX

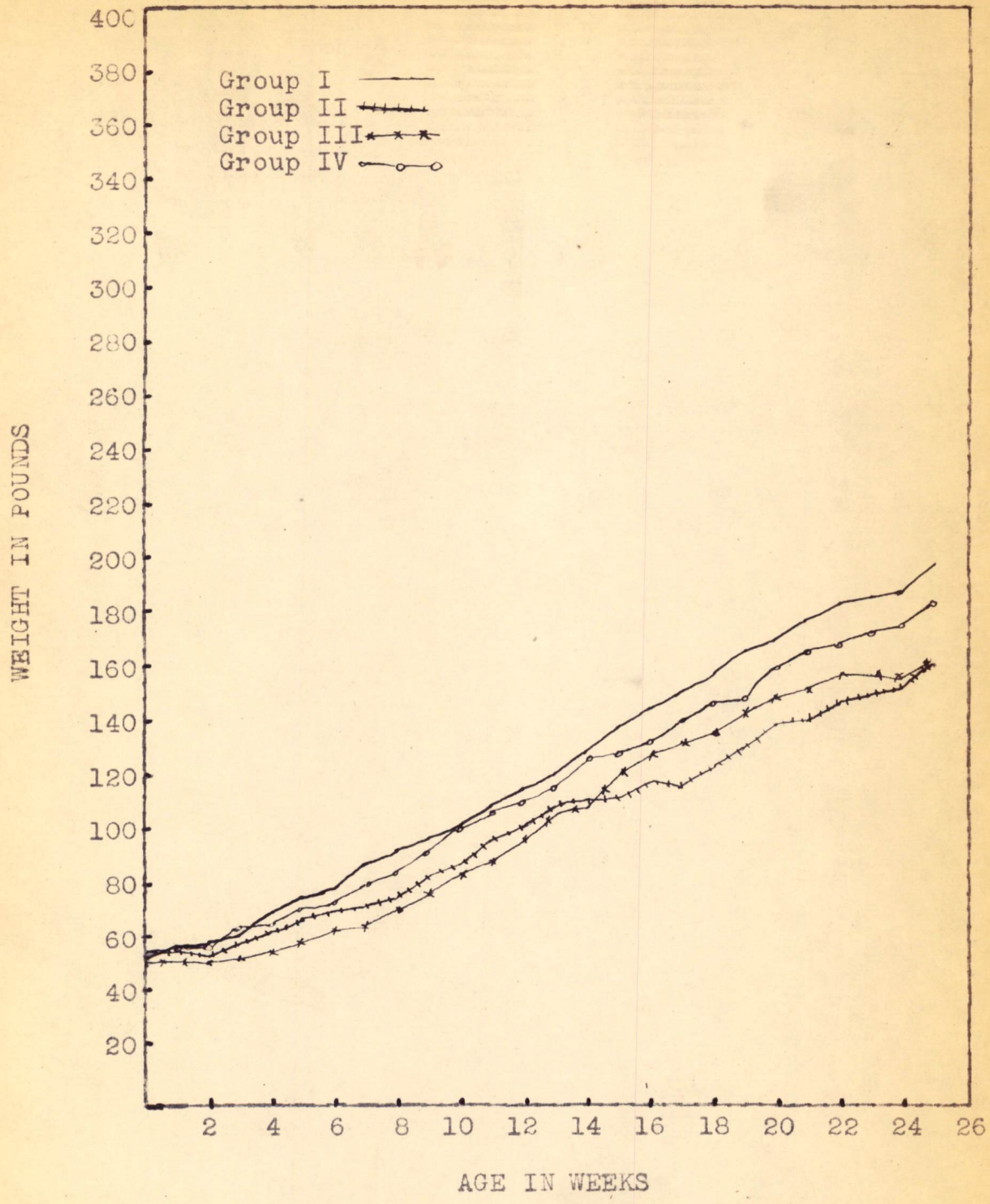


Figure 1. Average weights of Jersey calves by groups

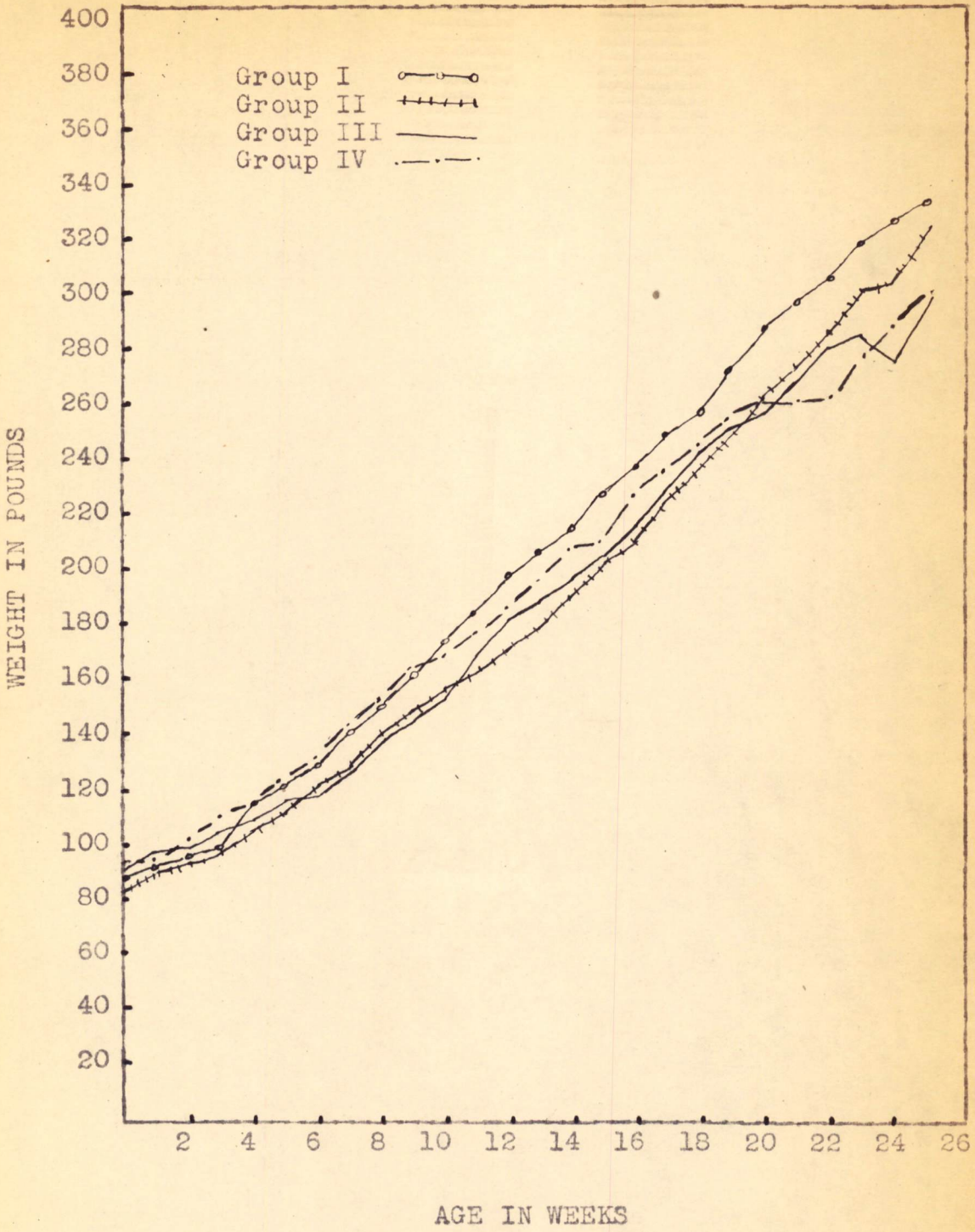


