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Provision of urea–molasses blocks to improve smallholder cattle weight gain during the late dry season in tropical developing countries: studies from Lao PDR

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Abstract

Context. Large-ruminant production in developing countries is inefficient with low growth rates and declining weights, particularly in the dry season.

Aims. The impact of *ad libitum* supplementation of cattle with high-quality molasses blocks (20 kg) containing either 8% urea (UMB) or nil urea (MB), was examined.

Methods. Field trials on smallholder farms compared weight changes and average daily gains (ADG = g/day) data of young calves <8 months of age (*n* = 25); growing calves 8–24 months (*n* = 35) and lactating cows (*n* = 46), of the indigenous breed when accessing either UMB or MB, with data being collected at Weeks 1, 4, 8 and 12. A pen study was also conducted at a research station involving mature, lactating crossbred cows (*n* = 37). Surveys of farming families experiencing use of the blocks was conducted (*n* = 20).

Key results. On smallholder farms, animals accessing UMBs were heavier than those accessing MBs at every collection day and in young calves these differences were statistically significant ($P < 0.05$). ADGs were higher in cattle accessing UMB than in those accessing MBs. Young calves had the highest ADG (251–265 g/day), followed by growing calves (198–237 g/day) and lactating cows (187–190 g/day), although differences in ADG between UMB and MB cohorts were not considered significant (young calves $P = 0.562$; growing calves $P = 0.509$; and lactating cows $P = 0.993$). Results from the pen study identified that ADGs were not significantly different ($P = 0.933$) between crossbred cows accessing MBs (236 g/day) and cows accessing UMBs (229 g/day). Surveys of farmers using blocks confirmed that their animals were calmer and healthier, and had better coat condition with minimal external parasites; these farmers wished to purchase the blocks and were willing to pay a mean up to US$6.5 ± 2.3 per block.

Conclusions. Provision of UMBs and MBs in Laos in the late dry season improved cattle growth rates, which is consistent with previous studies and far superior to the base-line data from Laos demonstrating declining ADGs. Farmers considered that the blocks contributed greatly to herd management and improved sale-ability of their cattle.

Implications. Provision of molasses blocks on low-input smallholder farms in developing countries significantly improves production efficiency, offering an 'entry point' intervention while forages are becoming established.

Keywords: agricultural development, large ruminants, Southeast Asia, supplementation.

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Introduction

Currently, livestock production accounts for ~40% of agricultural output in developed countries, with advanced genetics, feeding systems, animal-health controls and other technologies reducing land requirements for livestock by ~20%, producing a doubling of meat production over the past 40 years (FAO 2018). However, in subsistence agricultural systems of developing countries, livestock production is only ~20% of agricultural output, despite the rapidly rising demand for milk and meat in countries where there has historically been very limited access to these animal-source foods rich in protein (FAO 2018). With global meat and milk production projected to increase another 19% and 33% by 2030 (FAO 2011) respectively, improved adoption of existing 'best practice' technologies in feeding, health, husbandry, manure management and marketing is required. It has also been estimated that this improved production efficiency could potentially assist the global livestock sector to reduce greenhouse-gas emissions (GHG) by as much as 30% (FAO 2018).

Financial motivation to improve cattle and buffalo production efficiency has been increasing, particularly in Southeast Asia, where cattle and buffalo liveweight prices (US$/t) have increased by more than 500% and 800% respectively, from 2000 to 2012 (FAOstat 2015) in response to growing regional beef consumption. This trend continues in Southeast Asia, offering opportunities for smallholder famers to significantly improve their livelihoods. However, for smallholders to exploit these opportunities is challenging, because many livestock farmers in developing countries have low animal-husbandry skills, minimal nutritional, biosecurity, animal disease and reproductive management knowledge, poor access to markets, and high rates of illiteracy (Nampanya *et al*. 2014*a*; Young *et al*. 2014). Further, extension and veterinary services in developing countries are usually limited, diminishing opportunities for smallholders to use nutritional, health and reproductive interventions to improved productivity. For example, in Laos (Lao People's Democratic Republic) and Cambodia in Southeast Asia, fewer than 60% of farmers are using vaccines on cattle and buffalo and these are typically administered to only half the herd, preventing the establishment of herd immunity (Agricultural Census Office Lao PDR 2000; Kawasaki *et al*. 2015).

The Lao People's Democratic Republic (Lao PDR, or Laos henceforth) is a landlocked country where 77% of all households still rely on mainly subsistence agriculture for their livelihoods (Agricultural Census Office Lao PDR 2012). Over a third of agricultural households maintain cattle and/or buffalo, typically in herds of 5–10 heads in smallholder mixed-farming systems where they are used for manure production to support rice and crop cultivation, while also functioning as cash banks (Millar and Photakoun 2008; Nampanya *et al*. 2014*a*). In remote northern regions, buffalo is still occasionally being used for draught power to prepare rice-paddy fields, although numbers have been rapidly declining (Agricultural Census Office Lao PDR 2012). Historically, the small indigenous Laotian Yellow cattle with a mature bodyweight of 146–215 kg, and the native water buffalo with a mature bodyweight of 300–350kg (Young *et al*. 2014; Nampanya *et al*. 2014*a*), have survived on native tropical grass from vacant, owned, communal and forested land in the wet season from June to November. During the dry season, rice cultivation ceases and large ruminants typically consume rice straw from post-rice-harvest fields and less abundant native grasses (Kosaka *et al*. 2006). Rice straw has low metabolisable energy and percentage of crude protein, estimated at 4–6.5 MJ/kg dry matter and 2–6% respectively (Drake *et al*. 2002; Nour 2003). In addition, government re-zoning of forests for reforestation (Fujita and Phanvilay 2008) and increased dry-season irrigation for non-rice cropping have decreased land available for livestock grazing, leading to further constraints on nutrient availability for large ruminants.

