Research Article

Effects of Equaling either Concentrate and Nutrient Intake on Milk Production of Dairy Buffaloes: A Meta-Analysis

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Abstract | This study presents a meta-analysis of 20 independent studies to investigate the relationship between forage to concentrate (FC) ratio, nutrient constituent, and nutrient intake on milk production and milk component in dairy buffalo. A dataset comprised of 89 comparisons from multi-species of buffaloes were analyzed according to a linear mixed model methodology with explanatory variables declared as fixed effects and individual study as random effects. The results showed a negative curvilinear pattern of milk yield across buffaloes' breeds in response to the increasing FC ratio ($P<0.05$; $R^2 = 0.828$) and strong linear increased in response to the increasing DMI ($P<0.01$; $R^2 = 0.841$). The interaction effect was found between breed of buffaloes and NDF content of the diets ($P = 0.028$) and between breeds with FC ratio ($P = 0.016$) whereas increasing NDF content linearly decreased milk fat of Murrah buffalo ($P<0.05$; R2 = 0.90) but did not affect other species. A decreasing trend was also noticed on the milk protein content of Murrah buffalo in association with increasing FC ratio ($P<0.05$; $R^2 = 0.76$). In addition, increasing NFC content in the diets also contributed to decrease milk protein content across the breed of buffaloes but without a strong correlation ($P<0.05$; $R^2 = 0.149$). For milk lactose content, CP intake was the only factor explaining the decreased trend when the level increased ($P<0.05$). To conclude, DMI and FC ratio are two predictor variables with the greatest effect on milk yield of inter-species lactating dairy buffaloes, noticeably an importance role of concentrate supplementation for buffaloes to increase milk production. Milk fat and milk protein contents were influenced by NDF content of the diets, dependently varied among species.

Keywords | Buffalo, Concentrate, Dairy, Forage, Milk

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INTRODUCTION

Milk is one of major source of dietary energy, protein and fat for human, contributing on average 134 kcal of energy/person/day, 8 g of protein/person/day and 7.3 g of fat/person/day in 2009 (FAO, 2013). In East, Southeast Asia, and South Asia, milk consumption is increasing faster than meat consumption (FAO, 2013). Although the population as well as production yield are far below than the dairy cows, buffaloes are the second largest milk producers in the world (IDF, 2009) and are considered as an important commodity in many developing countries. They also serve as draft power in traditional farming that are essential part of livestock bioeconomy. Buffaloes are favored due to the efficient utilization of low-quality, high-roughage diet (Larsson, 2009), have good resistance to parasites, quick and easy calf growth, as well as good quality and rich milk (El-Salam and El-Shibiny, 2011). In addition, their milk has been recorded to be higher in level of fat, lactose, protein, casein, minerals, energy, vitamins A and C as compared to the milk from dairy cow, goat, and sheep (Bittante et al., 2022).

Reflecting on feeding management system in most extensive rearing system, insufficient energy supply is the first limiting factor that diminish productivity and nutrient use efficiency in buffaloes. It is because in tropical regions, high fibrous forages low in soluble carbohydrate and protein are becoming the main source of diet for buffaloes which limiting the production potential. Therefore, improving production efficiency as a means to increase milk production by nutritional approach has been the key objective to enhance performance of lactating dairy buffaloes. In recent decades, supplementary energy and protein to diets have been proposed as an efficient approach to strategically overcome the nutritional constraints. For this purpose, concentrate supplementation is often used as traditional approach, yet relevant strategy to provide more soluble energy and/or protein for buffaloes.

Increasing body of research suggested that improving dietary energy and protein through balancing concentrate to forage ratio could enhance milk production and production efficiency in ruminant livestock, as evidenced by previous meta-analyses in sheep and dairy cows . In buffaloes, however, discrepancies have been observed where increasing dietary metabolizable energy and protein in several studies have reported little to none effect on nutrient use efficiency and production performance of buffaloes . Meanwhile, other experiment demonstrated that optimizing fiber and protein balance could improve milk production of buffaloes . The evidence suggested that, in buffaloes, there may some associative effects either negative or positive among nutritional component and dietary composition. This is because different buffalo breeds have different genotypes, physiological needs, as well as function and production. Some buffaloes have dual-purpose use (draught and meat) while others have triple-purpose use (draught, meat and milk) . Various studies have demonstrated that supplementary high protein and energy sources to the diet of buffaloes have a positive effect on the quantitative production of the milk. However, existing discrepancies among studies need to be systematically quantified using robust model, i.e., meta-analysis approach. Meta-analysis well-known as the quantitative method to critically evaluate the importance of relatively study (Adli et al., 2022). It is imperative to further investigate the effect of dietary composition and possible interactive effects with nutrient composition on production performance of lactating buffaloes. Therefore, this study presents a meta-analysis using previously published articles to analyze the influence of forage to concentrate ratio as well as nutrient factors on production of dairy buffaloes.