Figure 2. Average weights of Holstein calves by groups

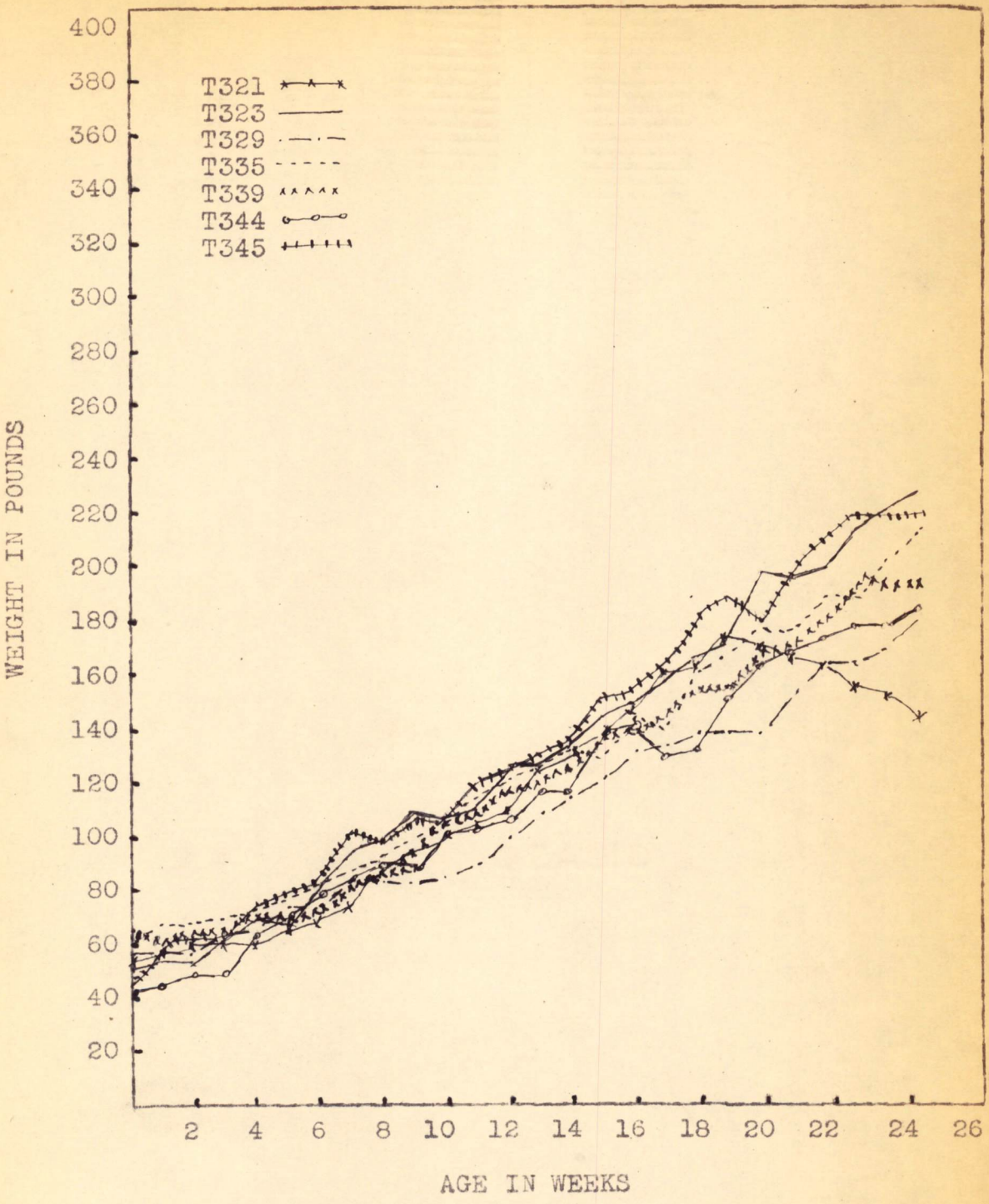