These current practices of dry-season feeding in Laos have a negative impact on large-ruminant bodyweights, especially in lactating females, measured as declines in average daily gains (ADGs). Longitudinal data from Laos identified that in January 2010 in the early dry season, ADGs were –40 to 9 g in cattle and –67 to 2 g in buffalo, whereas in March 2009 in the late dry season ADGs of –9 to 71 g in cattle and –21 to 23 g in buffalo were recorded (Nampanya *et al*. 2014*a*). These dry-season ADGs were considerably lower than early wet season ADGs of 208–212 g in cattle and 223–282 g in buffalo, whereas in the late wet season in 2009, ADGs of 102–122 g in cattle and 123–247 g in buffalo were recorded (Nampanya *et al*. 2014*a*). As the early dry season also coincides with both the calving period and increasing demand for animal sales for post-harvest festivities in Laos, decreased animal condition in the dry season has major implications for on-farm productivity and profitability (Matsumoto *et al*. 2017). Low-quality dry-season feed availability limits lactation capacity of cows, extends postpartum anoestrus and reduces livestock sale values. In addition, in Laos, unrestricted mating with uncastrated males is widespread and persists as the main method of breeding cows. Further, enforced weaning is rarely practiced, also contributing to extended inter-calving intervals, estimated at 14–20 months in cattle and 19–26 months in buffalo (Nampanya *et al*. 2014*a*; Matsumoto *et al*. 2017; Olmo *et al*. 2019).

To address constrained livestock productivity in developing countries including Laos and Cambodia, various research projects have demonstrated the importance of initial establishment as an 'entry point', of forage plantations, with whole of village large-ruminant vaccinations plus endoparasite control by deworming being introduced to address nutrition and health constraints (Bush *et al*. 2014*a*; Nampanya *et al*. 2014*a*, 2014*b*; Rast *et al*. 2014; Young *et al*. 2014; Rast *et al*. 2017). These interventions improve the body condition score (BCS) and sale value of cattle, preventing major infectious-disease outbreaks and chronic underperformance from unmanaged endoparasite burdens. Although establishment and expansion of forage plantations takes several years to provide impacts on village-level productivity, this intervention has demonstrated increases in ADGs across the targeted village large-ruminant population that were 2.5 times (150 g) those in villages without forages (50 g; Young *et al*. 2014; Bush *et al*. 2014*a*). Higher gains can be observed in target-fed animals. In Cambodia, feeding forages for 104 days resulted in an ADG of 190 g compared with a loss of 4 g in non-target-fed cattle (Bush *et al*. 2014*b*). In Laos, stall-feeding of forages to cattle for 120 days resulted in an AGD of 320 g, compared with the ADG in grazing animals of between 40 and 80 g (Nampanya *et al*. 2014*a*, 2017). However, forage growing is still practiced by <2% of households (Agricultural Census Office Lao PDR 2012) and has not been adopted in the dry season, presumably due to forage growing requiring household labour and land-resource trade-offs from crop production.

These constraints to forage availability indicate that additional strategies to provide nutritional supplementation of large ruminants are required. As molasses lick blocks have been widely used to provide energy and mineral supplementation for grazing ruminants (FAO 2007), field trials in Laos examined the supplementation of animals for 84 days with high-quality molasses blocks. These blocks were designed to resist meltdown from tropical heat and rain and deliver supplements safely, including optimal availability of phosphorus, sulfur, nitrogen, minerals and trace elements and GHG-reducing agents. The blocks were manufactured and delivered by ship from Australia (4 Seasons Pty Ltd, Brisbane, Queensland, Australia).

The positive impacts of providing access to high-quality molasses blocks to large ruminants in Laos (Windsor *et al*. 2019; Olmo *et al*. 2020) suggested that inclusion of urea in the molasses blocks may provide additional growth benefits, particularly in the dry season. The addition of urea to provide non-protein nitrogen can assist an animal to utilise poor-quality fibrous feed, increasing feed conversion efficiency and production. Urea provides a low-cost source of nitrogen for hydrolysis in the rumen to yield ammonia. Ammonia is an intermediary substrate for rumen microorganisms during their degradation of roughages, assisting amino acid and protein synthesis availability during digestion by ruminants in the small intestine (McDonald *et al*. 1995). Urea is most effective when combined with a readily available source of energy to encourage microbial growth and protein synthesis, leading to improved utilisation of roughages (Lu *et al*. 2019).

Molasses is an available by-product of sugarcane production for sugar in Laos, that is currently exported to Thailand as a waste product. Molasses provides a high-energy supplement that assists in lowering rumen pH, reducing the risk of urea toxicity (McDonald *et al*. 1995). As urea is a soluble and rapidly degradable source of nitrogen, supplements need to be taken in frequent and small quantities. This risk of urea toxicity can be further minimised by measured administration of urea in a quality lick-block that is manufactured to slow the rate of intake, enabling rumen microorganisms to adjust to the increased presence of rumen ammonia (FAO 2007). Urea supplementation in molasses lick blocks for ruminants has been proposed as an easy-to-use technology with few labour and land inputs, that can be applied safely if the urea content of blocks is 8% or less (FAO 2007). It has not been previously examined in Laos.

