Effect of Stepped Pattern of Feed Intake Using Rice Straw as Roughage Source on Regulation of Growth, Reproduction and Lactation in Dairy Heifers*

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ABSTRACT : An attempt was made to improve the efficiency of growth and lactation performance of dairy heifers subjected to a stair-step growth scheme using rice straw as the sole roughage source. Twenty-four young Holstein heifers were randomly assigned to either control or test group. The control diet met the National Research Council (NRC) requirement, with heifers calving at 24 to 26 mo of age. The test group was individually fed according to a schedule of 3, 2, 4, 2, 5 and 2 mo in which feed intake was alternately 20% below or 25% above the NRC requirements. Heifers on the stair-step growth pattern gained more body weight and consumed less dry matter (10.80 and 11.22%, respectively), resulting an increasing growth efficiency compared with the control. Body condition, first estrus, first conception, services per conception and calving difficulty (data not shown) were not affected. Milk yield of the test group was 8.5% higher than that of the control group. During the early lactation period, the milk yield was significantly higher in the stair-step group than in that of the control group ($p<0.05$). Milk composition was not affected by compensatory growth induced by the stair-step scheme. Also, weight at calving and calf growth performance was not affected by stair-step growth. The results indicate that using rice straw as a sole roughage source in a stair-step compensatory growth scheme can contribute to the improvement of growth efficiency and early lactation performance. ***(Asian-Aust. J. Anim. Sci. 2004. Vol 17, No. 6 : 794-798)***

Key Words : Compensatory Growth, Milk Yield, Rice Straw, Dairy Heifers

INTRODUCTION

Compensatory growth occurs when previously marginal or under-fed animals are re-alimented on a higher nutritional level. The degree of compensatory growth following a period of under-nutrition depends on the nature of the restricted diet, the severity and duration of under-nutrition, stage of development at the start of under-nutrition, relative mature BW of the animal and the pattern of re-alimentation (Abdalla et al., 1988).

Several investigators have reported on the compensatory growth responses in rats (Harris and widdowson, 1978; Park et al., 1988; Choi et al., 1992; Park et al., 1994), pigs (Sarkar et al., 1983; Ahn et al., 1996), rabbits (ledin, 1984), gilts (Crenshaw et al., 1989a,b), beef cattle (Bohman, 1955; Koch, 1982; Choi et al., 1996) and dairy heifers (Park et al., 1987; Park et al., 1989; Jang et al., 1994; Choi et al., 1997; Park et al., 1998). During compensatory growth, animals show significant BW gain, increased efficiency of energy utilization, reduced maintenance requirements due to the depression of the basic metabolic rate, enhanced appetite and feed intake capacity, changes in endocrine status, altered body tissue composition, and increased mammary growth and differentiation, with subsequent enhanced lactation performance compared with animals fed conventionally (Koch, 1982; Blum et al., 1985; Choi et al., 1992; Ryan et al., 1993a,b; Choi et al., 1997; Park et al., 1998). However, there are conflicting opinions on the physiological basis of compensatory growth.

Compensatory studies are valuable to the countries experiencing shortages of feed resources due to either severely cold winters or a serious summer drought. In particular, Korea is one of such countries and, thus, depends more on technique such as compensatory growth. Therefore, this study was conducted to evaluate whether using rice straw as the sole source of roughage in a stair-step compensatory growth scheme could affect the growth, reproductive efficiency and lactation performance of dairy heifers.

MATERIALS AND METHODS

Twenty-four six-month-old Holstein heifers, averaging 180 kg of BW (SE=2.28), were randomly assigned to either the control or the stair-step test group after a 60 d diet adaptation period. During the adaptation period, the best quality rice straws were fed to develop the rumen of the ruminant thereby avoiding various problems such as metabolic disease due to excessively concentrated feed during the stair-step growth period. The control group was fed a diet that was formulated to meet NRC (1989) nutrient recommendations for heifers calving at 24 to 26 mo of age.

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Table 1. Ingredients and chemical composition of experimental diets

Variable	Control		Stepwise	
	Rice straw	Concentrate[a]	Rice straw	Concentrate
0-3 mths	1.93	4.62	2.98	2.46
3-5 mths	2.59	5.57	1.18	8.09
5-9 mths	2.87	6.30	3.76	3.82
9-11 mths	3.83	5.97	2.59	8.45
11-16 mths	3.37	7.04	4.07	4.69
16-18 mths	3.35	8.28	2.46	10.75
Chemical analysis, % of DM	Rice straw		Concentrate	
CP	4.50		14.50	
Crude fat	2.20		2.00	
Crude fiber	28.30		9.00	
Ca	0.30		0.70	
P	0.10		0.40	
TDN	0.48		0.68	

[a] The concentrate is produced by Agribrands Purina Korea Ltd.

