Characteristics of feeding and breeding practices for intensification of smallholder dairy systems in the Kenya highlands

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Abstract

This study aimed at better understanding of the characteristics of feeding and breeding practices smallholder farmers adopt in intensifying their dairy production. Use of hired labour for fodder gathering, growing of fodder crops and purchase of feeds increased with increasing intensification, but *Bos taurus* breeds did not respond to increasing feeding intensification while *Bos indicus* cattle responded, calving at earlier age and yielding more milk. Overall, first calving occurred at 32 months, but days open prolonged to 250 days with milk yield of 4 litres per day of calving interval. A principal component analysis extracted six feeding and breeding components, explaining 71.79% of the total variations in feeding and breeding practices for dairy intensification. The six components were labelled: non- intensified feeding and breeding; breeding decisions based-intensification; high external resource based-intensification; moderate resource based-intensification; resource poor based-intensification; and moderate external resource based-intensification.

These characteristics
points to some 'evolutionary process' of intensification involving feeding and breeding decisions, depending on the risk-bearing capacity of the household. Intensification enhancing interventions for smallholders need be considered in the context of the household economy. Interventions on feeding and breeding have to be packaged together holistically if intensification is to enhance productivity. A selective intervention on only one of these is associated with low productivity levels, only contributing to sustaining family subsistence livelihoods.

Key words: dairy breeds, intervention, productivity, smallholders

Introduction

Smallholder dairy production in low income countries continues to attract substantial development support from national and international agencies as a viable pathway out of poverty. Development support is greater for dairy production in areas with high population pressure on land and high market demand for dairy products where intensification of production is encouraged (De Leeuw et al 1999; Tulachan et al 2000). As previously presented by Bebe et al (2002), smallholder dairy production systems in the Kenya highlands exemplify this dairy intensification process. In response to the continuously shrinking landholdings in the highlands, smallholders continue to intensify their production systems to sustain livelihoods from the limiting production resources of land, capital and labour.

In intensifying their dairy production, smallholders shift feeding practices from free- to zero-grazing and breeding practices from *Bos indicus* cattle to *Bos taurus*
breeds, but attain low levels of productivity, though with high variation (Staal and Omore 1998; Bebe et al 2003a). When asked about constraints to increasing dairy productivity under intensification process, smallholders in the Kenya highlands ranked lack of feed as the most important followed by lack of labour, poor animal performance and lack of cash to purchase inputs (Bebe et al 2002). Feeding practices include gathering of forages from common properties, planting small plots of napier grass (*Pennistetum purpureum*) and feeding of crop residues supplemented with purchased forages and concentrates. Breeding practices on the other hand, as demonstrated by Bebe et al (2003a), are inconsistent with the technical recommendations favouring the use of dairy breeds of small mature body size (Guernsey and Jersey) to match the inadequate quantity and quality feeding. Instead, smallholders prefer the larger dairy breeds (Friesian and Ayrshire), which are potentially high milk yielding, have higher salvage value due to their

heavier bodyweight, and provide more total benefits including being fluid capital assets with higher non-marketed production of insurance and financing roles (Ørskov 1999; Bebe et al 2003b).

Knowledge of characteristics of feeding and breeding practices that smallholders apply to intensify their dairy systems in the Kenya highlands can be useful in the design of targeted interventions rather than uniform blanket promotion of productivity enhancing interventions. In this way, feeding and breeding interventions can be considered in the context of the socio-economic and environmental conditions of the individual households. With this background, this study aimed at characterising feeding and breeding practices that smallholders adopt in intensifying their dairy systems in the Kenya highlands.

Research methodology

Research framework

This study was conducted under Smallholder Dairy Project (SDP), which was broad and multi-level diagnosis of smallholder dairy systems in the Kenya highlands to identify research and development needs for supporting dairy intensification (Staal et al 2001). The SDP project focused on identifying and assisting the most resource poor. In intensifying their feeding systems from free- to zero-grazing and replacing *Bos indicus* with *Bos taurus* breeds, smallholders employ diverse management strategies, which could better reflect their socio-economic and environmental constraints to enhancing dairy productivity. Contributing to the broad goals of the SDP project, this study aimed at better understanding of the characteristics of feeding and breeding practices of smallholders for intensifying dairy production.