In the present study, we determine the impact of offering urea–molasses blocks (UMB) versus non-urea–molasses blocks (MB) to cattle in three different age cohorts in smallholder production systems in Laos. This strategy, if successful, may provide a practical intervention to help address the deterioration in nutrient availability from dry-season declines in forage availability for improved smallholder large-ruminant production efficiency in Laos and beyond. Further, as establishing forages may take several years before providing returns to smallholder large-ruminant production (Nampanya *et al*. 2014*a*, 2017; Young *et al*. 2014), access to molasses blocks may potentially offer a more convenient intervention 'entry point' for development projects aiming to enhance large-ruminant production efficiency in smallholder systems.

Materials and methods

Study sites and household selection

To evaluate the effect of access to molasses blocks supplemented with 8% urea (UMB), compared with access to molasses blocks without inclusion of urea (MB), on dry-season large-ruminant productivity, cattle from smallholder farms were recruited into the study. Animal and human ethics approval was obtained from the University of Sydney Ethics Committee (Project numbers 2015/765 and 2014/783 respectively) and complied with the National Health and Medical Research Council's (NHMRC) National Statement on Ethical Conduct in Human Research (2007) and the Universities Australia Australian Code for the Responsible Conduct of Research.

The Provinces of Xayabouli, located in the north-west, and Savannakhet, located in central Laos, were selected for inclusion in the field studies (Fig. 1). Xayabouli has mean temperatures of 26–28°C and mean monthly rainfall of 42–164 mm (Climate-Data 2012*a*). Savannakhet has mean temperatures of 28–29°C and monthly rainfall of 33–170 mm (Climate-Data 2012*b*). All trials commenced in March 2018, coinciding with the late dry season. The mean monthly rainfall for March in the Provinces of Xayabouli and Savannakhet is 42 and 33mm respectively, increasing in April to 88 and 91 mm respectively (Climate-Data 2012*a*, 2012*b*).

Two villages from each of Xayabouli and Savannakhet provinces were randomly selected from a list of eight villages per province (Table 1) that had previous involvement in an Australian Centre for International Agricultural Development (ACIAR) funded livestock research project (ACIAR 2016) and then had participated in an Australian Department of Foreign Affairs (DFAT) Business Partnership Platform Project (BPP 2019). In each village, six households were recruited into the study following discussions among leaders at the Lao Department of Livestock and Fisheries (DLF), Provincial and District Agricultural and Forestry Offices (PAFO and DAFO) and village chiefs. For inclusion, households were required to be willing to participate in the trials, have at least 10 available ear-tagged cattle, were not feeding large ruminants forage, and have road access.

To further the scope of the study, cross-breed lactating cows at the National Agriculture and Forestry Institute (NAFRI), Vientiane, located in central Laos (Fig. 1), were

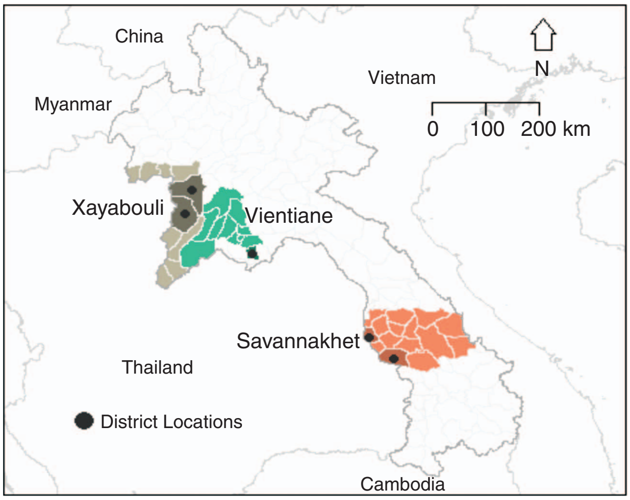

Fig. 1. Province and district locations of field trials conducted in Laos PDR, 2018.

also recruited into the study. Vientiane has late dry-season temperatures of a mean of 26–28°C and average monthly rainfall of 32–234 mm, although the mean monthly rainfall for March is 32 mm, increasing in April to 83 mm (Climate-Data 2012*c*).

Animal selection and experimental design for field trials

The number of cattle per farm type, allocated to each treatment, is presented (Table 1). For the purpose of the study, 'farm type' refers to smallholder or research farms. On smallholder farms, 3–5 cattle were selected per household to be monitored for the effects of the blocks. Cattle were proportionately randomly selected per production group, defined as young calves (0 to <8 months old), growing calves (8–24 months old) and lactating cows. The choice of 8 months for separation of young from growing calves was chosen as a period when natural weaning would be expected to be occurring, with the young calves still being variably dependent on access to milk.

To overcome the lack of fencing on smallholder farms and their participation in dry-season common grazing, entire households were randomly allocated to either UMB or NMB treatments. They were instructed to place blocks on elevated stands in sheltered animal houses for exclusive consumption by household animals from evening till morning when animals were corralled. Block administration and animal selection occurred on Day 1 of the trial. This was undertaken to minimise disruptions to farmers and to reduce travel to villages and associated logistical difficulties. Animals were selected with the aim of sampling at least 20 animals per production group, in line with sample sizes used in similar published studies (Avcioglu and Balkaya 2011; Duressa and Bersissa 2016; Lawania and Khadda 2017). At trial completion, blocks were weighed and the average daily block consumption was estimated.