MATERIALS AND METHODS

Literature search and selection criteria

This study used empirical experiments publicly available on reputable publishers and/or academic journals. A literature search was conducted using online scientific platforms of Google Scholar, Science Direct, Scopus, Web of Science, and PubMed interface to search for studies of the milk production in dairy buffaloes with varying diets. A combination of keywords was used for systematic search of the literatures: 'dairy', 'buffalo', 'milk production', 'concentrate', "energy supplementation', and 'protein supplementation'.
Hierarchical evaluation was performed to select targeted articles and to minimize biases using a Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) as a systematic and reproducible method. Initially, non-research article outputs were excluded from each platform and the research articles outputs were further evaluated in an excel spreadsheet. All titles obtained from each single running search were combined and screened according to evaluation criteria determined a priori. The inclusion criteria were: (a) peer-reviewed article published in English; (b) article which reported milk production performance; (c) contained information on dietary supplementation and used control and treatment groups; (d) reported a clear and reproducible methodology including number or replicate, dietary composition, and experimental design. Studies published in a non-reputable journal, without control group, and intended to test any additive were not included.

A flowchart explaining the process of study selection based on PRISMA protocol is provided in Figure 1. Briefly, a total of 1,445 peer-reviewed research articles were identified based on the title of the papers. According to the criteria, 1,381 articles were excluded, and 64 articles were selected. After carefully reviewing the full texts, contents and variables, we also excluded a further 44 studies for the following reasons: (i) the variable did not meet the minimum criteria needed to run the meta-analysis, (ii) incomplete information on the parameters studied, (iii) did not involve the target animal species which is buffalos and other species such as cows, (v) repeatedly published articles on different online platforms and (vi) not published in a peer-reviewed journal. Finally, 20 studies with 89 comparisons were integrated in the database and used for the meta-analysis.

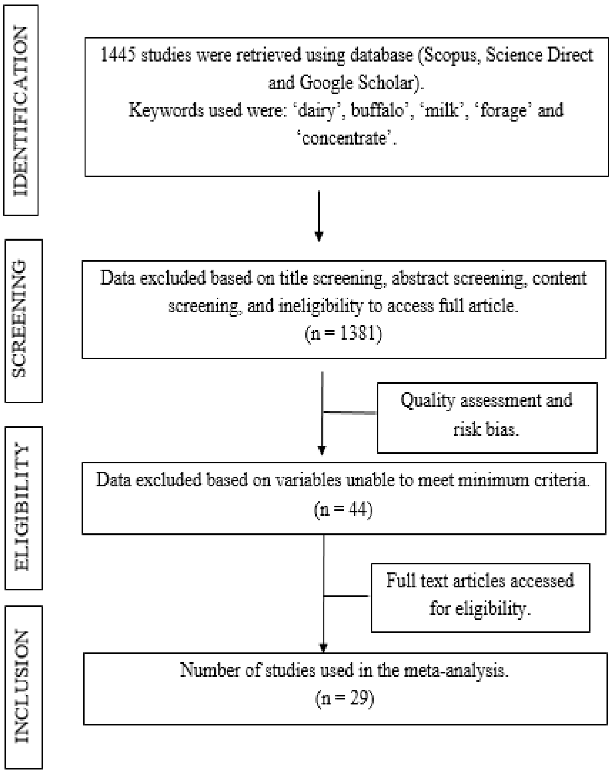

Figure 1: Flowchart explaining process of study selection based on PRISMA protocol.

Dataset development

Information on authors, buffaloes' breed, treatment used, design, number of replication and number of animals per replicate, study period, and parity were inputted as a basic information. In addition, percentages of concentrate and forages (DM basis) used in the study, supplement given, nutrient composition of feed, and nutrient intake, were carefully reviewed and inputted in the dataset and were used to determine possible predictor variables. For this purpose, calculation was performed to obtain forage to concentrate ratio and specific nutrient intakes. Response variables included in the dataset were milk yield, milk fat, milk protein, milk total solid (TS), milk ash, milk solid non-fat (SNF) and milk lactose. Milk yield was recorded in kg/d while the rest were recorded/converted into percentages (%), as the same unit of measurement will allow calculations and analyses.