Table 2. Effect of a stair-step nutrition regimen on growth performance of Holstein heifers

Item	Control[a]	Stair-step[a]	p[b]
Body weight (kg)			
Initial (6 mo of age)	180.00±4.33	180.50±3.61	0.93
Final (24 mo of age)	698.40±7.12	704.30±9.72	0.63
Weight gain (kg)	518.40±9.07	523.80±11.09	0.71
Daily weight gain (kg/d)	0.96±0.02	0.97±0.02	0.71
Feed intake (DM, kg/d)	9.31±0.28	8.75±0.45	0.29
Rice straw	2.98±0.12	3.15±0.17	0.41
Concentrate	6.33±0.21	5.59±0.46	0.15
Growth efficiency[c] (%)	10.80±0.76	11.22±0.69	0.68

[a] Data is the mean±SE for 12 head.
[b] p=significance of F test for equality of two experimental groups.
[c] Growth efficiency calculates as: growth efficiency=daily(weight gain/dry matter intake)×100.

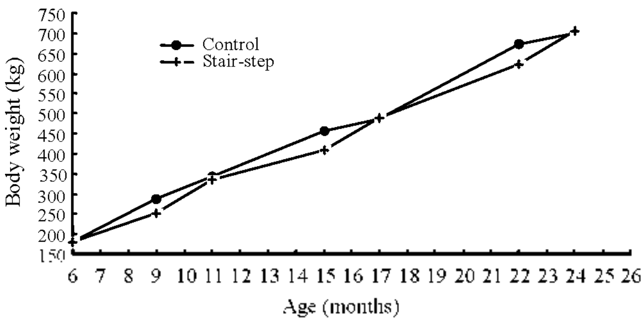

Figure 1. Change of body weight during three stair-step growth pattern.

The test group was subjected to a stair-step nutrition scheme according to an alternating schedule of 3-2-4-2-5-2 mo. The first stair-step began with feeding for maintenance for 3 mo (20% below the control) followed by feeding for compensatory growth (25% above the control) for 2 mo. The second step was 4 mo of maintenance feeding followed by 2 mo of compensatory feeding. The third and final step consisted of 5 mo of maintenance feeding followed by 2 mo of compensatory feeding. Nutrient amount and feed intake were controlled by the amount of concentrate during both the maintenance and compensatory feeding periods. Ingredients and chemical composition of experimental diets are presented (Table 1). Heifers were housed and managed individually. The amount of concentrate feed for each heifer was preweighed and the heifers were fed at 5 and 8 pm the following day. High quality rice straw was fed. The amount of diet fed and orts were weighed before the morning feeding, and feed intake was recorded once daily. Heifers were weighed twice monthly. Stair-step heifers that did not reach the BW of that of the controls during compensatory period, were fed more concentrate feeds in order for them to catch up at the earliest time possible and heifers, whose BW and daily gain did reach the targets, were restricted to feeds required for minimal maintenance. Water was provided continuously and dicalcium phosphate and trace-mineralized salts were made available at all times. Growth efficiency was calculated ad daily BW gain×100/daily DMI. The heifers were bred between 14 and 16 mo of age to calve at 4 to 26 mo of age. Two days before the end of each diet change, body length, withers height, and chest girth were measured after the morning feeding. Milk weights were recorded daily. Milk samples were obtained from a pool of two milkings each month. Milk composition was analyzed using Milkoscan (model 300; Foss Electric, Hillerod, Denmark). In our study, all animal-based procedures were in accordance with the "Guidelines for the Care and Use of Experimental Animals of Seoul National University of Agriculture and Veterinary Medicine", which were formulated from the "The Guide to the Care and Use of Experimental Animals -Canadian Council on Animal Care".