Survey methodology and data collection

A stratified random sample cross-sectional survey of 1755 households in the Kenya highlands was conducted between June 1996 and April 1998 to characterise the smallholder dairy systems supplying the Greater Nairobi urban market. Stratification was by agro-ecological potential (for cropping and dairying) and milk market access. The agro-ecological potential (medium and high) was according to land use defined by Jaetzold and Schmidt (1983). Milk market access (low, medium and high) was defined on the basis of human population densities, local demand for milk, types of roads and the availability of milk marketing institutions. Based on the 1989 population census, the total sample size represented approximately 1% of the total number of households. Data were collected through household interviews using a pre-tested, structured questionnaire on both farm-level and individual animal performance information from each of the respondents. Farm-level data included farm size, land allocated to growing of food crops (maize, Irish potatoes, sweet potatoes, vegetables, and beans), cash crops (coffee, tea, wheat and pyrethrum) and forage crops (napier, oats, forage legumes). Other farm-level data were herd size, sources of labour (family only and hired casual or permanent labour) and estimated costs of fodder and concentrate purchases in the past year.

From each household keeping cattle, individual animal production and reproductive data were collected on breed; age at first calving; milk yield on the day prior to the survey; the dates of the two most recent consecutive calvings; the date of the first known service post-calving and the date of drying-off for the most recent calvings. The *Bos taurus* cattle breeds included Friesian, Ayrshire, Guernsey and Jersey and the *Bos indicus* breeds were East African Zebu, Boran and Sahiwal. Dates of calving, service and drying-off were used to compute days-open, lactation length and milk yield per day of lactation and per day of calving interval. Days-open was defined as the period between dates of calving and the subsequent pregnancy. The dates of two most-recent calvings and the date of subsequent post-calving service were used for checking for reliability of days-open information.

Definition of variables describing feeding and breeding practices of smallholders

Definitions of variables describing feeding and breeding practices are presented in Table 1. The total land owned by a household, the land allocated to maize and the land allocated to napier were considered to reflect access to own-produced feed resources and were computed in hectares per Tropical Livestock Unit (TLU). The TLU units used were 1 for bull, 0.7 for cow, 0.5 for heifer and young bull, and 0.2 for calves. Purchased fodder and concentrates were considered to reflect the level of use of external feed resources and were computed in Kenya shillings per TLU per year (Ksh/TLU/y). The estimated hectares of napier planted (ha/TLU) and the costs (Ksh/TLU/y) of fodder and concentrates purchased during the year prior to the survey were considered as feed resource variables related to intensification.

Variables indicative of breeding practices included breed kept, age at first calving, days open, milk yield per day of calving interval and use of artificial insemination (AI). Labour hiring and membership to dairy cooperative society was included in the analysis because they potentially influence feeding and breeding practices. Labour is hired for gathering forages and husbandry of the herd while cooperative membership enhances access to inputs and services on credit basis.

Statistical method

SURVEYMEANS procedure (SAS 1999) was used to compute descriptive statistics for investigating patterns in the land allocation to crops (food and cash) and forages as farmers shift from free-to zero-grazing feeding system. The same procedure was applied to investigate patterns of associations between feeding and breeding practices. Following descriptive statistics, the data was subjected to Principal Component Analysis (PCA) using procedure PRINCOMP (of SAS 1999) to gain insight into the interrelationships amongst variables relating to feeding and breeding practices. PCA statistical technique adequately deals with outliers (causing high CV) and transforms all information from correlated variables (here, feeding and breeding practices) into a number of uncorrelated new variables termed Principal Components (PCs). The PCs are all linear combinations of the original (feeding and breeding practices) variables and are orthogonal to each other (Lattin et al 2003). This reduces the dimensionality amongst the correlated variables, selecting only a few PCs that contribute to most variance.