On Day 1, information including ear-tag number, age and sex at trial commencement were collected. Animal age was estimated by dentition or provided by owners from recall. Blocks (20 kg) were distributed at a rate of one per 10 animals, equating to one block per household, with farmers being instructed to request new blocks when the provided blocks were nearing complete consumption (14–21 days per block). Cattle farms were revisited at 28, 56 and 84 days post-block provision throughout the 12-week trial. At each collection point (including Day 1), block and cattle weight were assessed with portable electronic weight scales, and BCS (1–5 scale), coat condition (normal, abnormal) and liveweight value (USD) were assessed and recorded.

All cattle on the smallholder farms were of the indigenous 'Yellow' breed, a small non-descript *Bos indicus* breed with a mature bodyweight of 146–215 kg (Young *et al*. 2014; Nampanya *et al*. 2014*a*). As the smallholder farmers in these villages had previously participated in large-ruminant trials, none of the farmers that were initially designated as not to receive blocks and form a negative control group, agreed to participate in the trial.

Animal selection and experimental design for research-station trial

On the research station, lactating cows ($n = 13$) were randomly selected from the herd and randomly assigned to either the UMB or MB treatments (Table 1). Animals were corralled separately per treatment group and exposed to normal management practices, with rice straw provided *ad libitum* and consumption was estimated by subtracting the weight of remaining rice straw from the amount placed on offer. Animals in both groups also received 500 g/day of locally sourced commercial feed concentrate and 2000 g/day of beer brewery by-product, although analyses of these supplements for their feed values were not available. Blocks were administered to trial cattle on Day 1, and animals were visited at Days 28, 56 and 84 following provision of blocks for the 12-week trial. At each collection point, including Day 1, the same measurements were taken as on smallholder farms, plus girth measurement and minus average block intake.

Both UMB and MB treatments were provided from Australia (4 Season Co. Pty Ltd, Brisbane, Queensland, Australia) with each block measuring 400 × 180 × 260 mm.

Table 1. Break-down of cattle allocated to treatments in urea–molasses block (UMB) and molasses block (MB) trials in Laos

n, cattle number per village; *N*, size of sample per farm type; NAFRI, National Agriculture and Forestry Research Institute; NMB, non-urea–molasses blocks; UMB, 8% urea–molasses blocks; SVK, Savannakhet Province; XYL, Xayabouli Province

Farm type	Province	Village	Treatment	*n*	*N*
Smallholder farms	SVK	Nonghai	MB	12	105
			UMB	17	105
		Xebang Hieng	MB	12	105
			UMB	18	105
	XYL	Namtoun	MB	9	105
			UMB	5	105
		Pakthang	MB	14	105
			UMB	18	105
NAFRI	–	–	MB	18	37
			UMB	19	37

Treatment administration, sampling and data collection were conducted by Lao staff advised by a project design developed in consultation with researchers from The University of Sydney and the leadership of the DLF. At the research farm, responsibility for trial compliance and management was delegated to NAFRI staff who received protocols from The University of Sydney and leaders from DLF.

Farmer responses to blocks and price

A subset of five farmers per village in the field trials ($n = 20$) participated in a survey comprising open-ended questions, occurring over the course of the study (available on request). They were asked questions on their attitudes towards using blocks, their observations of impacts of the blocks, and how much they would be willing to pay for them in the future. Survey questions were asked in Lao language by staff from PAFO and DAFO with experience in survey collection. Survey responses were subsequently translated to English by an experienced Lao researcher for interpretation.

Statistical analyses

Data storage and cleaning was undertaken in Microsoft Excel (2016) and analysis was performed using R statistical software (R Core Team 2015). Average animal age at trial enrolment, BCS, estimated liveweight value and block and rice-straw consumption were calculated per production group. Bar graphs were generated using the ggplot2 package in R (Wickham 2016) to display trends in animal weight over the course of the 84-day trials per production group and farm type. Animal weight and ADG were assessed for differences between treatment groups at each sample-collection day per trial type, using univariable linear mixed models (LMMs) in the asreml package in R (Butler *et al*. 2009). Codes for province, village and farm were included as random terms in univariable models for smallholder farms, while the NAFRI model did not contain random effects due to all animals being derived from the same location (Table 1).

Then, repeat-measures multivariable LMMs were fitted to data to identify explanatory variables associated with animal weight. Available explanatory variables per farm type are presented (Table 2). Ear-tag number was added as a random effect to all models to account for multiple observations being taken from the same animal over time. Prior to model fitting, variables were filtered to ensure they met model assumptions. Variables were also removed if >95% of variable responses were the same. Remaining variables underwent univariable analysis, whereby a cut-off P-value of 0.2 was used to determine inclusion into the candidate predictor set for multivariable modelling. Interactions were fitted between treatment and day in all models to assess treatment effect over time. Variables with $0.05 \leq P < 0.1$ were considered suggestive of significant associations, while variables and P-values under 0.05 were considered statistically significant. Model-based means were graphed for significant variables to visualise the rates of changes. For significant continuous variables, splines were fitted and retained if demonstrable improvements to probability plots were observed.