Statistical analysis

The meta-analysis was performed using PROC MIXED of SAS (v9.4), considering the forage to concentrate ratio and nutrient constituents as the fixed effects and different studies as random effects according to Forage to concentrate ratio, dietary crude protein (CP), ether extract (EE), neutral detergent fiber (NDF), acid detergent fiber (ADF), non-fibrous carbohydrates (NFC), dry matter intake (DMI), CP intake (CPI), and NDF intake (NDFI) were considered as continuous variables. Individual effect and interaction among those variables were also assessed in the models. In addition, parity, breed, and study period were included as covariates as they were possible to influence the results. When non-significance, these covariates were removed from the model. Akaike information criterion (AIC) was used as a fit of statistical goodness when selecting the models. Unstructured variance–covariance matrix (type = UN) statement was declared in the random part of the model to avoid a positive correlation between intercepts and slopes. Number of animals used in each study was declared as weighting factor stated in the model. Adjusted predicted value of the response variables was estimated by adding the predicted values with corresponding residual values.

RESULTS

Description of the database included in the meta-analysis

In this present meta-analysis, 89 data with varying forage to concentrate ratio from 20 studies were compared involving a total of 687 buffaloes, which is summarized in Table 1. Six breeds of buffaloes including Mediterranean, River buffalo, Murrah, Egyptian, Nilli-ravi, and Bangladesh indigenous sp. were involved with Murrah buffalo is the most predominant breed used which is representing 43.4% (14/29). 89.6% of the studies used multiparous buffaloes and more than 80% of studies were long run performed (>50 d). These data indicated that the studies are quite homogenous except for species variability that could potentially be a strong covariate. According to Table 2, most studies reported milk yield data with the average milk production 8.16±2.07 kg/d, milk fat of 7.46±0.183, milk protein 4.13±0.32, and milk lactose 4.91±0.47, respectively. The sample size for each study is sufficient to develop the robust model (>30 sample size for each variable). These values are considered acceptable according to various references regarding the milk production and milk composition of dairy buffaloes.

Table 1: Studies included in the meta-analysis.

No	Study	Year	Animal (n)	Breeds	Parity	Period (d)	Forage (%)	Concentrate (%)
1	Bovera et al	2002	24	mediterranean	multiparous	57	61.7	38.3
2	Bartocci et al	2005	14	mediterranean	multiparous	114	48	52
3	Faruque and Hoosain	2007	12	river buffalo	multiparous	365	100	0
4	Gaafar et al.	2009	16	murrah	multiparous	28	40	60
5	Chandra et al.	2010	18	murrah	multiparous	90	60	40
6	Bartocci and Terramoccia	2010	16	mediterranean	multiparous	114	53	47
7	Kholif et al	2011	21	egyptian	multiparaous	180	70	30
8	Shelke and Thakur	2011	36	murrah	multiparous	150	80	20
9	Srinivas et al.	2013	12	murrah	multiparous	.	80	20
10	Mahmoud and Ebeid	2014	12	egyptian	multiparaous	90	50	50
11	Sakai	2015	12	murrah	multiparous	63	10	90
12	Kanakkahewage et al	2016	16	murrah	multiparaous	30	100	0
13	Fahmy et al.	2016	6	egyptian	multiparous	60	90	10
14	Santillo et al.	2016	48	mediterranean	multiparous	49	63.89	36.11
15	Ojha et al.	2017	28	murrah	multiparous	120	90	10
16	Mahesh	2017	18	murrah	multiparous	120	68	32
17	Mustafa	2017	15	murrah	multiparous	120	20	80
18	Kumar et al	2018	12	murrah	multiparous	21	80	20
19	Anjum et al.	2018	16	nilli-ravi	multiparous	60	70	30
20	Naveed ul Haque	2018	12	nilli-ravi	multiparous	63	42	58
21	Arif et al	2018	32	nilli-ravi	multiparous	60	60	40
22	Saleem et al	2018	72	egyptian	mixed	60	65	35
23	Katiyar et al	2019	40	murrah	multiparous	120	31	33
24	Anil et al.	2019	72	murrah	multiparous	70	75	25
25	Eldahshan et al.,	2020	18	egyptian	multiparaous	60	70	30
26	Habib et al.	2020	6	Bangladesh indigenous sp	multiparous	110	85	15
27	Saadullah	2020	28	nilli-ravi	primiparous	831	95	5
28	Delfino et al.	2021	30	murrah	primiparous	63	80	20
29	Lima et al.	2021	25	murrah	multiparous	11	100	0