Table 1. Descriptive statistics for the feeding and breeding practices of smallholder dairy farmers in the Kenya highlands

Indicator variables	**Variable description**	**Units**	**Average values**	**Coefficient of variation, %**
Feeding practices				
Free grazing	Practicing free-grazing (1=Yes, 0=No)	%	26	
Semi-zero-grazing	Practicing semi-zero-grazing (1=Yes, 0=No)	%	29	
Zero-grazing	Practicing zero-grazing (1=Yes, 0=No)	%	44	
Napier fodder	Napier fodder planted	ha/TLU	51	114.72
Fodder available	Fodder purchased	Ksh/TLU/y	1923	149.80
Concentrates	Concentrate purchased	Ksh/TLU/y	5233	161.75
Breeding practices				
Friesian/Ayrshire	Preference for large sized dairy breeds (1=Yes, 0=No)	%	62	
Guernsey/Jersey	Preference for small sized dairy breeds (1=Yes, 0=No)	%	16	
Zebu cattle	Preference for zebu cattle (1=Yes, 0=No)	%	22	
Age at first calving	Average age at first calving achieved on the farm	months	32	21.72
Days open	Days open achieved on the farm	*days*	250	51.35
Milk yield	Average milk yield per day of calving interval attained on the farm	l/d	4	74.46
AI service	Breeding using artificial insemination breeds (1=Yes, 0=No)	%	35	
Feeding and breeding				
Labour hired	Labour hired for dairy activities (1=Yes, 0=No)	%	69	
Cooperative membership	Registered member of a dairy cooperative society (1=Yes, 0=No)	%	43	

Of 1755 randomly sampled households, 987 had cattle of which only 365 had all records needed for the PCA analysis

The PCs were computed from the correlation matrix among the variables relating to feeding and breeding practices. Using correlation matrices instead of covariance matrices or the original values for feeding and breeding practices ensures that all variables are considered on a standardized scale and treated equally important, not giving more weight to variables with larger variance. Based on Lattin et al (2003), a decision on the number of PCs to retain for further analysis was based on Kaiser-Guttman or eigenvalue criterion, in which only PCs with eigenvalues ≥1 are retained. This criterion ensured that each of the retained PCs accounted for more variation than any individual variable describing feeding and breeding practice. In the PCA statistical procedure, A VARIMAX rotation was applied in order to obtain factor pattern coefficients after redistributing variance among factors. The rotation procedure enhances interpretation of the factors without changing their statistical explanatory power.

Results

Characteristics of feeding and breeding practices from descriptive analysis

Figure 1 illustrates patterns of land allocation to fodder supporting progressive intensification of dairying. In free-, semi-zero- and zero-grazing farms, the average (with 95% confidence interval) hectares for each TLU of maize planted was respectively 0.27 (0.23-0.30), 0.25 (0.20-0.30) and 0.18 (0.15-0.20). The corresponding averages for napier planted were respectively 0.09 (0.06-0.11), 0.09 (0.05-0.12) and 0.13 (0.11-0.15). Thus, zero-grazing farms planted more land (1.4 times) in napier (P<0.05) compared to free- or semi-zero-grazing farms.

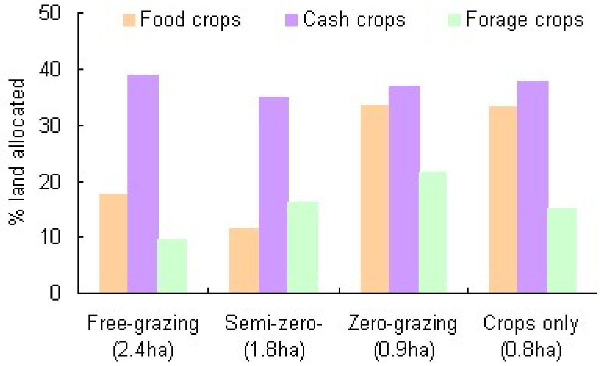

Figure 1. Proportion (%) of farm (ha in brackets) that is allocated to food crops, cash crops and forage crops
by households practising free-, semi-zero- or zero-grazing and those households only growing crops in the Kenya highlands