Results

Animal-group characteristics

Numbers of animals and average age at trial commencement by production groups are presented (Table 3). Animals on smallholder farms consisted of 35 young calves (~3 months

Table 2. Explanatory variables analysed for associations with animal weight collected on collection days in 84-day trials conducted on smallholder and research farms in Laos, 2018

MB, molasses block; NMB, non-urea–molasses block; UMB, urea–molasses block

Farm type	Explanatory variables
Smallholder	Day of the collection point, treatment group (MB/UMB), sex (male/female), age at trial commencement (months), body condition score (BCS) at each collection point (1–5 scale), Estimated animal value (US$) at each collection point, overall average daily block consumption.
Research	Day of the collection point, treatment group (NMB/UMB), sex (male/female), age at trial commencement (months), body condition score (BCS) at each collection point (1–5 scale), girth measurement (cm), coat condition (normal/abnormal)

Table 3. Breakdown of average cattle ages per production group on smallholder and research farms trialing the effect of feeding multi-nutrient blocks in Laos, 2018

n, number of animals sampled; μ, sample mean, s.d.; standard deviation

Trial	*n*	Age (μ ± s.d.)	Age or age range (months)	Breed
Smallholder				
Young calves	35	3.3 ± 2.1	1–8	Native Yellow cattle
Growing calves	24	12.4 ± 2.5	10–24	Native Yellow cattle
Lactating cows	46	54.3 ± 17.4	36–120	Native Yellow cattle
Research				
Lactating cows	13	36 ± 0	36	Brahman × Native yellow cattle

old), 24 growing calves (~12 months old) and 46 lactating cows (~4.5 years old). Of the 35 young calves, 23 were female and 12 were male. Of the 24 growing calves, 17 were female and 12 were male. At the NAFRI research farm, 13 Brahman × Native yellow lactating cows ~3–5 years old were recruited into the study.

Weight and ADGs

Liveweight increased consistently over the course of the 84-day trials in both treatment groups (Fig. 2). On smallholder farms, cattle accessing UMBs were heavier than cattle accessing MBs at every collection day of the trial. In young calves, the differences were considered statistically significant ($P < 0.05$; Table 4). On the research farm, cross-breed lactating cows accessing MBs were 3–8-kg heavier than were cows accessing UMBs at each collection point, although these differences were not considered statistically significant (Fig. 2). Average BCS of lactating cows remained constant for the duration of the trial in the UMB group at 2.3 and in the MB group at 2.7–2.9. In lactating cows, mean girth trended upward and ranged from 144.7 to 153.8 cm in the UMB group and from 146.6 to 148.9 cm in the MB group over the course of the trial.

On smallholder farms, ADGs were higher in cattle accessing UMBs than in those accessing MBs, although the differences were not considered significant in young calves ($P = 0.562$), growing calves ($P = 0.509$) or lactating cows ($P = 0.993$; Fig. 3). Young calves had the highest ADGs at 251–265 g, followed by growing calves at 198–237 g and lactating cows at 187–190 g. On the research farm, ADGs were not significantly different between cross-breed cows accessing UMBs at 229 g and those accessing MBs at 236 g ($P = 0.933$).

Estimated liveweight value

Estimated liveweight value was available on smallholder farms and trended upward over the course of the trials for all production groups (Table 4). Young calves accessing UMBs had weight increases of a mean of 30.6 kg compared with 23.1 kg in calves accessing MBs over the 84-day trial. This was reflected in an increased estimated value in young calves accessing UMBs that was US$13.50 greater than in young calves accessing MBs. Growing calves accessing MBs had a weight gain increase of 21.1% compared with 17.6% for those accessing UMBs. This was reflected in an increased estimated value in growing calves accessing MBs of US$31.70

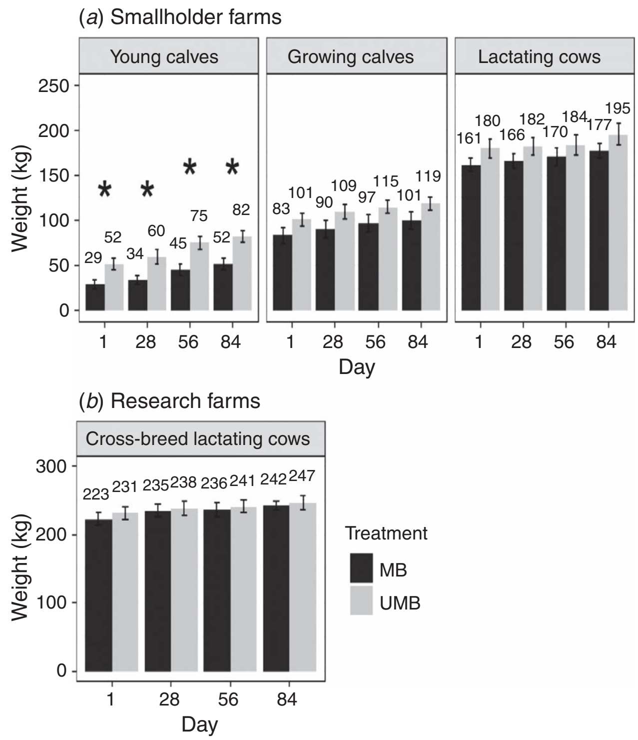

Fig. 2. Weight gain of cattle receiving urea–molasses blocks (UMB) or non-urea–molasses blocks (MB) for 84 days on smallholder and research farms in Laos, 2018 (*$P < 0.05$).