Table 2: Descriptive statistics of the database used in the meta-analysis

Response variables	Unit	n	Mean	SD	Min	Max
Nutrient Composition						
OM	g/kg DM	48	896	17.9	857	925
CP	g/kg DM	77	162	35.9	107	226
EE	g/kg DM	66	40.7	19.1	15.0	106
NDF	g/kg DM	61	393	133	201	911
ADF	g/kg DM	50	260	101	131	664
ADL	g/kg DM	10	38.6	9.28	27.0	57.6
NFC	g/kg DM	21	330	81.6	153	533
ME	Mcal/kg DM	15	5.89	9.23	1.75	35.5
Nutrient Intake						
DMI	kg/d	51	14.6	2.55	9.96	19.2

NDF	kg/d	40	6.15	0.680	5.19	7.34
CP	kg/d	50	1.81	0.600	0.762	3.09
Productive Performance						
Milk Yield	kg/d	77	8.16	2.07	2.65	11.9
Feed efficiency	Kg/kg	51	0.640	0.183	0.250	0.980
Milk Fat	%	73	7.46	1.01	5.80	9.80
Milk Protein	%	74	4.13	0.320	3.41	4.71
Milk Total Solid	%	48	17.2	1.23	14.7	19.5
Milk Ash	%	24	0.860	0.150	0.670	1.22
Milk Solid Non-Fat	%	44	9.53	0.590	7.60	10.9
Milk Lactose	%	51	4.91	0.470	4.17	6.00

Table 3: Model equations of the effects of nutrient intake, forage to concentrate ratio, and nutrient components on milk composition

Response variable	Predictor	n	Model	Parameter estimates				Model statistics				
				Intercept	$SE_{intercept}$	Slope	SE_{slope}	RMSE	AIC	$adjR^2$	Slope[1]	Slope vs breed[2]
Milk yield, kg/d	CP	72	L	8.18	0.979	0.0470	0.148	2.24	186	0.0370	0.750	0.523
	EE	63	L	8.50	0.808	0.0890	0.279	2.32	239	0.0150	0.708	0.600
	NDF	58	L	8.82	2.19	-0.0240	0.036	2.35	64.4	0.232	0.138	0.893
	NFC	21	L	5.42	1.66	0.195	0.100	1.24	70.4	0.0430	0.374	0.713
	FC ratio	77	L	9.97	0.575	-0.530	0.166	2.03	192	0.814	0.0040	0.119
			Q			0.0180	0.0080		187	0.828	0.0370	
	DMI	51	L	1.79	2.26	0.572	0.191	2.41	266	0.841	0.0060	0.234
			Q			-0.0850	0.0320		275	0.829	0.0130	
	CP intake	29	L	4.57	2.89	1.74	3.12	1.66	97.6	0.673	0.585	0.711
	NDF intake	18	L	6.62	4.31	0.93	1.31	1.79	70.5	0.304	0.495	0.830
Feed efficiency	CP	50	L	0.660	0.0730	-0.0120	0.0110	0.186	-47.9	0.0170	0.302	0.202
	EE	44	L	0.630	0.0760	-0.0160	0.0250	0.015	-48.5	0.0240	0.513	0.787
	NDF	20	L	0.750	0.0800	-0.0010	0.0030	0.177	-14.6	0.141	0.362	0.752
	NFC	16	L	0.940	0.168	-0.0090	0.0100	0.176	5.90	0.0650	0.166	0.747
	FC ratio	50	L	0.720	0.0540	-0.0120	0.0470	0.179	-58.5	0.0530	0.107	0.282
	DMI	51	L	0.680	0.175	0.0030	0.0150	0.178	-38.9	0.0550	0.772	0.548
	CP intake	50	L	0.640	0.0680	0.0350	0.0520	0.185	-52.0	0.0090	0.546	0.461
	NDF intake	40	L	0.740	0.0810	-0.0040	0.0200	0.179	-29.6	0.0180	0.421	0.831

n = sample size; SE=standard error; RMSE= Root mean square error, AIC= Akaike information criterion; L = linear term; Q = quadratic term; [1)] p-value of the predictor variable; [2)] p-value of the interaction between predictor variables and breed of buffaloes

Effects of nutrient intakes and nutrient components on milk yield and efficiency

Table 3 reports regression models of dietary constituents on milk yield and feed efficiency. To develop the model, all possible moderating variables were initially included such as breed, parity, country of origin, and period of the experiment. Among them, breed was the only covariates that resulted in some interaction with nutrient intake and constituents. Thus, interaction effect between breed and predictor variables were retained in the model.

