（Form　No. 13）

SUMMARY OF DOCTORAL THESIS

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Title: Stall feeding regimen for indigenous dairy cow production in northwestern Ethiopia
(エチオピア北西部における在来種乳牛生産のための舎飼い給餌法)

Dairy production is one of the most important agricultural sectors for global food security and nutrition. Though, the average per capita global milk consumption amounts at 113 kg of milk/year, this is significantly much less in developing countries such as Ethiopia, with a per capita milk less than 20 kg per annum (2018). The major constraints affecting milk production in Ethiopia are attributed to the dominant free grazing feeding practice of poor-condition natural pasture feed sources combined with lack of improved feeding practice which is influenced by feed shortage both in quality and quantity. Free grazing cause low productivity, increase overgrazing and aggravate land degradation. Moreover, the indigenous dairy cow breeds (98%) being characterized by low milk yield (average 1.5 kg/cow/day). To enhance dairy production improving feeding and designing appropriate feeding strategies are crucial. On the other hand, stall-feeding increase potential productivity.

A stall feeding system has been promoted by the Ethiopian government for improving livestock productivity to improve feeding management as well as reduce land degradation by avoiding free grazing. The key research gaps identified in this study are two folds: lack of information on the type, nutritive value, anti-nutritional factors of locally available or improved feedstuffs and feeding regimen, an optimal diet that specifies the amount and schedule of nutritional intake. Thus, the overall goal of this thesis is to improve the productivity of indigenous dairy cows through formulating stall-feeding regimen taking a case study of the Fogera breed in northwest Ethiopia. The specific objectives were: 1) to identify the available feedstuffs and evaluate the nutritive values, 2) to improve feed quality through mitigating the anti-nutritional factors, 3) to formulate optimal diet for lactating indigenous dairy cows and 4) to evaluate and validate the effect of some selected diets containing improved grasses hays and treated teff straw silage on milk yield, nitrogen utilization, and methane emission. These objectives cover chapters 2–5 of this thesis summarized as follows:

Chapter 1 explains the introductory section of the study. It presents an overview of the background for the study, focusing on dairy production, feed resource, past stall feeding practice, and methane emission from dairy cows based on the existing literature. Subsequently, it presents the background, problem statement, objectives, study areas description and outline of the thesis.

Chapter 2 identifies the available feed resources in the study sites and analyze the nutritive values. A total of 32 feedstuffs are found in the studied sites, of which natural pasture and crop residue are the most dominant (43% and 25%, respectively). On the other hand, both natural pasture and crop residue are poor quality feeds due to their low nutritive value and digestibility hence they cannot fulfill the maintenance nutrient requirement of lactating dairy cows. Whereas, improved forages, agro-industrial by-products and green fodders have high crude protein (CP) value (>100 g/kg DM) with better digestibility that can be used as supplementation for poor-quality feeds. This study also revealed a number of potentially valuable indigenous fodder species which can be used as feed supplementation for CP particularly in the dry season. The mineral profile result also indicates that most of the feedstuffs are rich in calcium, magnesium, potassium, phosphorus and iron content but

deficient poor in sodium, cobalt and copper. Then, it is necessary to supplement those deficient minerals in the diet of dairy cow by providing a mineral mixture.

Chapter 3 deals with the evaluation of polyethylene glycol (PEG) to reduce the anti-nutritional effects of polyphenols on in vitro digestibility and fermentation characteristics of fodder plant species. The study was designed as a 10 x 2 x 2 factorial arrangement with 10 fodder species, 2 seasons (wet and dry), and 2 states of PEG (with and without PEG). The result showed that addition of PEG improves the in vitro organic matter digestibility (IVOMD), metabolizable energy (ME) and volatile fatty acids (VFA) production on average by 48%, 42%, and 20%, respectively. Moreover, the ant-nutritional factors such as phenols and tannins were (negatively correlated $p<0.001$) with IVOMD, ME, and VFA. In summary, PEG markedly reduced the anti-nutritional effects of polyphenols on in vitro fermentation and improve the nutritive value of fodder species.

Chapter 4 evaluates the existing lactating dairy feeding practices and formulated optimized diet formulation. The result indicates that the existing feeding practice doesn't satisfy the nutrient demand for lactating dairy cows resulted in low milk yield. This implies that dairy cows should be supplemented for optimum milk production. The optimized diet formulation indicates that with a combination of high-quality feed ingredients it can be possible to fulfill the maintenance as well as the lactation nutrient requirements that enhances the productivity of indigenous dairy cows.

Chapter 5 investigates the evaluation and validation of selected diets containing improved forage grasses hay and treated teff straw silage on milk yield, nitrogen utilization and methane emission using eight lactating indigenous Fogera cows. The following four roughage basal dietary treatments supplemented with formulated concentrate in total mixed ration (TMR) were evaluated: control (natural pasture hay (NPH)); treated teff straw silage (TTS); Napier grass hay (NGH), and brachiaria hybrid grass hay (BhH). The results showed that compared with the NPH based TMR diet, the daily milk yield increased ($P < 0.05$) by 32%, 53% and 89% with TTS, NGH and BhH diets, respectively. Cows fed BhH had the highest dry matter intake (8.8 kg/d), followed by NGH (8.1 kg/d) and TTS (7.7 kg/d); all of these intakes were greater ($P < 0.05$) than that of NPH (6.2 kg/d). Nitrogen digestibility increased ($P < 0.05$) from the NPH diet to TTS (by 28%), NGH (22%) and BhH (40%). The milk urea nitrogen (MUN) concentration found higher ($P < 0.05$) in cows fed TTS (975.6 µmol/L) than other diets. Remarkably, cows fed NPH had higher ($P < 0.05$) non-esterified fatty acid (NEFA) (0.5 mmol/L) and ß-hydroxybutyrate (BHBA) (0.2 mmol/L) than those fed other TMR diets. Feeding TTS, NGH, and BhH hay as a basal diet changed the nitrogen excretion pathway from urine to feces, which can benefit the protection against environmental pollution. Dairy cows fed BhH, NGH and TTS emitted less daily CH4 expressed as per unit of milk yield ($P < 0.05$) than NPH diet. The validation of the formulated diet milk yield has a positive relation ($r2 = 0.61$) with the actual milk yield. Consequently, this study indicated the possibility of increasing milk yield and reducing methane emissions in countries like Ethiopia, where precision-feeding is a limitation. Hence, the results provide feeding regimen through feeding nutritionally upgraded roughages basal diet that can improve milk productivity of Fogera breeds on average up to 58%.

Chapter 6 provides the general conclusion and recommendations of the whole thesis based on the key findings from Chapters 2–5. If the stall feeding system is integrated with feeding optimal diet it would be possible to increase milk productivity of Fogera cow breeds on average by 58%, while significantly reducing N fecal excretion (23%) and methane emissions per kilogram of milk yield (28%).