山形大学紀要（農学）第9巻，第1号，昭和57年1月
Bull. Yamagata Univ., Agr. Sci., Vol. 9, No. 1, Jan. 1982

Analysis of Changes of Properties and Compositions from Colostrum to Normal Milk

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(Received September 1, 1981)

Introduction

It has been known that the properties and compositions of milk changes with the stages of lactation, calving number, feeding regimen and other factors[1)2)3)4)]. The most remarkable change of properties and chamical compositions of milk is found in the transitory period from colostrum to normal milk. As the lactation period advances, the concentrations of total solids (T. S.), solids-not-fat (S. N. F.), protein, fat, ash, lactate, non-protein-nitrogen (N. P. N.), Na, Cl, Ca, Mg and P and specific gravity (S. G.) in the colostrum decrease and those of lactose, K and pH conversely increase. The properties and compositions of colostrum approach to those of normal milk within about a week and change little for about 200 days of lactation[1)2)3)].

In the present experiment following three investigations were carried out. Firstly, to assume the changes of properties and compositions of milk for about 80 days after parturition, an asymptotic regression equation of $Y=a+b \cdot \exp(c \cdot X)$ was applied in this report. Where Y ; property or composition, X ; days after parturition, a, b and c ; coefficients, exp ; base of natural logarithm. The coefficients of "a+b" and "a" mean the initial and final values respectively, where initial value Y when zero is substituted for X and "c" is assosiated with speed of asymptotic rate. Secondly, to show a curve of daily yield of a milk composition, a quadratic regression equation was applied. Thirdly, to examine the suitability of the application of the above equation, the values estimated in the present work were compared with those obtained in the previous reports.

Materials and Methods

Animals and milk samples

Colostrum and normal milk were sampled from seven Holstein cows ranging from first to seven calving numbers which were fed on Japanese feeding standard[5)]. Milking was carried out twice a day at 9 A. M. and 4 P. M. except first two or three days after parturition. About 100 ml of milk for analysis was reserved from 244 samples collected by TRU-test milking machine (made in New Zeeland) which

devides equally the total milk yield to one fiftieth. Analytical values expressed as a weighted average depending on the amount of morning and evening milk.

Analytical method of the milk

General properties and compositions of milk were analysed by the following conventional methods[6], nitrogen by Kjeldahl method, protein by nitrogen x 6.38, fat by Gerbel method, lactose by method of Munson-Walker, ash by ashed at 450 C, S. G. by lactometer, pH by electric pH meter, N. P. N. by Kjeldahl method after deproteinization by 10% trichloroacetic acid and lactate by expressed by titrable acidity by 0.1 N sodium hydroxide. Pre-treatment of analysis of minerals was ashed by wet method with nitric and perchloric acid, K, Na, Ca and Mg by atomic absorption spectrophotometer, Cl by volumetric method of Volhard[7], P by colorimetric method of molybdic blue[7].

Statistical analysis were carried out at the Computer Center of Tohoku University in Sendai.

Results and Discussions

The live weight change of used cows is shown Table 1. The live weight continued to decrease till about 2 months after parturition.

Table 1. Changes of live weight of seven Holstein cows weighed once a month

lab. No of cow	13	16	11	22	23	24	17
calving No	5	4	7	2	2	1	6
date of parturition	Jul. 13	Aug. 2	Sep. 18	Sep. 19	Oct. 12	Nov. 11	Nov. 30
	−19	− 8	−24	−25	−14	−17	− 5
	677	708	655	525	606	567	810
	+12	+23	+10	+ 9	+13	+14	+25
	617	636	590	505	554	490	636
	+43	+57	+37	+36	+43	+44	+56
	593	610	586	517	562	515	635
	+78	+84	+67	+66	+74	+75	+87
	590	630	578	525	588	520	642
	+105	+115	+98	+97	+105	+106	+115
	618	627	590	536	598	514	648

above : absolute age in days after parturition, below : live weight (kg)