FC ratio and DMI were the only variables influenced milk yield of buffaloes, each with different pattern. Milk yield showed a negative curvilinear pattern in response to the increasing FC ratio ($P<0.05$; R^2 = 0.828; Figure 2) and strong linear increased in response to the increasing DMI

Table 4: Linear regression model of the effects of nutrient intake, forage to concentrate ratio, and nutrient components on milk composition

Response variable	Predictor	n	Parameter estimates				Model statistics				
			Intercept	SE $_{intercept}$	Slope	SE $_{slope}$	RM SE	AIC	adj R^2	Slope[1]	Slope vs breed[2]
Milk fat %	CP	70	7.34	0.489	-0.0220	0.0750	1.19	174	0.163	0.765	0.0760
	EE	61	7.07	0.384	0.0510	0.130	1.14	145	0.175	0.696	0.0840
	NDF	56	7.19	0.381	-0.0340	0.0400	1.15	142	0.161	0.399	0.0280
	NFC	21	8.43	1.17	-0.0660	0.0690	0.760	57.4	0.133	0.354	0.666
	FC ratio	70	6.94	0.258	0.0280	0.201	1.12	160.0	0.184	0.919	0.0160
	DMI	49	6.89	2.77	0.0590	0.391	0.814	100.0	0.216	0.881	0.186
	CP intake	26	8.59	1.53	-1.86	1.540	1.002	49.2	0.231	0.247	0.301
	NDF intake	18	2.40	1.69	1.40	0.491	0.889	38.5	0.248	0.0170	0.105
Milk protein %	CP	69	4.07	0.326	0.0160	0.0460	0.763	118	0.0770	0.725	0.152
	EE	58	3.76	0.174	0.106	0.0570	0.455	48.9	0.138	0.0730	0.801
	NDF	53	4.19	0.439	-0.0020	0.0180	0.437	48.5	0.110	0.901	0.0360
	NFC	21	4.89	0.344	-0.0460	0.0190	0.280	13.7	0.147	0.0390	0.654
	FC ratio	71	4.46	0.298	-0.107	0.135	0.722	72.7	0.139	0.0080	0.0020
	DMI	46	3.70	1.45	0.0110	0.204	0.322	36.9	0.272	0.957	0.146
	CP intake	24	4.77	0.793	-0.696	0.774	0.348	2.50	0.153	0.384	0.339
	NDF intake	18	4.25	0.773	-0.0460	0.224	0.391	14.7	0.0930	0.842	0.535
Milk Lactose %	CP	48	5.01	0.433	0.0450	0.0560	1.13	103	0.0140	0.425	0.895
	EE	46	4.88	0.399	0.0780	0.115	1.15	83.4	0.0100	0.502	0.348
	NDF	36	5.08	1.08	0.0130	0.0420	1.28	93.0	0.0010	0.768	0.757
	NFC	19	5.66	0.392	-0.0370	0.0190	0.475	17.5	0.0090	0.0780	0.472
	FC ratio	50	5.75	0.468	-0.298	0.204	1.070	96.7	0.0210	0.155	0.912
	DMI	36	7.83	4.93	-0.284	0.668	1.275	85.9	0.141	0.675	0.898
	CP intake	14	7.88	2.95	-3.30	3.683	0.396	1.90	0.524	0.0320	0.118
	NDF intake	8	38.0	1.36	-7.65	2.973	0.0620	8.40	0.153	0.155	0.945
Milk Total solid %	CP	44	15.9	1.40	0.024	0.220	2.53	188	0.0160	0.708	0.981
	EE	38	15.2	1.12	0.202	0.371	2.67	161	0.590	0.548	0.519
	NDF	38	16.6	2.99	-0.0280	2.99	2.66	174	0.821	0.736	0.932
	NFC	12	6.72	2.99	0.508	1.63	3.39	65.1	0.765	0.881	0.0450
	FC ratio	47	17.01	1.25	-0.503	0.603	2.39	192	0.411	0.755	0.957
	DMI	34	11.0	8.28	0.806	1.203	2.23	139	0.510	0.698	0.728
	CP intake	17	14.6	9.60	1.48	12.6	3.14	67.7	0.909	0.717	0.0840
	NDF intake	9	22.0	1.70	-2.62	8.87	3.25	35.2	0.783	0.992	0.806
Milk ash %	CP	24	0.890	0.0680	-0.0080	0.0090	0.27	-29.8	0.155	0.0940	0.702
	EE	24	0.880	0.0640	-0.0160	0.0130	0.24	-35.8	0.153	0.121	0.221
	NDF	18	1.04	0.167	-0.0070	0.0070	0.32	-6.9	0.164	0.119	0.283
	NFC	9	3.63	0.506	-0.130	0.0230	0.0050	3.00	0.192	0.0140	.
	FC ratio	24	0.870	0.0760	-0.0210	0.0260	0.439	-39.0	0.156	0.048	0.926
	DMI	16	0.650	0.823	0.0370	0.121	0.768	-11.4	0.178	0.201	0.0200
	CP intake	3	1.78	0.507	-0.750	0.433	0.333	-3.00	0.0710	0.942	.
	NDF intake	3	9.25	4.82	-1.500	0.866	0.333	-4.40	0.0710	0.942	.