The basic statistical model for the stair-step growth regimen has been described previously (Park et al., 1989). The Duncan's multiple range test using general linear model (GLM) procedures of SAS (1988) was used for data

Table 3. Effect of a stair-step nutrition regimen on body measurements (6-17 months)

Phase	Control[a]	Stair-step[a]	p[b]
Body length (cm)			
Initial	117.42±1.12	117.50±1.55	0.97
Final (at 17 mo of age)	146.25±1.90	148.83±1.55	0.30
Withers height (cm)			
Initial	108.00±1.34	107.25±1.32	0.69
Final (at 17 mo of age)	139.67±1.36	139.75±1.22	0.91
Chest girth (cm)			
Initial	132.25±1.37	132.75±1.87	0.83
Final (at 17 mo of age)	199.42±2.09	201.83±1.97	0.41

[a] Data is the mean±SE for 12 head.
[b] p=significance of F test for equality of two experimental groups.

analyses.

RESULTS AND DISCUSSION

The stair-step regimen was designed to induce compensatory growth during the compensation phase, which coincided with hormone-sensitive developmental stages (prepuberty, puberty and breeding, gestation). Heifers fed on the stair-step growth regimen gained more (p=0.71) BW and consumed less (p=0.29) DM, especially concentrate (p=0.15), thereby tending to improve growth efficiency (p=0.68) compared with that of control heifers, although statistically insignificant (Table 2 and Figure 1). The energy restriction phase allowed the BW of the heifers to lag behind the BW of traditionally fed heifers. Energy restriction redirects energy flow to energy conserving activities, mainly maintenance and repair functions (Walford and Crew, 1989). The results are in agreement with those of Choi et al. (1997), who reported that underfed heifers exhibited faster BW gain with less feed consumption during the compensatory growth phase, resulting in significantly improved efficiencies of growth, energy and protein. Sheeny and Senior (1942) have suggested that, upon re-alimentation, animals fed a restricted diet have greater BW gains than animals fed the same diet for ad libitum, partly because their maintenance requirements are lower than those of the unrestricted controls. Studies by Abdalla et al. (1988) showed similar results. Ryan et al. (1993a) found that compensatory growth could be characterized by increased protein deposition, reduced maintenance requirements and greater feed intake. As a result of growth restriction, weight reductions in liver and intestine have been reported by Carstens et al. (1991) and Ledin (1984). Ledin (1984) suggested that the digestive tract would be expected to be better developed in relation to BW in rabbits fed a restricted diet, resulting in an improved growth efficiency during subsequent re-alimentation. These were no differences in body length, withers height, chest girth during the 2nd and 3rd maintenance-compensatory periods between the control and stair-step groups (Table 3).

Table 4. Reproductive performance of heifers on a stair-step compensatory nutrition scheme

Item	Control[a]	Stair-step[a]	p[b]
First estrus (mo)	13.17±0.17	13.17±0.17	1.00
First conception (mo)	15.96±0.13	15.50±0.18	0.08
Conception per AI[c] time	1.36±0.15	1.25±0.13	0.58

[a] Data is the mean±SE for 12 head.
[b] p=significance of F test for equality of two experimental groups.
[c] Artificial insemination.

Table 5. Effect of a stair-step nutrition regimen on growth performance of calf

Item	Control[a]	Stair-step[a]	p[b]
Calf weight (kg), initial	41.40±1.40	44.40±1.56	0.18
Weight at one month (kg)	54.50±1.86	59.10±1.49	0.89
Average daily gain (kg)	0.43±0.05	0.49±0.05	0.22

[a] Data is the mean±SE for 12 head.
[b] p=significance of F test for equality of two experimental groups.

This indicates that 20% restriction is reasonable and is in agreement with the results of Jang et al. (1994). However, total weight gain, daily gain and body conditions were improved compared with the our previous studies (Choi et al., 1997), probably due to the combination of perfect individual feeding system and a stair-step growth pattern. Heifers were weighed twice a month, measured and regulated thoroughly so they could fully exert their abilities. The above result indicate that the use of rice straw alone as a roughage source can lead to a successful stair-step pattern.

First estrus, first conception, and services per conception were not affected by restriction and refeeding (Table 4). These results were in agreement with earlier observations (Jang et al., 1994; Choi et al., 1997). Several studies (Bronson, 1986) have demonstrated that gonadotropin secretion is suppressed during on undernutrition state, delaying the puberty of young animals and decreasing the reproductive performance of adults. However, Kirkwood et al. (1987) reported that moderate restriction (60 to 80% of *ad libitum* intake) has little effect. Thus, the level of development achieved before feed restriction is important. Kirkwood et al. (1987) reported that undernutrition prior to weaning could influence subsequent reproductive development, but the effects may only be evident when pre-weaning growth is severely retarded and the animal fails to compensate for loss during the post-weaning period. Results of reproductive performance of this study indicate that 20% restriction during maintenance period had no adverse effect on the reproductive performance of the test group. That verifies, in preparation against the worst environmental condition, use of rice straw as the sole roughage source may result in successful stair-step pattern.