Wood[4] reported that the changes of percentages of fat and protein in whole stage of lactation were applied to a regression equation of $Yn=a \cdot n^b \cdot \exp(c \cdot n)$; where the coefficients a, b and c define the curve of a character Y expressed as percentage at week n. This equation could be applied for the curve in which a component increases rapidly to its maxmum value followed by the gradual decrease and vice versa. He showed that the percentage of fat and protein lowered to minimum at 8 th and 11 th week of lactation respectively and that of fat increased remarkably at late lactation when equation $Yn=a \cdot n^b \cdot \exp(c \cdot n)$ was applied for

the estimation. Accoding to the work of Waite et al[1], however, the percentages of the maximum contents of S. N. F., fat, crude protein, casein and lactose were different only about 0.2~0.4% from those of the minimum between 15 th and 195 th days of lactation stage. These results were almost the same as those appeared in the report of Johnson et al[3] in which only fat, S. N. F. and T. S. were considered. Moreover Rook et al[2] reported that contents of fat, S. N. F., protein, lactose, Na, K, Ca and P varied little throughout the whole lactation period except for the first 5 th and the last 7 th days of lactation period. In the present study, the final values by asymptotic regression equation for the period of 10~200 days from start of lactation were found agreeable to those in previous reports. As shown in Figure 1, it is evident that the asymptotic regression equation with significant correlation ($P<0.01$) was obtained in all properties and compositions of sampled milk. As the significant correlations were obtained in this equation, it could be postulated that change of properties and compositions during the period from colostrum to normal milk could be applied to the asymptotic regression equation. Especially high correlation coefficient ($R=0.903$) was found in ash concentration. Correlation of fat and K, however, was low. Parrish[8] reported that fat content generally decreased from first to 28 th milk when milking intervals were kept twelve hours. He also mentioned that fat content was variable at early stages of lactation. In present study, fat contents in early stages of lactation were different among the individuals, it also seemed that fat contents of the colostrum of low or high calving number were not so different in normal milking period. The reason of low correlation of asymptotic regression for fat content might be due to the inclusion of samples obtained from the low and high calving number.

Initial and final values of properties and compositions estimated from asymptotic regression equation were shown in Table 2. Parrisn[8] reported that analytical values of colostrum were 1.056, 23.9%, 16.7%, 14.0%, 6.7%, 2.7% and 1.11%, and those of normal milk were 1.036, 12.9%, 8.8%, 3.1%, 4.0%, 5.0% and 0.74% for S. G., T. S., S. N. F., protein, fat, lactose and ash, respectively. It was reported that concentration of N. P. N. was 53.8 for colostrum by Parrish[9] and 23.8 mg/dl for normal milk by Shahani[10]. Garret[11] and Imamura[12] reported that mineral contents of colostrum were 137, 74, 118, 256, 37 and 235 mg/dl, and those of normal milk were 151, 53, 99, 104, 11 and 86 mg/dl for K, Na, Cl, Ca, Mg and P, respectively. In the present study, the initial values were not generally equal to the previous reports but the final values were almost equal in all properties and compositions examined. Estimated values as a whole were found lower than those in previous reports except for initial contents of Na and Cl. The lower values for colostrum in present experiment than those of previous reports appear to be due to the use of weighted average for the computation. According to the present study, the period required to approach nearly the normal milk was almost ten days or more. In case

Table 2. Initial and final values of properties and compositions estimated by the asymptotic regression equation

property and composition		initial (colostrum)	final (normal milk)	days required to approach the normal milk value*
S. G.		1.054	1.032	10
pH		6.62	6.78	15
T. S.	(%)	18.43	11.77	10
S. N. F.	(%)	14.92	8.17	10
protein	(%)	12.20	3.11	10
fat	(%)	5.03	3.60	15
lactose	(%)	1.36	4.33	15
ash	(%)	1.21	0.71	10
lactate	(%)	0.297	0.126	10
N. P. N.	(mg/dl)	57.6	27.4	30
K	(mg/dl)	141	168	30
Na	(mg/dl)	150	47	40
Cl	(mg/dl)	186	105	15
Ca	(mg/dl)	144	95	10
Mg	(mg/dl)	37	14	15
P	(mg/dl)	187	97	55

* Days are assumed through the computed date.

of Na and P, it took about 40~50 days.