Milk SNF %	CP	40	8.64	0.860	0.0680	0.0360	2.79	103	0.0690	0.0390	0.0580
	EE	33	9.39	0.703	0.121	0.107	2.32	79.2	0.271	0.0320	0.871
	NDF	28	9.47	0.882	0.0150	0.0180	2.48	69.7	0.414	0.0100	0.782
	NFC	9	7.67	2.88	0.0890	0.162	0.197	20.6	0.614	0.937	.
	FC ratio	42	9.41	0.818	-0.236	0.176	2.85	103	0.194	0.0130	0.120
	DMI	27	10.71	2.93	-0.311	0.402	2.38	60.3	0.450	0.0880	0.925
	CP intake	10	10.86	1.43	1.43	1.22	1.93	5.10	0.880	0.271	0.708
	NDF intake	5	13.77	2.58	-1.78	1.35	0.055	0.100	0.414	0.999	0.255

n = sample size; SE=standard error; RMSE= Root mean square error, AIC= Akaike information criterion; L = linear term; Q = quadratic term

(P<0.01; R^2 = 0.841; Figure 3). No interaction effect was observed on those variables with breeds, indicating that all buffaloes' species had a similar response to the change in FC ratio and DMI. Other predictor variables including CP, EE, NDF, NFC, as well as CP and NDF intakes had no effect on milk yield of buffaloes (P>0.05). In this study, feed efficiency among breeds of buffaloes was not affected by factors tested (P>0.05).

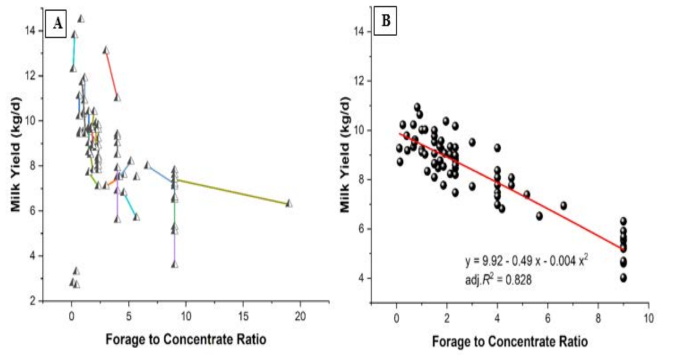

Figure 2: The relationship between forage to concentrate ratio and milk yield (kg/d) of lactating dairy buffaloes from individual studies (A) and after aggregated and adjusted using meta-analysis (B) (number of studies used = 26 with 77 data points).

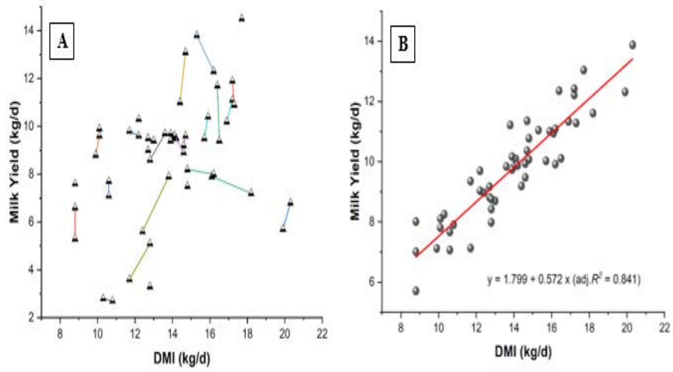

Figure 3: The relationship between DMI (kg/d) and milk yield (kg/d) of lactating dairy buffaloes from individual studies (A) and after aggregated and adjusted using meta-analysis (B) (number of studies used = 17 with 51 data points)