Figure 3. Individual weights of Jersey calves in Group I

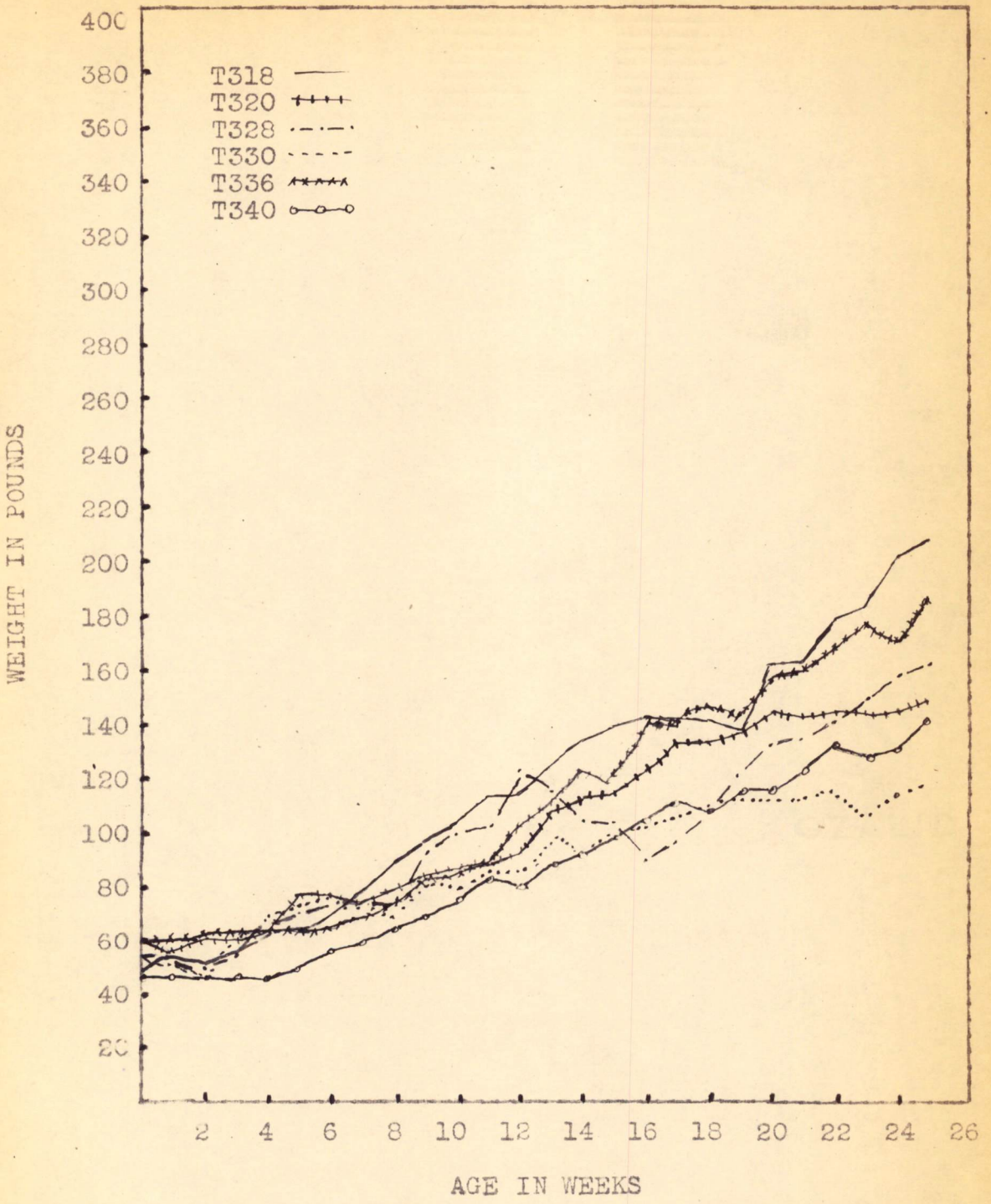


Figure 4. Individual weights of Jersey calves in Group II