Table 4. Average estimated liveweight value (US$) of cattle with access to urea–molasses blocks (UMBs) or non-urea–molasses blocks (MBs) on smallholder farms in Laos, 2018

Day	Variable	NMB	UMB
	Young calves (n = 35)		
1	Mean (US$)	98.3	127.5
84	Mean (US$)	107.3	150
	Price change (US$, % change)	+9 (9.2)	+22.5 (17.6)
	Weight change (kg, % change)	+23.1 (80.2)	+30.6 (59.0)
	Growing calves (n = 25)		
1	Mean (US$)	180	208
84	Mean (US$)	217.2	213.5
	Price change (US$, % change)	+37.2 (20.7)	+5.5 (2.6)
	Weight change (kg, % change)	+17.5 (21.1)	+17.8 (17.6)
	Lactating cows (n = 46)		
1	Mean (US$)	520.5	563.5
84	Mean (US$)	525.6	576.3
	Price change (US$, % change)	+5.1 (1.0)	+12.8 (2.3)
	Weight change (kg, % change)	+15.7 (9.7)	+15.6 (8.7)

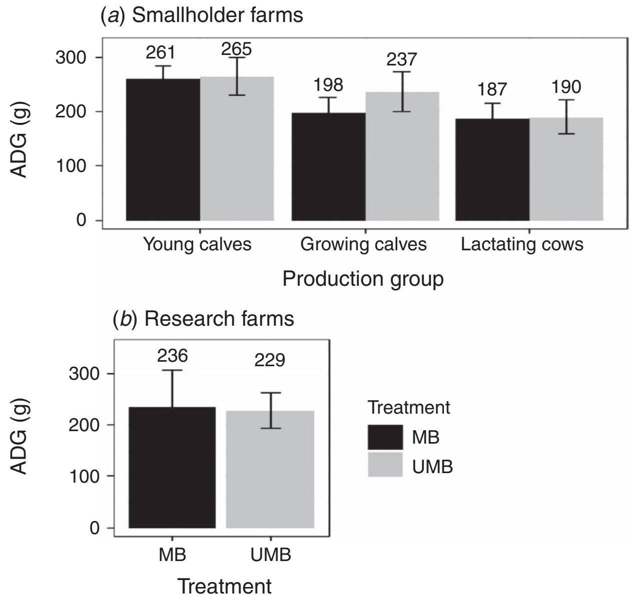

Fig. 3. Average daily gain (ADG) of cattle receiving urea–molasses blocks (UMB) or non-urea–molasses blocks (MB) for 84 days on smallholder and research farms in Laos, 2018 (*$P < 0.05$).

greater in value than for growing calves accessing UMBs. Lactating cows with access to UMBs made gains in liveweight value that were US$7.70 greater than those for lactating cows with access to MBs, despite cows in both groups having similar weight-gain increases (8.7% and 9.7% respectively).

Block and feed consumption

Consumption of MB was greater than UMB for all production groups (Table 5). On smallholder farms, all production groups consumed 116–117 g/day.animal of UMB. Consumption of MB varied but was still in a small range of 139–145 g/day. animal across the production groups.

Average rice-straw consumption was estimated on the research farm. In lactating cows, consumption of rice straw varied between treatment groups, with means of 4.92 ± 0.59 in cows accessing MBs and 10.66 ± 0.22 in cows accessing UMBs.

Repeat-measures multivariable LMMs

Effects of significant variables on predicted weight from final repeat-measures LMMs for smallholder farms are presented (Fig. 4).

For young calves, weight increased with increasing days of the trial ($P < 0.001$), calf age at enrolment ($P < 0.001$) and the UMB treatment ($P = 0.007$). Young calves had a predicted ADG of 270 g and were 7.9 kg heavier with each additional month of age at trial commencement. Independent of time, calves accessing UMBs had a predicted mean weight 22.3 kg heavier than did calves accessing NMBs (Fig. 4*a*).

Increase in growing calf weight on smallholder farms was associated with an increased estimated liveweight value ($P < 0.001$) and the interaction between treatment and day ($P = 0.003$; Fig. 4*b*). Each additional US dollar of liveweight value was associated with a 160 g increase in weight, with calves receiving UMBs having ADGs 237 g higher than calves receiving MBs at 140 g.

Table 5. Estimated block consumption (g/day.animal) of cattle given access to urea–molasses blocks (UMB) and non-urea–molasses block (MB) for 84 days on smallholder farms in Laos, 2018

Production group	MB	UMB
Young calves (*n* = 35)	138.5 ± 16.5	116.1 ± 32.1
Growing calves (*n* = 25)	144.8 ± 18.1	116.0 ± 30.9
Lactating cows (*n* = 46)	139.2 ± 14.9	116.6 ± 29.2

Increasing lactating-cow weight on smallholder farms was associated with increasing trial days ($P < 0.001$) and increasing estimated liveweight value ($P < 0.001$; Fig. 4*c*). Each additional day of the trial and each additional US dollar of estimated value were associated with 160-g and 130-g increases in weight respectively. There was no significant effect of treatment, which had a P-value of 0.298, in the univariable repeat-measures LMM.

Effects of significant variables on predicted weight from final repeat-measures LMMs for the NAFRI research farm are presented (Fig. 5). For lactating cows, trial day was the only significant predictor of weight ($P < 0.001$) where weight increased over the course of the trial at a predicted ADG of 200 g. Treatment was not included in multivariable modelling as it had a P-value of 0.690 in univariable analysis.