Households with smaller farms (zero-grazing and crops only) allocated a larger proportion (P<0.05) of their land to food crops, but the proportion of land allocated to growing of cash crops was not different (P>0.05) amongst all household categories Farmers allocated an
increasing proportion of land (from 9 to 22%) to growing of fodder crops as they intensified feeding systems from free- to zero-grazing. Not all households grew fodder: the proportion of households growing fodder (28%) was significantly higher (P<0.001) amongst those practising zero-grazing than amongst those practising free- (19%) or, semi-zero-grazing (4%) or only growing crops (5%). In these dairy systems,
about a third of the households used only family labour while the other two-thirds hired labour, mainly on a casual basis (Table 2) to support dairy intensification. Use of hired labour increased with the intensification of production systems from free- to zero-grazing (P<0.001) and with the change from keeping *Bos indicus* to *Bos taurus* cattle breeds (P<0.013).

Table 2. Percentage (%) of households using only family and hired labour by grazing system and breed kept

Source of labour	Grazing systems			Breed of cattle kept			
	Free-	**Semi-zero-**	**Zero-**	***Bos indicus***	**Guernsey /Jersey**	**Ayrshire**	**Friesian**
Family labour only	35.2	28.2	29.6	39.2	31.7	29.3	23.5
Casual labour only	36.3	48.1	53.0	35.1	53.8	52.5	50.1
Both casual and permanent labour	13.0	13.1	6.4	11.3	3.5	8.8	12.8
Permanent labour only	15.5	10.6	11.0	14.4	11.0	9.4	13.6
Number of households	227	326	434	217	157	189	424

Figure 2 is presented to illustrate patterns in smallholders' breeding practices by feeding systems. While *Bos indicus* cattle responded to changes in feeding management from free- to semi-zero and zero-grazing with earlier first calving age and increased milk yield, the *Bos taurus* cattle breeds did not respond. However, amongst the *Bos taurus* breeds, the smaller (Guernsey/Jersey) body sized achieved shorter days open (202days vs 295-384 days) and more milk yield per day of calving interval (6.8 litres vs 1.2 -3.6 litres) in the free-grazing systems but not in the other systems. The interval calving to conception averaged 250 days (Table 1), suggesting average calving intervals in excess of 520 days in these herds. A noticeable exception is Friesian in semi-zero- and zero-grazing farms which attained shorter (P<0.05) days-open than the other dairy breeds (Ayrshire, Guernsey and Jersey). These differences in breed performances between systems are likely related to the attention farmers pay to feeding under different production systems.