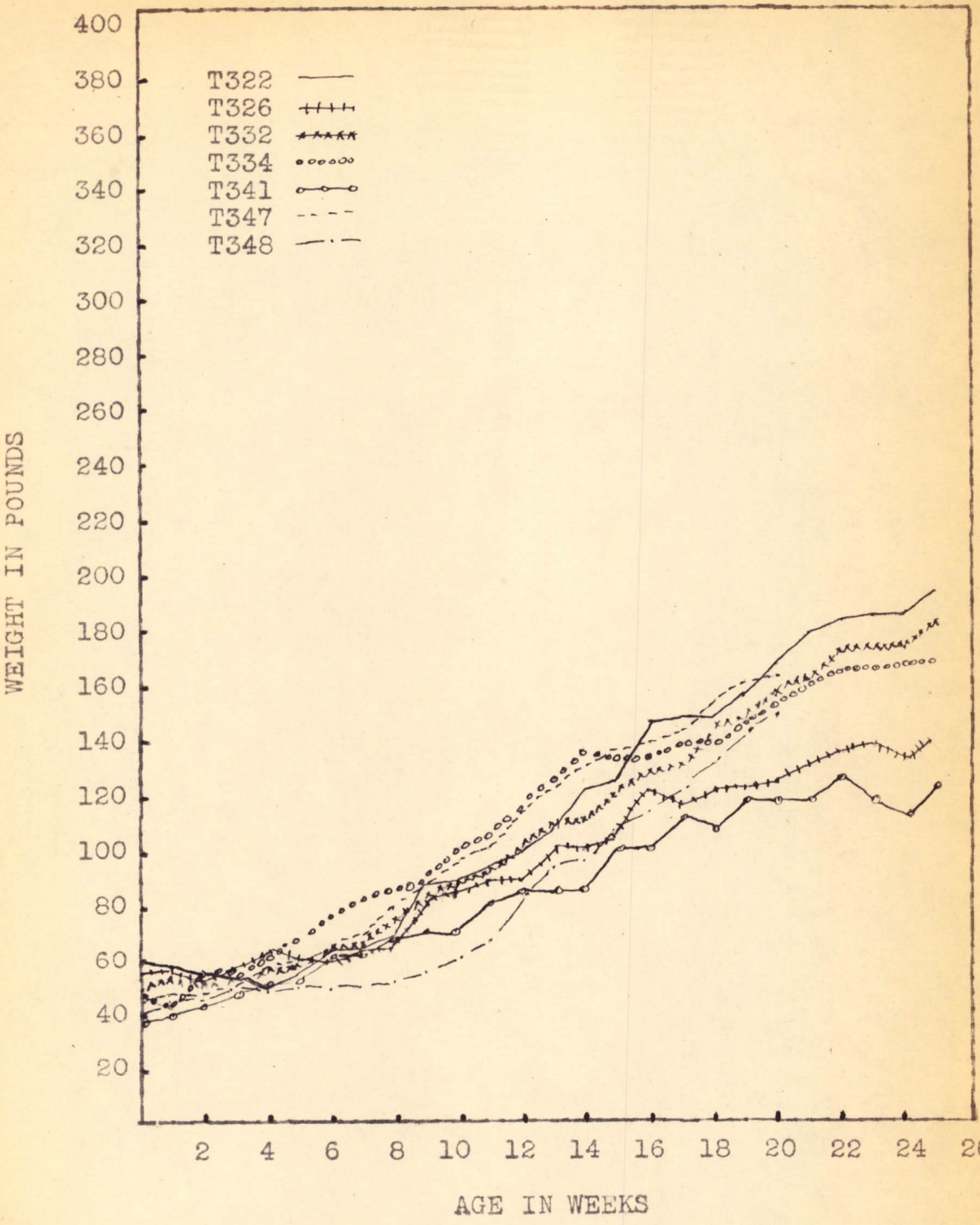


Figure 5. Individual weights of Jersey calves in Group III