Farmer responses to blocks and price

During the survey, all farmers reported that they would be interested in purchasing the blocks, with farmers receiving MBs reporting a willingness to pay US$6.5 ± 2.3 (mean ± standard deviation) per block, whereas farmers receiving UMBs reported a willingness to pay a mean of US$5.9 ± 1.5 per block. All farmers reported that the benefits of the blocks were that they contributed greatly to herd management as animals were calmer and easier to muster, plus improved the condition and coat of the animals, increasing sale-ability.

Discussion

On smallholder farms, throughout the 12-week trials, animals accessing UMBs were heavier than those accessing MBs, with ADGs increasing in all three cohorts and higher in animals accessing UMB than in those accessing MBs. Young calves had the highest ADG (261–265 g) presumably due to their access to milk and the importance of protein in growth, followed by growing calves (198–237 g), then lactating cows (187–190 g) carrying the energy-draining burden of lactation. These data compare very favourably with longitudinal base-line data from Laos that established that in grazing large ruminants through the dry season, ADGs were either in decline (–40 g to 9 g in January) or rising only modestly in the late dry season in cattle (–9 g to 71 g in March) in cattle (Nampanya *et al*. 2014*a*). The dry-season ADGs achieved in these trials with UMBs and MBs were similar to those in the early wet season (208–212 g) and considerably

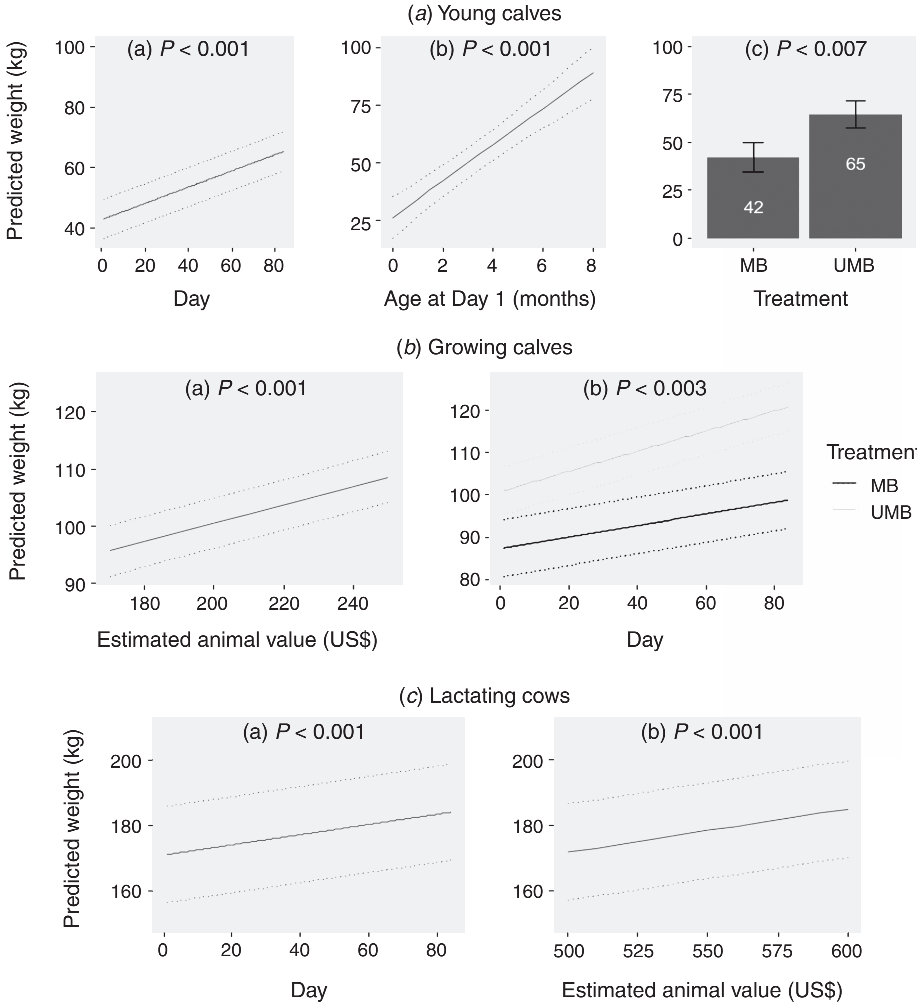

Fig. 4. Predicted cattle weight associated with variables in final multivariable repeat-measures linear mixed models for (*a*) young calves, (*b*) growing calves and (*c*) lactating cows from smallholder farms involved in an 84-day trial in 2018, Lao PDR.

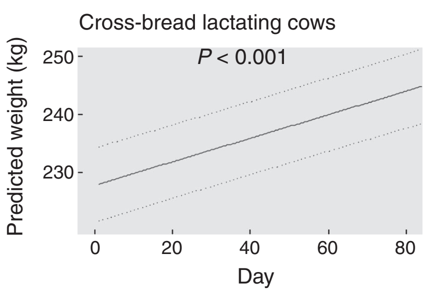

Fig. 5. Predicted cattle weight associated with variables in final multivariable repeat-measures linear mixed models for lactating cows from the National Agriculture and Forestry Research Institute research farm involved in an 84-day trial in 2018, Lao PDR.

superior to those in the late wet season (102–122 g) in cattle in Laos (Nampanya *et al*. 2014*a*). The ADG data in these field trials were also similar to those achieved in non-dry-season trials with triclabendazole-medicated molasses blocks (TBMs; 201 g), fenbendazole-medicated molasses blocks (FBMs; 200 g) and MBs (230 g), exceeding that of unsupplemented animals (94 g; 170 g) respectively (Windsor *et al*. 2019; Olmo *et al*. 2020).