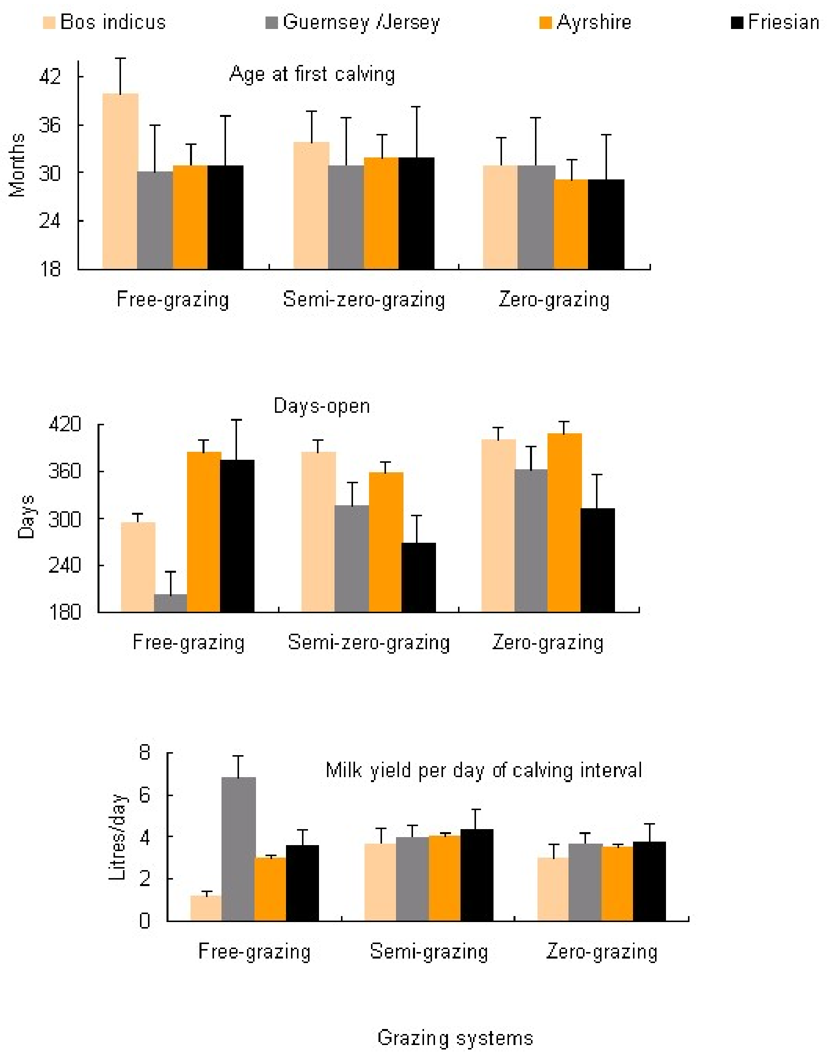

Figure 2. Means with their standard deviations of age at first calving, days-open and milk yield per day of calving interval for cattle breeds in free-, semi-zero- and zero-grazing farms of smallholders in the Kenya highlands

Characteristics of feeding and breeding practices from Principal Component Analysis

Eigenvalues and the proportion of the total variation explained in feeding and br eeding practices by each PC are listed in Table 3. Presence of multicollinearity is evident given the near zero eigenvalue (0.031) for PC15, with the first PC accounting for 17.12% of the total variation among the 15 variables of feeding and breeding practices. App lication of Kaiser-Guttman rule of retaining only PCs with eigenvalues ≥1 for subsequent analysis yielded 6 PCs, which accounted for 71.79% of the variance in feeding and breeding practices.

Table 3. Eigenvalues and proportion of the total variance explained by principal components

Principal components	Eigenvalues	Total variance explained, %	
		Proportion	Cumulative
PC1	2.568	17.12	17.12
PC2	2.196	14.64	31.76
PC3	2.020	13.47	45.23
PC4	1.590	10.60	55.83
PC5	1.230	8.20	64.03
PC6	1.650	7.77	71.80
:	:	:	:
PC13	0.175	1.167	99.11
PC14	0.103	0.687	99.79
PC15	0.031	0.207	100.00

The Factor pattern coefficients of the selected PCs after rotation are presented in Table 4, ordered according to the variation accounted for. The coefficients show the relative contribution of individual indicator variable of feeding and breeding practice to the particular factor. For each factor, variables with the largest pattern coefficient make the largest contribution to the particular factor. The coefficients are interpreted on the basis of their sign and magnitude, within the context of the farming systems under study. With a sample size greater 350, a coefficient greater than ±3 (bolded in the table), is considered significant, and this was used in interpreting interrelationship amongst variables defining feeding and breeding practices (Lattin et al 2003).

Smallholders with high coefficients for FB1 show high preference for zebus cattle (+ sign) at low feeding intensification level (+ sign for free-grazing and - sign for semi-zero-grazing). Those with high coefficients for FB2 prefer utilising larger dairy breeds (+ sign for Friesian/Ayrshire) and not the smaller mature sized breeds (- sign for Guernsey/Jersey). Smallholders depicted in FB3 are members of dairy cooperative societies (+ sign) more frequently using AI services (+ sign), more frequently hiring labour (+ sign) and feeding high levels of concentrates (+ sign), which combine to contribute to achieving high milk production levels (+ sign). Those loading heavily on FB4 are more dependent on own planted napier fodder (+ sign), use AI service less frequently (- sign) and have their cows experiencing prolonged days open (+ sign), resulting in low milk yields (- sign). Loading heavily on FB5 are smallholders also more dependent on own napier fodder (+ sign) under semi-zero-grazing system (+ sign) but hardly practice zero-grazing system (- sign). The last group of smallholders loading heavily on FB6 use bulls for service (- sign for AI services) and feed more purchased fodder and concentrates (+ signs), which contribute to achieving earlier age at first calving (- sign).