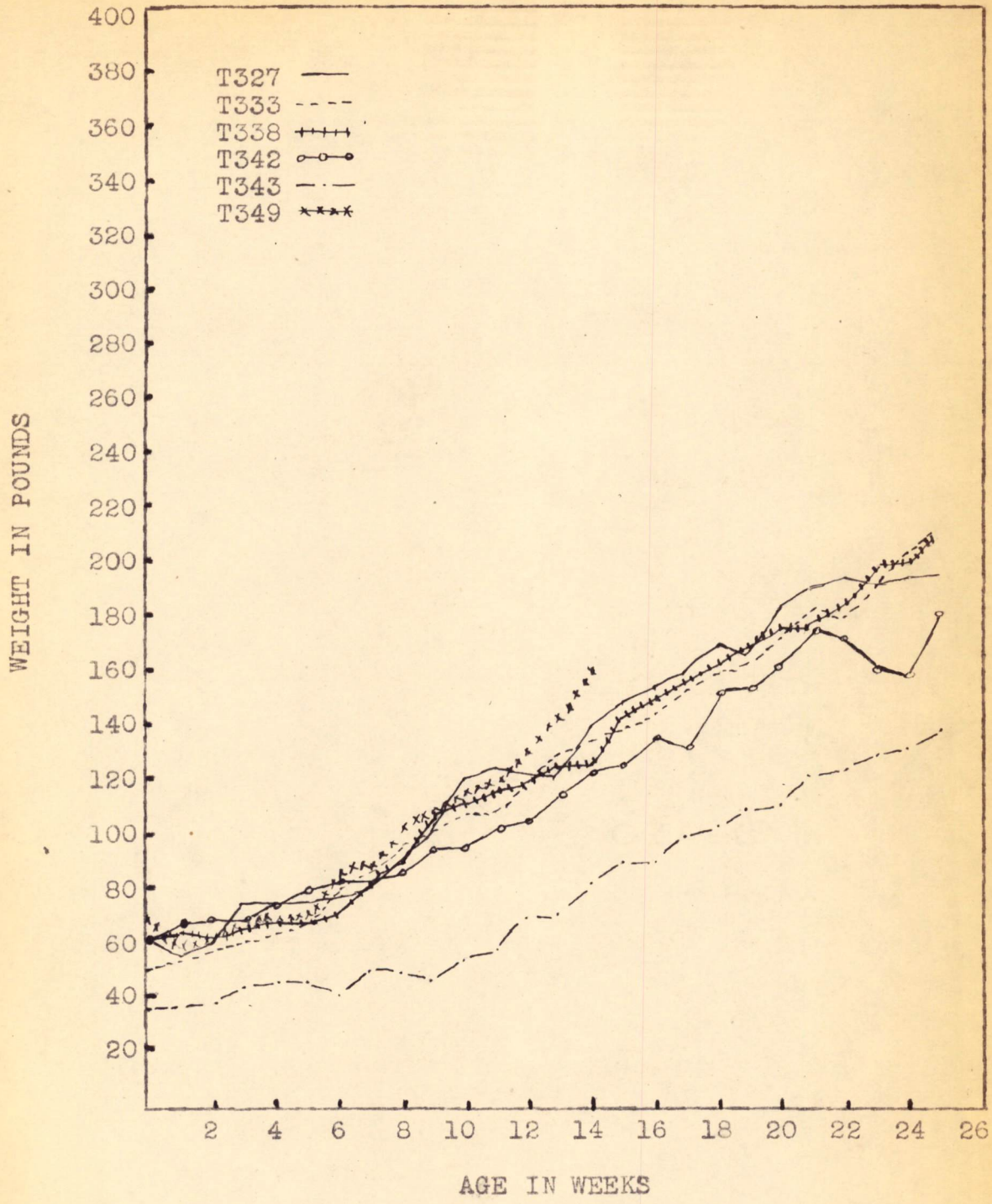


Figure 6. Individual weights of Jersey calves in Group IV

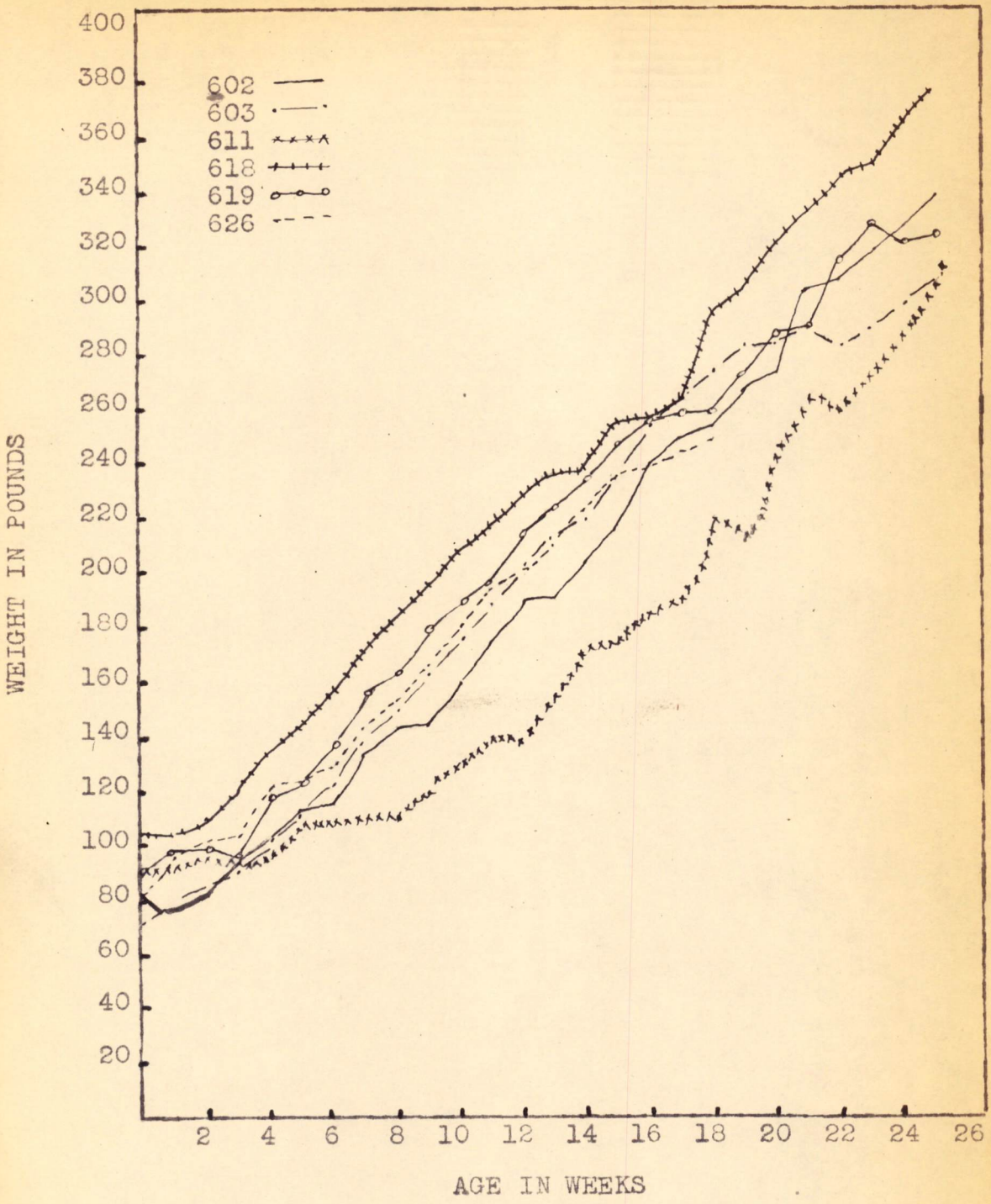