The plotting of the daily production of each milk component from colostrum to normal milk and its quadratic regression equation were significant at 1 % level of probability for all except that of Na as shown in Figure 2. The period showing the maximum yield for all compositions was between the 40 to 50 days of lactation except for Na, which corresponded to the period when the maximum yield of milk was obtained. The day exhibiting the maximum yield of Na, however, was earlier in all samples examined, because the yield of Na content in colostrum was remarkably high and it was almost same in normal milking period. It was speculated that the maintenance of unvariable Na yield in colostrum and normal milking stage might be due to the fixed amount of Na in the blood.

A part of this report was presented at 71 th Conference of Japanese Society of Zootechnical Science.

Acknowledgement

We are grateful to Prof. Y. Arimori for his kind suggestions to this work. We wish to thank Prof. T. Tsuda of Tohoku University for his helpful advices and the review of the work and to Mr. H. Nakatsuka of Tohoku University for his considerable assistance for making out the computer programing. Thanks are also

due to Mr. K. Ugai for his assistance on chemical analysis and to the staff of Department of Dairy Production, Yamagata University Farm for their cooperation.

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Summary

The change of properties and chemical compositions of milk during the period of about 80 days from colostrum to normal milk were investigated at Yamagata University Farm. The samples were collected from seven Holstein cows and specific gravity, pH, total solids, solids-not-fat, protein, fat, lactose, ash, lactate, non-protein-nitrogen, K, Na, Cl, Ca, Mg and P of 244 milk samples were examined.

It was reasonable from the analytical results that the change of the properties and compositions could be applied a ssymptotic regression equation $Y=a+b \cdot \exp(c \cdot X)$ i. e. Y : properties or compositions, X : days after parturition, a, b and c : coefficients, exp : base of natural rogarithm. The results also proved that the yield change for each milk composition except for Na could be expressed in a quadratic regression equation.

初乳から常乳移行に伴う乳性状・乳成分の変化に関する解析

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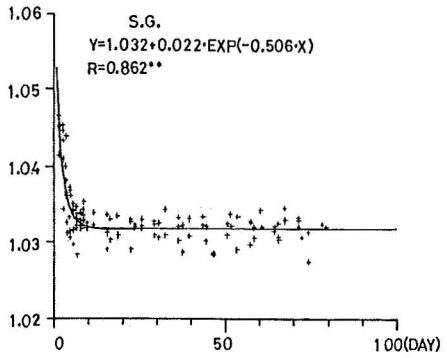
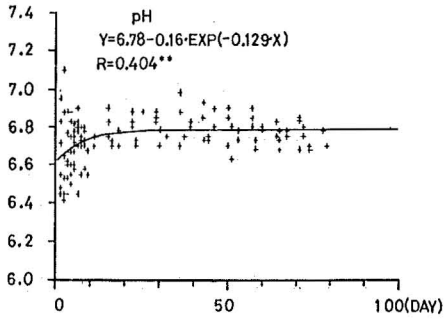
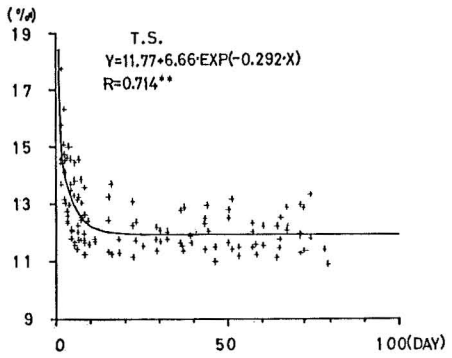
摘　　要