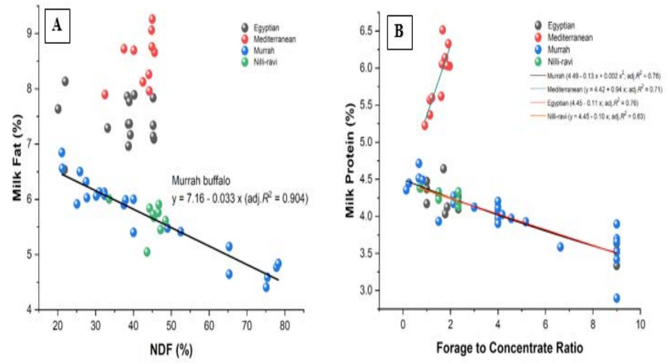

Figure 4: A meta-analysis of the relationship between NDF content and milk fat content (A) and between forage to concentrate ratio and milk protein content (B) for major breeds of buffaloes evaluated in the studies

Effects of nutrient intakes and nutrient components on milk composition

In our meta-analysis, quadratic effects of the regression analysis on milk components were not significant in all parameters. Thus, we retained the linear regression models for milk component parameters as shown in Table 4. The interaction effect was observed between breed of buffaloes and NDF content of the diets (P = 0.028) and between breeds with FC ratio (P = 0.016) on milk fat, although NDF and FC ratio did not significantly influence milk fat content. Instead, milk fat content was positively associated with NDF intake (P<0.05; R^2 = 0.248). In buffaloes' species point of view, increasing NDF content linearly decreased milk fat of Murrah buffalo (P<0.05; R2 = 0.90) but did not affect other breeds including Mediterranean, Egyptian, and Nilli-ravi buffaloes (P>0.05; Figure 4a). A decreasing trend was also noticed on the milk protein content of Murrah buffalo in association with increasing FC ratio (P<0.05; R^2 = 0.76; Figure 4b). Meanwhile, Mediterranean buffalo was the only species showing positive correlation between milk protein and FC ratio (P<0.05; R^2 = 0.71), although the interpretation should be carefully understood because the sample size corresponded to this breed was smaller compared to Murrah breed. In addition, the regression equation showed that increasing NFC content in the diets also contributed to decrease milk protein content across the breed of buffaloes but without a strong correlation (P<0.05; R^2 = 0.149). For milk lactose content, CP intake was the only factor explaining the decreased trend when the level increased (P<0.05). NFC content also showed to linearly influence total solid content and milk ash content with opposite direction for each of the parameter (P<0.05). For milk SNF content, CP, EE, and NDF content of diets shared a similar linear pattern (P<0.05) while increasing FC ratio negatively decreased the SNF content of the milk (P<0.05), all with relatively weak correlation.

DISCUSSION

Effects of nutrient intakes and nutrient components on milk yield and efficiency

When looking into studies centered around the big question of whether concentrate play a big role in affecting milk yield, studies with differing results were found. For instance, a study by Gaafar et al. (2009) concluded that lactating buffaloes fed ration consisting of 40% concentrate and 60% roughages on DM basis (berseem hay and rice straw) with 15g baker's yeast supplementation/head/day showed the best results concerning milk yield, feed conversion and economic efficiency. Besides, Habib et al. (2020) stated that, the additional of concentrate in the existing feed of lactating buffaloes can inclined the milk yield and reduce of postpartum heat period. However, at the same time Habib et al. (2020) explained that there were no significantly difference in the body weight, body condition score, calf birth weight, and milk compositions among the buffaloes. In contrast, another study by Purcell (2016) stated that concentrate feeding method had no effect on the performance of high-yielding cows in early to mid-lactation, when all the cows were offered the same amount of concentrate in addition to a basal diet offered *ad libitum*. The difference in the findings could be attributed to the statement that concentrate is not the only factor affecting milk yield.