The characteristics exhibited in feeding and breeding practices for intensifying dairy systems in the Kenya highlands can thus be labelled: FB1 non-intensified feeding and breeding; FB2 breeding decisions based-intensification; FB3 high external resource based-intensification; FB4 moderate resource based-intensification; FB5 resource poor based-intensification; and FB6 moderate external resource based-intensification.

Table 4. Factor pattern coefficients for rotated factors

Feeding and breeding variables	**Factors**					
	FB1	**FB2**	**FB3**	**FB4**	**Fb5**	**Fb6**
Free-grazing practised	**0.923**	0.092	-0.037	0.019	-0.100	-0.073
Semi-zero-grazing practised	0.040	0.112	0.016	-0.114	**0.898**	0.123
Zero-grazing practised	**-0.843**	-0.151	0.023	0.054	**-0.469**	-0.012
Napier ha/TLU planted	-0.046	-0.011	0.296	**0.349**	**0.599**	-0.166
Fodder Ksh/TLU/y purchased	-0.088	-0.208	0.216	-0.208	-0.039	**0.724**
Concentrates Ksh/TLU purchased	0.142	-0.026	**0.713**	0.181	0.074	**0.366**
Friesian/Ayrshire breeds kept	-0.227	**0.941**	-0.054	0.051	0.099	0.056
Guernsey/Jersey kept	-0.218	**-0.885**	-0.108	-0.069	-0.017	0.011
Zebu breeds	**0.718**	-0.287	0.259	0.016	-0.145	-0.115
AI services used	0.127	0.101	**0.565**	**-0.340**	0.142	**-0.443**
Age at first calving	0.053	-0.289	0.100	-0.002	-0.099	**-0.579**
Days open period	-0.029	0.175	0.122	**0.840**	-0.009	0.073
Milk per calving interval day	-0.057	0.083	**0.309**	**-0.741**	-0.067	0.294
Labour hired for dairy	-0.142	-0.238	**0.489**	0.076	0.260	0.116
Cooperative membership	0.075	0.130	**0.714**	-0.153	-0.032	-0.116

Discussion

This study aimed at identifying the characteristics of feeding and breeding practices of smallholders as they intensify their feeding systems from free- to zero-grazing and breeding practices from using *Bos indicus* to using *Bos taurus* breeds. Results suggest that a major constraint to dairy intensification is the inadequate quality and quantity of feeding. A strategy adopted by smallholders is planting some napier, a perennial fodder crop with high dry matter yields and high vegetative growth (Muia et al 2000; Devendra and Sevilla 2002). Though recommended for the land-scarce smallholders, many face difficulties growing adequate amounts for their animals. Land is more limiting and napier competes with other cash and food crops for the limited arable land. Furthermore, nutritive quality of napier is often low because technical recommendations for napier management are not followed in practice. Recommendations in the Kenya highlands are that farmers allocate 0.33ha of napier for each TLU of cattle kept in order to meet the daily dry matter intake requirement (Muia et al 2000). Though dependency on napier increased with intensification levels, zero-grazing smallholders only allocated napier 0.13ha, an indication that the available napier cannot provide adequate dry matter requirements of the dairy breeds. Many supplement napier by externally sourcing forages outside the farm (road reserves, forests and schools) using hired labour, but being a recurrent cost, presents sustainability issues as when subsistence objectives feature more prominently amongst those resource poor households.

Smallholders depending on own produced feed resources could only sustain low levels of milk production, essentially ensuring a supply of milk for family consumption and may be some little marketed surplus for cash income. When milk sales are the primary production objective, feeding of concentrates is attractive at a milk/concentrate price ratio of greater than one (Walshe et al 1991). For much of the year in this study area in Kenya the prevailing milk/concentrate price ratio varies from 1.2 to 1.5, but nevertheless the level of concentrate use as supplementary feed to the fodder basal diet is a too low level to exploit the high milk yield potential of the dairy breeds.
The estimated mean of Ksh 5233 of concentrates for each TLU in a year with the prevailing prices of Ksh 11 per kg of concentrates indicates that farmers fed low levels of concentrates (about 2 kg of concentrates daily for each TLU). The prolonged days open of 250 days are indicative of inadequate supply of energy to support critical nutritional periods, corresponding to Romney et al (2002) estimates from longitudinal studies of these systems that cows are fed about 8 kg of DM per day, a larger proportion (60%) of which is crop residues. Prolonged days open in cows result in long calving intervals, a major constraint to improved productivity identified in many smallholder systems (Alejandrino et al 1999; Bebe et al 2003a; Msanga et al 2005) and it is related partly to under nutrition (Ørskov 1999).