Figure 7. Individual weights of Holstein calves in Group I

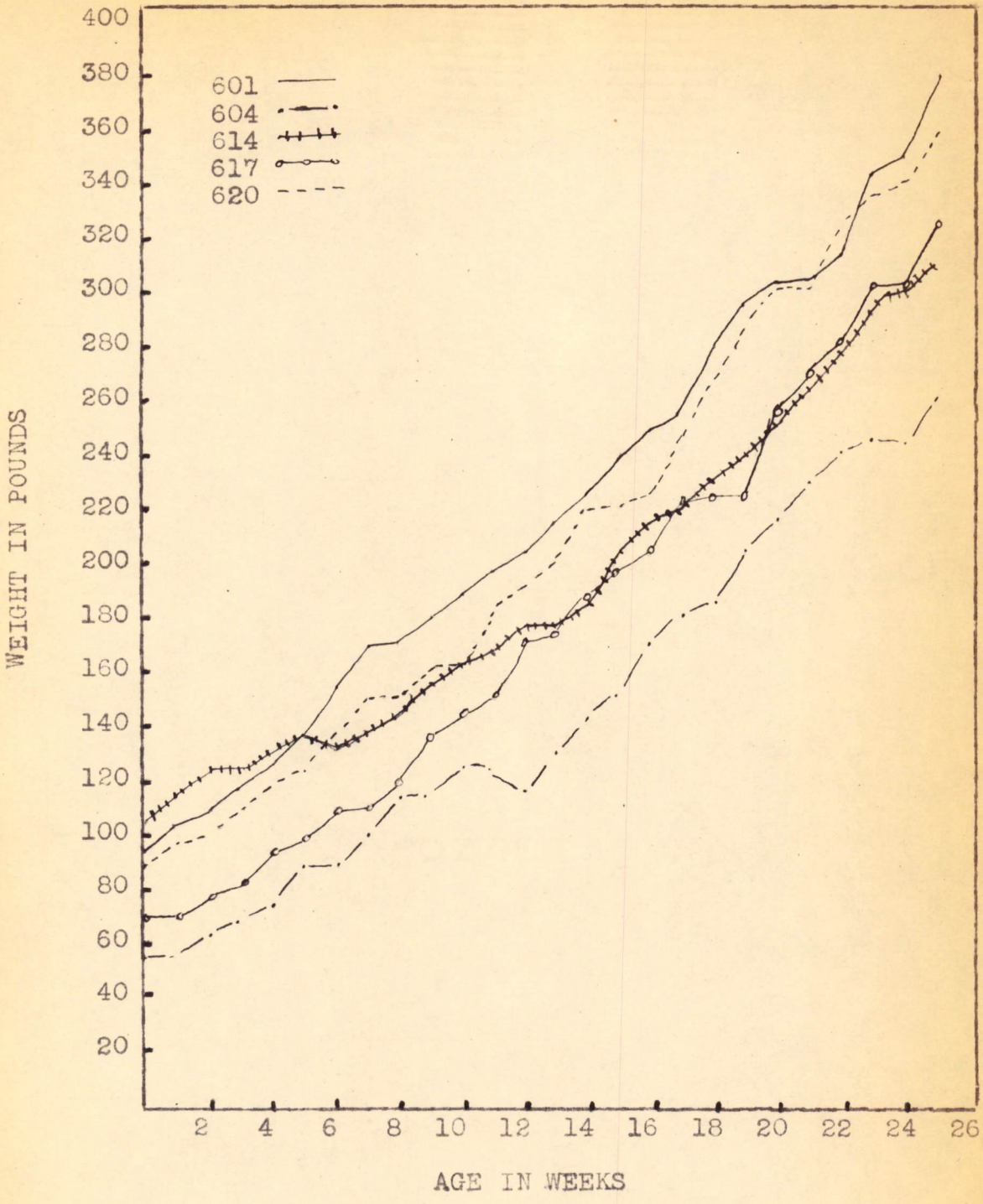