Calf weights at the first were similar in both groups, an indication that a stair-step pattern using only rice straw did not lower the growth performance (Table 5). Apparently all

Table 6. Milk yield and composition averaged by treatment

Item	Control[a]	Stair-step[a]	P[b]
Milk yield (305 d, kg)	7,970.70±1,321.81	8,971.60±1,433.77	0.20
Milk fat (%)	4.07±0.12	3.77±0.14	0.14
Milk fat yield (kg)	324.38±23.17	338.23±16.88	0.96
Milk protein (%)	3.23±0.04	3.16±0.07	0.39
Milk protein yield (kg)	257.45±16.62	283.50±14.37	0.45
Milk lactose (%)	4.93±0.04	4.77±0.06	0.03
Milk lactose yield (kg)	392.96±26.74	427.95±24.59	0.57
TS (%)	13.02±0.17	12.51±0.14	0.05
TS yield (kg)	1,037.79±67.61	1,122.35±54.34	0.59
SNF (%)	8.86±0.06	8.64±0.10	0.06
SNF yield	706.20±45.90	775.15±42.07	0.48

[a] Data is the mean±SE for 12 head. [b] p=significance of F test for equality of two experimental groups.

Table 7. Milk yield during different phages of lactation as influenced by a stair-step nutrition regimen

	Early lactation	Mid lactation	Late lactation
Control	2,305.87±469.49	3,271.27±457.40	2,393.51±429.76
Test	2,804.80±317.88	3,479.97±622.95	2,686.83±537.50
p[a]	0.03	0.48	0.28

[a] p=significance of F test for equality of two experimental groups.

test heifers. mother and test calves. were stimulated by hormones and enzymes from the fetal period.

Heifers that had undergone stair-step growth yielded 8.5% more (p=0.31) milk than the control heifers (Table 6). Even though total milk yield was tended to higher in the treatment group, the individual milk components were generally tended to lower. During the early lactation, milk yield of the stair-step group was significantly ($p<0.05$) higher than that of the control and as lactation progressed, the difference gradually reduced (Table 7). Our data is consistent with that of Park et al. (1989). it suggested that compensatory growth results in a rapid and fuller development of mammary tissues because the compensation phase is synchronous with the allometric mammary growth occurring during one or more distinct hormonal stage of development. including prepuberty through late gestation. Choi et al. (1997) reported that mammary tissues from heifers managed under the compensatory growth scheme contain more parenchyma and less fat than those of the control group. They showed that, in mammary cells. levels of DNA, RNA and protein. and the ratio of RNA to DNA and protein to DNA under the stair-step compensatory growth scheme are higher than those of the control group. Munford (1964) reported that DNA concentration in mammary tissue is an excellent indicator of cell number of cells. Hackett and Tucker (1968) observed a high correlation between the number of mammary cells and milk yield. As revealed by these previous studies, a stair-step pattern affects gene replication, transcription and translation within mammary cells. resulting in increases in the number of epithelial and somatic cells. In this experiment, milk production efficiency was also improved indicating that the use of rice straw as the sole source of roughage is a viable option in the stair-step growth pattern. However, milk yield improvement was observed only during the early lactation period. According other studies. the increase in the number and differentiation of mammary epithelial cells occurs through hormonal or enzymatic stimulation during pregnancy (Park et al., 1988). Mammary epithelial cells increase most during and early lactation the most biologically activate this time lactation.

IMPLICATIONS

In summary, heifers on the stair-step compensatory growth regimen gained tended to increase BW and decrease consumed DM. resulting in a better growth efficiency compared with the control heifers. Reproduction. body condition and offspring were unaffected by the stair-step growth pattern. Stair-step feeding tended to increase milk yield by approximately 8.5% over the entire lactation compared with the control and milk yield was increased significantly ($p<0.05$) during early lactation. Our results indicate a stair-step growth pattern using rice straw as the sole source of roughage can improve the growth rate and lactation performance and enhance the lactation capacity during lactation.

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