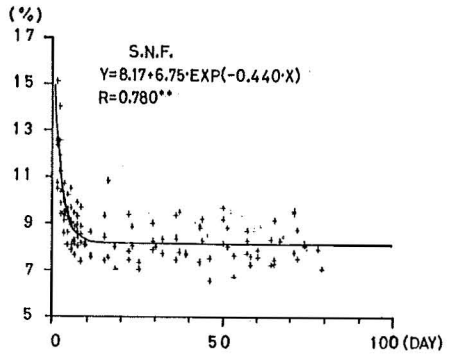
山形大学付属農場において初乳から常乳へ移行する際の約80日間の乳性状・乳成分の変化を検討した．供試材料は7頭のホルスタイン種乳牛から得た244例の牛乳であり，比重，pH，全固型分，無脂固型分，蛋白質，脂肪，乳糖，灰分，乳酸，非蛋白態窒素，K，Na，Cl，Ca，Mg およびPについて分析した．

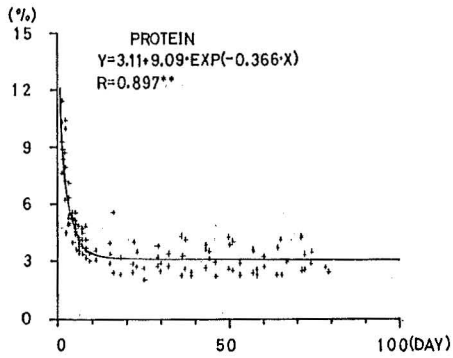
その結果，乳性状と乳成分の変化ともY＝a＋b•exp（c•X）（Y：乳性状又は乳成分，X：分娩後日数，a，b および c：係数，exp：自然対数の底）なる漸近回帰式に適応できることが明らかとなった．乳成分絶対量の変化も Na を除いて2次の多項式回帰式として表わされることが認められた．

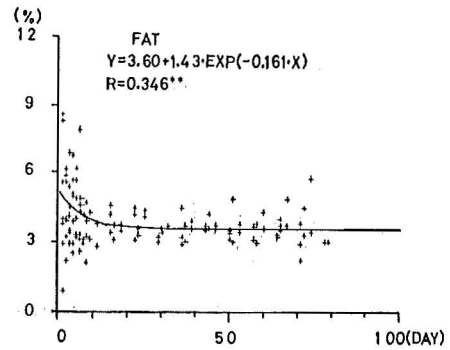


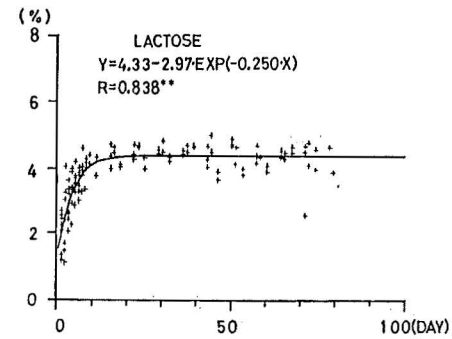


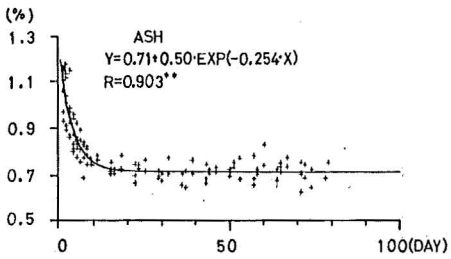

(%)
T.S.
Y=11.77+6.66·EXP(-0.292·X)
R=0.714**
19
17
15
13
11
9
0
50
100(DAY)