Average daily block consumption of MB per animal exceeded that of UMB per animal (139–145 g versus 116–117 g), although this may reflect the fact that UMBs are designed to include vegetable oil content that will limit intake and prevent risk of urea toxicity, and that these blocks may be less palatable than are MBs. This is an observation previously considered, with superior ADGs being determined in cattle accessing MBs compared with FMBs (Olmo *et al*. 2020). Consumption of both the UMB and MB was also less than that described in the literature, with intakes exceeding 200 g/day having commonly been reported (FAO 2007). However, this was expected and presumably reflects the small stature and mature bodyweights (146–21 5kg) and, thus, lower metabolisable-energy requirements and intakes of Lao indigenous cattle, compared with most other breeds and cross-breed cattle (Young *et al*. 2014; Nampanya *et al*. 2014*a*).

On the research station, the cross-breed cows accessing MBs had higher ADGs (236 g/day) than did cows accessing UMBs (229 g/day), presumably reflecting the proposed higher palatability of the MBs and that the UMB group consumed more rice straw of a low nutritional value. As expected, the ADGs of these cross-breed lactating cows exceeded those of the native adult cattle in these field trials (187–190 g) and the baseline data (40 g) from free-grazing systems (Nampanya *et al*. 2014*a*), which is likely to reflect a combination of genetics by environmental interaction differences between these trials, particularly the nutritional and management interventions.

An interesting finding was that in surveys of farmers using blocks, the farmers wished to purchase the blocks and were willing to pay a mean of ~US$6.50 for MBs but only ~US$5.90 for UMBs. Although all farmers confirmed that their animals were calmer and healthier, and had better coat condition and minimal external parasites with both blocks, there was an apparent preference for MBs. This preference has been reflected in subsequent high sales of blocks to these and other farmers in 2020.

There are many challenges in managing field and research trials in developing countries. Of importance was the reluctance of participating farmers in these villages to include submitting unsupplemented animals for a negative control group. The research leadership was left with the decision to either cancel the trial or proceed in the expectations that findings would still be an important guide to the potential of including urea in the block manufacturing process. Further, it was considered likely that the findings would still be valid when interpreted in the context of the considerable data previously collected on baseline growth rates and ADGs when animals were provided with access to MBs, TMBs and FBMs. However, these challenges delayed the commencement of the trials until the late dry season, when rainfall was increasing, providing access to 'green pick' that would be expected to decrease the impact of supplying nitrogen from urea to the production system.

A further complication was the almost universal lack of recording of herd information and an established system of animal identification. This required researchers to rely on information provided by largely illiterate farmers, potentially preventing accurate selection of age cohorts and requiring dependence on clinical examination and farmer recall. Despite the numerous logistical difficulties, with inclusion of the most motivated farmers and ear-tagging of participating animals, the trials managed to achieve adequate screening of animals and ensure that age cohorts were robust, with treatment groups being of a comparable mean age. An aspect of 'random allocation' in field studies conducted in developing countries is the usual practice of selecting animals for treatment groups before collection of weights, a practice intended to prevent group allocation bias. Allocation was particularly challenging in the present trial as the design required that animals were first allocated to an age cohort, with numbers being restricted, before collection of weights at trial commencement. It is also of note that in cattle-productivity studies in Laos, animal values are determined by visual assessment of an estimated meat yield, rather than weight or BCS. This usually occurs when farmers need to sell animals due to shortages of household funds, ensuring that cattle farmers continue to be 'price takers' (Nampanya *et al*. 2015). Improvements in smallholder cattle marketing have previously been identified as a requirement for improving livestock productivity in developing countries (Nampanya *et al*. 2014*a*, 2017; Young *et al*. 2014).

This research concludes that the addition of high-quality MB supplementation is a practical and efficacious livestock management strategy in Laos and, potentially, other developing countries, capable of significantly improving tropical smallholder livestock production efficiency, in the order of 2.5–5 times in ADG over baseline data. In certain circumstances, the addition of urea to the blocks offers the potential for even greater gains, although participants in these trials conducted in the late dry season when monthly rainfall had commenced to increase, demonstrated their preference for blocks that did not contain urea. This presents a potentially important additional project entry-point intervention for livestock development. They appear to motivate farmers to improve their cattle and buffalo production efficiency, addressing the extended lag period when forage plantations are being established. This is particularly important in dry seasons when nutrition is often severely limited, and in developing countries, where lack of cattle-handling equipment means that administration of medication is difficult.

A livestock development strategy that includes a combination of (1) establishing forage plantations and feeding, (2) multiple health interventions with vaccination, biosecurity and parasite management, and (3) use of high-quality MBs to improve rumen function, appears capable of delivering superior production efficiency for smallholder large-ruminant production in developing countries. Adoption of this multi-intervention strategy, will likely be precipitated by use of high-quality MBs for more rapid impact in improving production efficiency in low-input low-output developing-country settings, potentially reducing GHG emission intensity from their cattle production. If applied efficiently, this multi-intervention strategy will likely create both major socioeconomic benefits that improve resilience in some of the poorest of rural communities, and enable the global livestock sector to reduce GHG emissions by as much as 30% (FAO 2018), diminishing the risks of the impending climate-change catastrophe. The 'scale-out' of this strategy is proposed.

Conflicts of interest

The authors declare no conflicts of interest.

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