Figure 8. Individual weights of Holstein calves in Group II

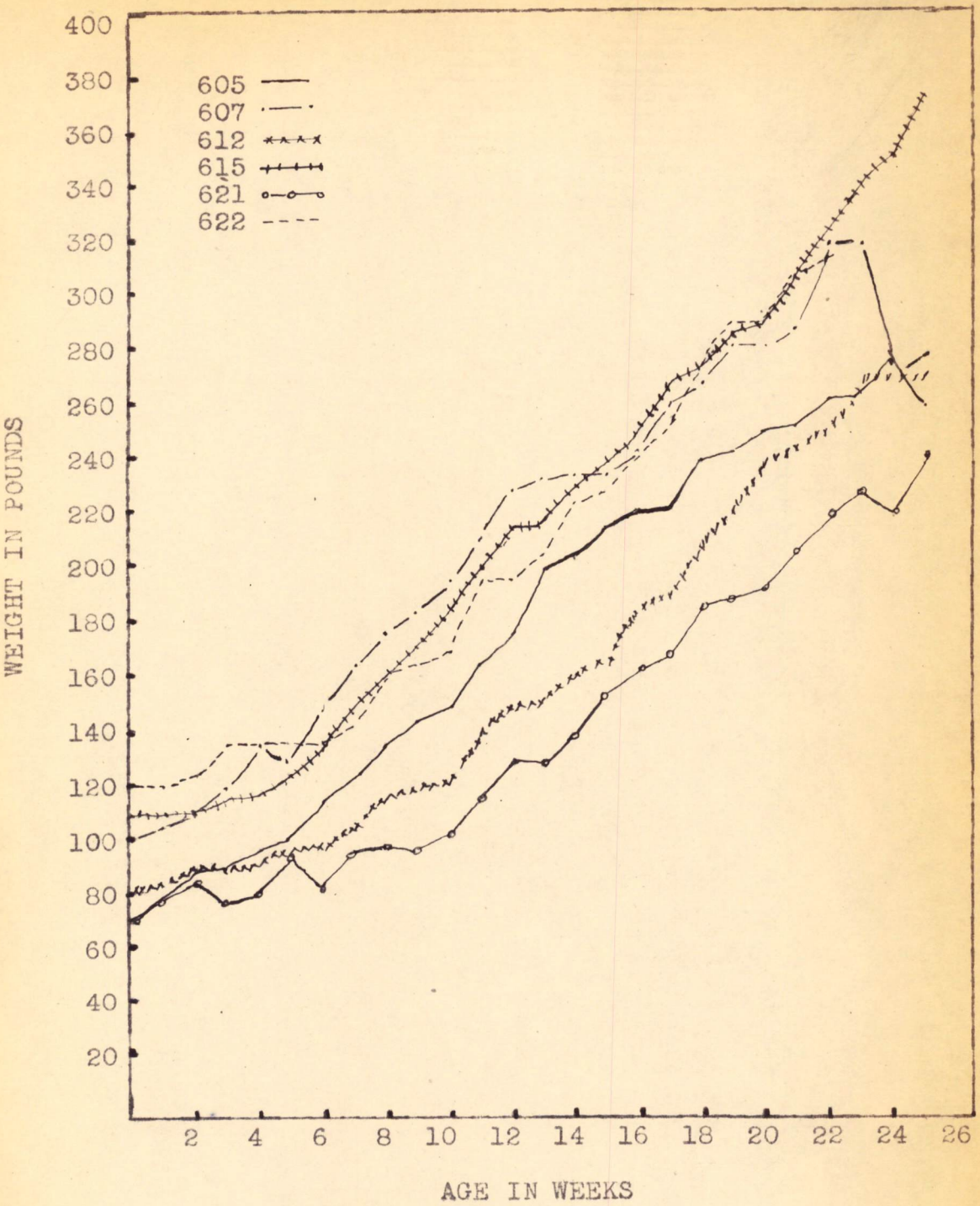


Figure 9. Individual weights of Holstein