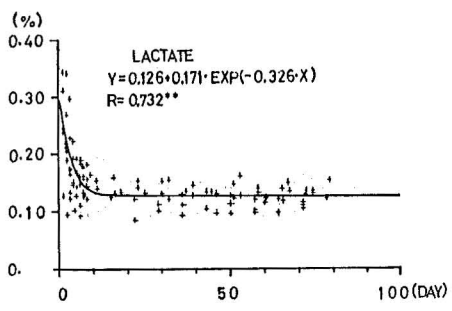

(%)
S.N.F.
Y=8.17+6.75·EXP(-0.440·X)
R=0.780**
17
15
13
11
9
7
5
0
50
100(DAY)

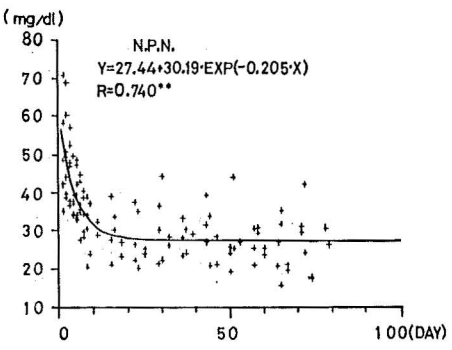

(%)
PROTEIN
Y=3.11+9.09·EXP(-0.366·X)
R=0.897**
15
12
9
6
3
0
0
50
100(DAY)


(%)
FAT
Y=3.60+1.43·EXP(-0.161·X)
R=0.346**
12
9
6
3
0
0
50
100(DAY)


(%)
LACTOSE
Y=4.33-2.97·EXP(-0.250·X)
R=0.838**
8
6
4
2
0
0
50
100(DAY)


(%)
ASH
Y=0.71+0.50·EXP(-0.254·X)
R=0.903**
1.3
1.1
0.9
0.7
0.5
0
50
100(DAY)


(%)
LACTATE
Y=0.126+0.171·EXP(-0.326·X)
R=0.732**
0.40
0.30
0.20
0.10
0.
0
50
100(DAY)


(mg/dl)
N.P.N.
Y=27.44+30.19·EXP(-0.205·X)
R=0.740**
80
70
60
50
40
30
20
10
0
50
100(DAY)