The dual purpose zebus (Sahiwal and Boran) responded well to feeding intensification with improved reproduction and production, suggesting that feed quality and quantity in these systems meet their nutrient requirements well. However, they are unpopular with smallholder dairy farmers in the Kenya highlands, and their adoption is likely to remain low**.** Use of external feed resources (fodder concentrates) necessary to support improved productivity of dairy breeds, was associated with membership to co-operative society, where inputs may be obtained on credit basis. Encouraging co-operative movement can help reduce risks that may be associated with the dependency on external feed resources.

Using PCA
results, feeding and breeding practices for intensification of dairy systems in the Kenya highlands could be characterised into six progressive stages that somewhat reflect
evolutionary process' of intensification, apparently varying with the risk-bearing capacities of the households. It is hypothesized that intensification progresses from non-intensified feeding and breeding to breeding decisions based-intensification, and subsequently through resource poor based-intensification, moderate resource based-intensification, moderate external resource based-intensification and eventually topping at high external resource based-intensification. The characteristics of these evolutionary stages are now described based on previous studies of smallholder dairy systems in the Kenya highlands (Staal and Omore 1998; De Leeuw et al 1999; .Staal et al 2001, Bebe et al 2002; Romney et al 2002; Bebe et al 2003a and b).

Smallholders characterised as non-intensified feeding and breeding are yet to adopt feeding and breeding interventions associated with intensification process. These characteristics corresponds to lacking incentives to intensify, which includes land being not a production constraint, being more risk averse to new interventions, applying indigenous knowledge in livestock management, and lacking access to extension, input and output markets. Those at the stage of breeding decisions based-intensification are entering intensification process and have the cash to invest. Their decision to first invest on larger dairy breeds is probably driven by the need for surplus marketable milk to earn income, because the breeds popularly promoted as having potential for high milk yielding.

After investing on dairy stock, some smallholders experience transitional problems in mobilizing adequate resources necessary to supporting intensification process, hence the next stages of resource-poor-, moderate-resource-, or moderate external-resource based-intensifications. In the transitional stages, feed resource is a major constraint to enhancing system productivity. Depending on the risk-bearing capacity of the individual household, some invest on producing fodder on-farm while others supplement with purchased feeds. Depending on investments made on feeding influences results in breeding practices (open days and age at first calving), with those investing more improving breeding results (Table 4). Smallholders that get out of the transitional stage enter the stage of high external resource based-intensification, where heavy use of external resources enhances productivity and sustains intensification. These are the specialised dairy producers, with market-oriented production objectives, supported with access to input and output markets.

For development targeted at alleviating poverty through dairy intensification, the appropriate target group are those in transitional intensification stages, who urgently need
adjust to the pressures of sustaining intensification without recourse to dairy production. Breeding interventions alone will be not support intensification, a package of feeding and breeding interventions fitting the household economy will be needed. Promising feeding interventions include forages and fodder that fix nitrogen, survive droughts and yield high biomass with relatively good nutritive values. Choice of species that prevent soil erosion and preserve fragile environments while feeding farm animals would more successfully adopted in many parts of the Kenyan highlands where smallholder dairy production is a key to sustainable land use as landholding sizes continue shrinking.

Conclusion

- Feeding and breeding interventions are major components of intensification process of smallholder dairy production.

- In intensifying their dairy production systems, smallholders could be adopting feeding and breeding interventions progressively through somewhat 'evolutionary processes, depending on their risk-bearing capacity. Interventions on these two components have to be packaged together holistically if productivity is to be enhanced with intensification.

- A selective intervention on only one component is associated with low productivity levels, only contributing to sustaining family subsistence livelihoods.

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