calves in Group III

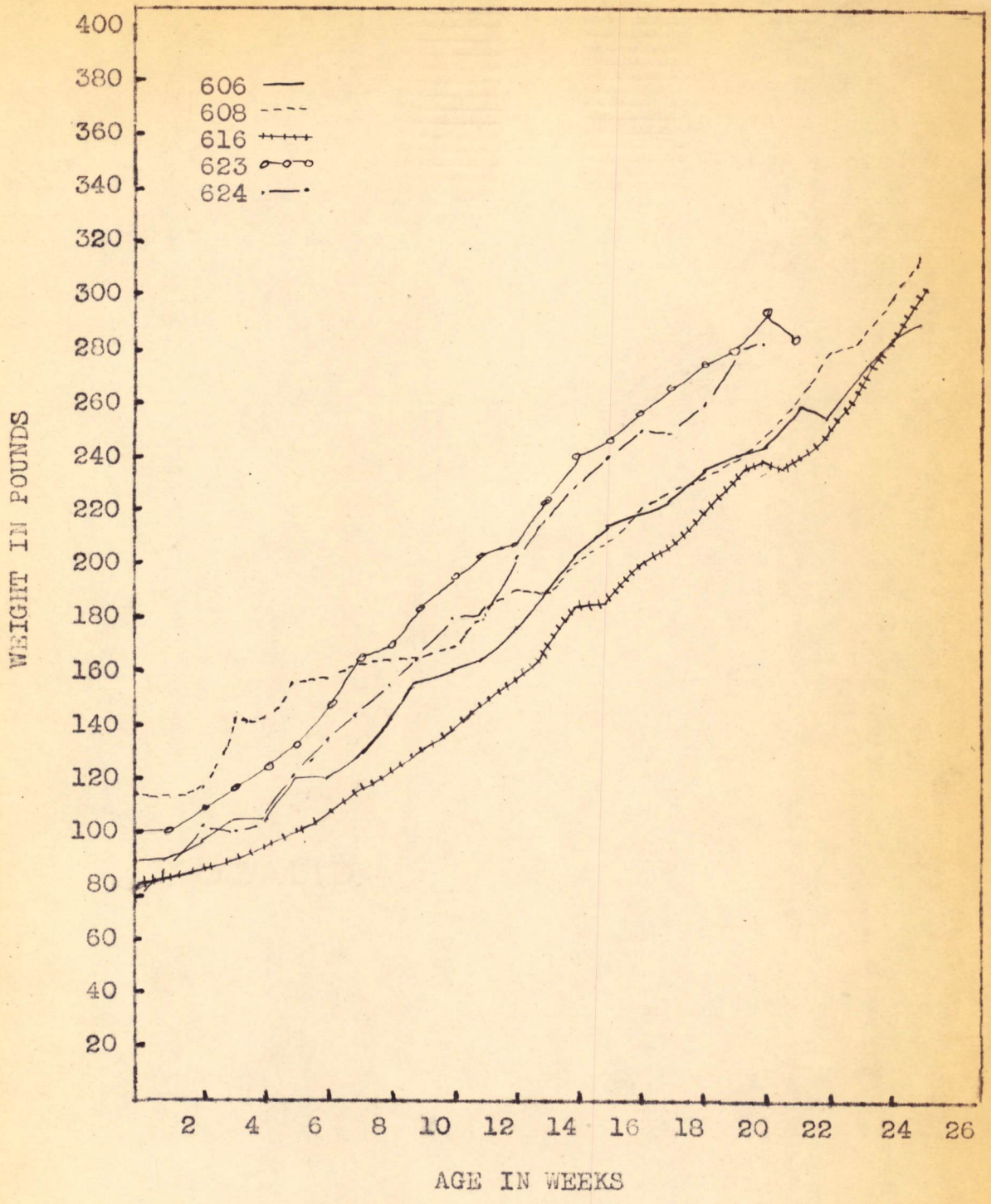


Figure 10. Individual weights of Holstein calves in Group IV