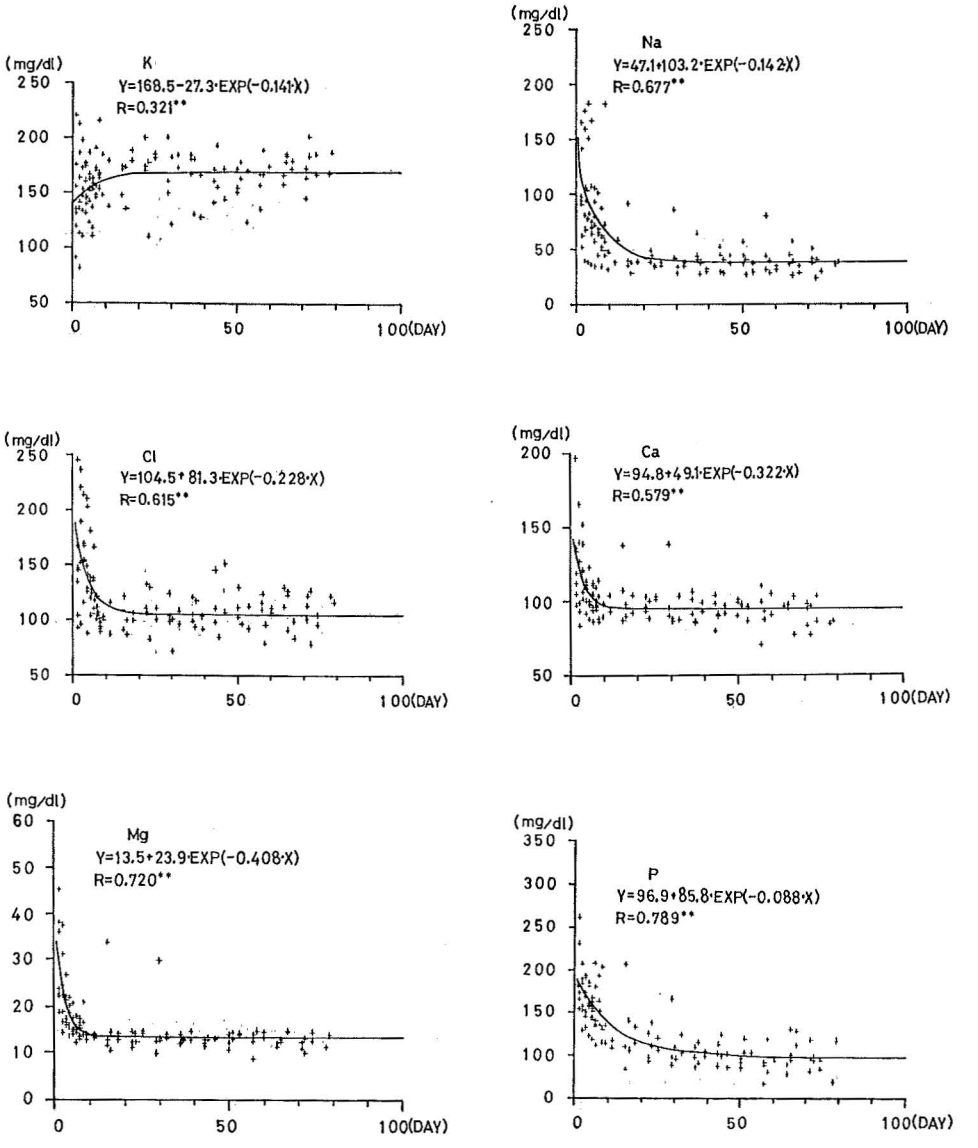
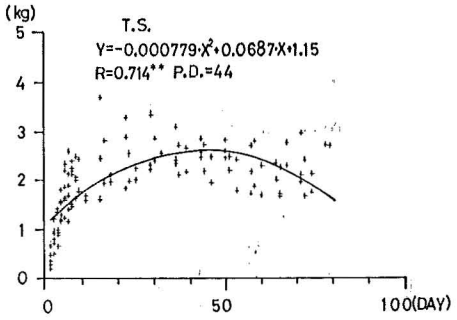
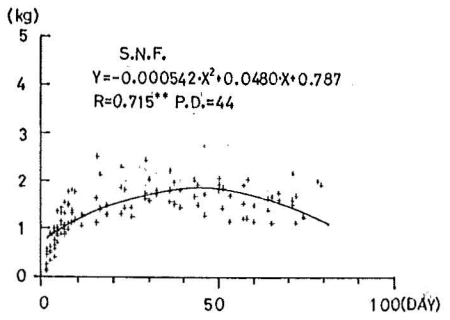
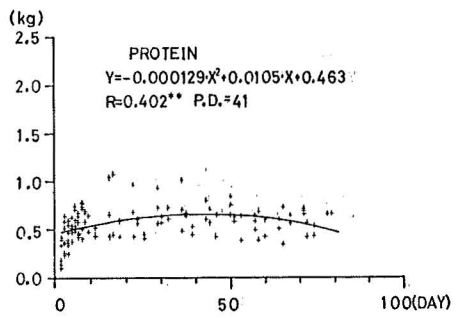
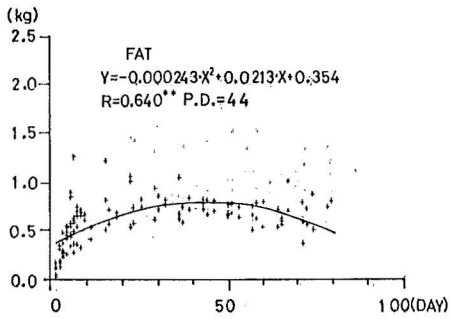


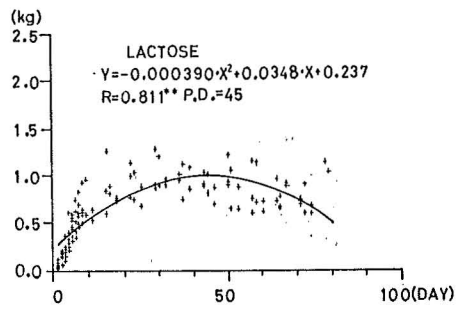
Fig. 1. Change of properties and compositions during the period from colostrum to normal milk and their asymptotic regression curve. Described by the drafter technique at Computer Center of Tohoku University. + : weighted average value calculated from morning and evening sample analyses. Applied asymptotic regression equation was $Y=a+b \cdot \exp(c \cdot X)$ where a plus b : initial value (colostrum at the day of calving), a : final value (normal milk), c : factor associated with speed of asymptotic rate, exp : base of natural rogarithm, X : days after parturition, R : correlation coefficient, ** : significant at the 1% level of probability.

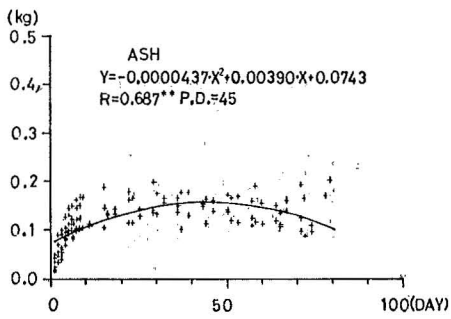

(kg)
T.S.
Y=-0.000779·X²+0.0687·X+1.15
R=0.714** P.D.=44
0
50
100(DAY)

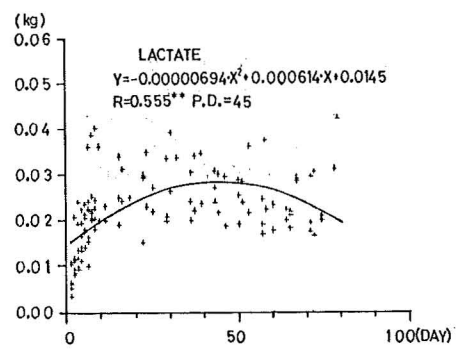

(kg)
S.N.F.
Y=-0.000542·X²+0.0480·X+0.787
R=0.715** P.D.=44
0
50
100(DAY)

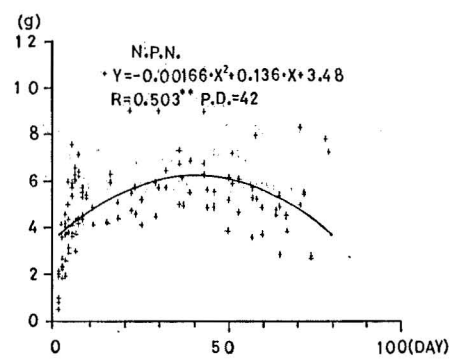

(kg)
PROTEIN
Y=-0.000129·X²+0.0105·X+0.463
R=0.402** P.D.=41
0
50
100(DAY)


(kg)
FAT
Y=-0.000243·X²+0.0213·X+0.354
R=0.640** P.D.=44
0
50
100(DAY)


(kg)
LACTOSE
Y=-0.000390·X²+0.0348·X+0.237
R=0.811** P.D.=45
0
50
100(DAY)


(kg)
ASH
Y=-0.0000437·X²+0.00390·X+0.0743
R=0.687** P.D.=45
0
50
100(DAY)


(kg)
LACTATE
Y=-0.00000694·X²+0.000614·X+0.0145
R=0.555** P.D.=45
0
50
100(DAY)


(g)
N.P.N.
Y=-0.00166·X²+0.136·X+3.48
R=0.503** P.D.=42
0
50
100(DAY)

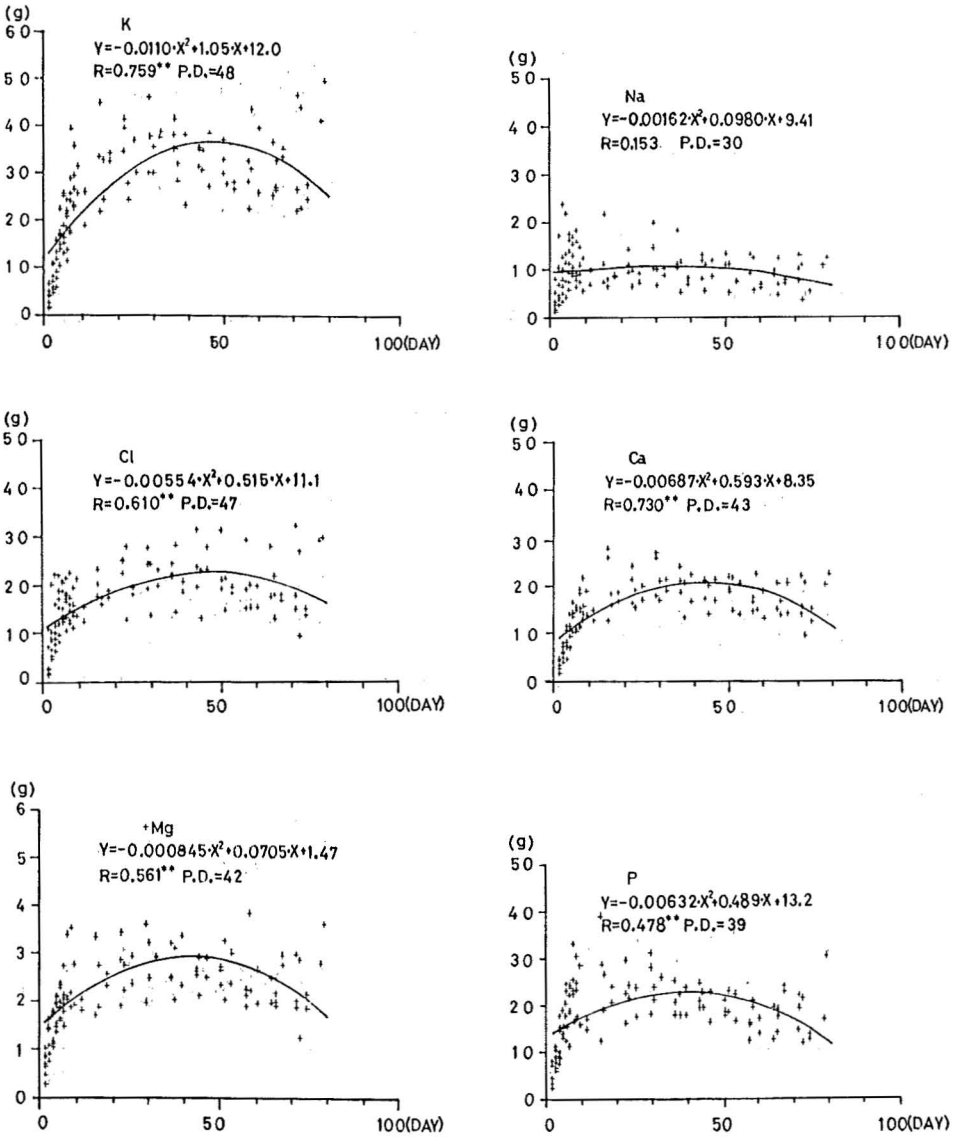


Fig. 2. Change of yield of milk compositions during the period from colostrum to normal milk and their quadratic regression curve. Described by the drafter technique at Computer Center of Tohoku University. + : daily yield of milk composition caluculated from milk yield and weighted average of concentration of composition. R : correlation coefficient, P. D. ; peak day,** ; significant at the 1% level of probability