Production of milk, just like any other biological activity, requires energy and thus supplementation with feed concentrates that generally are low-fiber and high-energy when compared to forages serves this purpose. Lawrence et al. (2015) reported that by increasing the total amount of concentrate offered, cows had higher TDMI and energy intake, which resulted in increased milk production and reduced negative energy balance and body condition score loss. In addition, in their study, Gaafar et al. (2009) explained that the increasing level of concentrate in feed can significantly increase the digestibility coefficient of DM, CP, EE, NFE and TDN and DCP values of the lactating buffaloes. This is a common trend in dairy production, where concentrates are most often fed to raise energy level as well as to compensate for other deficiencies in the total mixed ration. Increasing the concentrate feed input in diets based on grass silage (Agnew et al., 1996) and maize silage (Fitzgerald and Murphy, 1999) has a positive effect on milk production and BCS loss (Delaby et al., 2009), otherwise known as a response to concentrate (Bargo et al., 2003). However, animals respond differently to concentrate supplementation due to variation within the herd, which is caused by differences in stage of lactation, parity, and genotype (Horan et al., 2005).

Forage is cheaper, economical and easy to produce of energy and protein sources to feed the dairy animals. Stokes (2002) outlined the important points regarding the role of forage in milk production. The points mentioned were to provide a highly fermentable diet that supports high intakes, promotes consistent ruminal fermentation and to prevent metabolic upsets if requirements are not met. Metabolic upsets can cause losses as they lead to milk production losses, treatment costs and if the condition does not improve, culling or total loss of the livestock. Therefore, while concentrate provides most of the energy source for milk production, forage is just as important in ensuring the nutrients can be absorbed and utilized aside from maintaining general health of the animal. Forage consisted fiber that important for dairy production. Amount of fiber also correlated with total microorganism on digestive tract (Ardiansyah et al., 2022).

Effects of nutrient intakes and nutrient components on milk composition

Milk plays an important role in human for growth and health development as well as for calf. Milk compose of protein, amino acid, fatty acid, lipid, vitamins and minerals (Prasanta et al., 2018). One of the factors that affected the composition of buffalo's milk was nutrient intake and nutrient quality (Sarwar et al., 2019). As stated in the result, the nutrient intake and nutrient component may influence the milk composition of dairy buffaloes. Similarly, study by Wahid and Rasnina (2011) stated that feeding buffaloes with concentrate can increased the fat content of milk as much as 15% because the buffalo release the excessive fat into the milk and stores only a minimum fat in body tissues. They added, the buffalo milk content higher fat which was in range 9-15%, protein as 7.1%, lactose 4.9%, ash 0.89% and low in cholesterol compare to cow milk. Riaz et al. (2014) stated in their study, buffaloes turn out to be more responsive to the CP in the diet compare to the other ruminant species. In other study, buffaloes were advanced in degraded of both crude protein and protein freed dry matter compare than cattle (Sarwar et al., 2009). According to Faraque and Hossain (2017), the concentrate given to the buffaloes may significantly influence the composition of some chemical's component of milk such as protein, ash, TS and SNF, however there was significantly different in the fat content of milk. Therefore, with the good feeding management and nutrient intake, there are potential in the improvement of milk composition of the buffaloes.

Aside from feeding management, other factors that affect milk yield and composition are breed, age and size of the cow, the health status of the cow, the stage of lactation and environment as well as forage quality. Momin et al. (2016) stated that in terms of breed, river types buffalo's performance was superior to other breeds. The parameters used in this study was live weight, daily milk yield, lactation length and lactation production. Study by the same authors also outlined that in terms of farming system or environment, semi-intensive farming system was superior to other systems, when considering the live weight and daily milk yield as observed parameter. In addition, Prasanta et al. (2018) explained in their study that Murrah buffaloes were the most superior in producing milk fat, total milk protein, and milk casein, followed by Mehsana buffaloes for SNF and Bhadawari buffaloes for total solids in milk. Another study by Uzun. et al. (2018) concluded that inclusion of fresh sorghum in a buffalo TMR with at least 26.5% on a DM basis could modify the fatty acid composition of buffalo mozzarella cheese. In short, all these factors coexist and interact with each other, thus affecting the overall milk results and the co-products.

Studies concerning buffalo milk production are significant because buffalo milk plays an important role in human nutrition, particularly in developing countries such as India and Pakistan. Aside from that, in comparison with cow milk, buffalo milk is richer in almost all the main milk nutrients. Besides, in term of milk color, buffaloes convert the yellow pigment beta carotene into colorless vitamin A and passed on the milk, make the milk's color less yellowish compared to dairy cows milks (Wahid and Rosnina, 2011). Besides, individuals having allergies to dairy cows' milk are capable of tolerating buffalo milk, in certain cases (Sheehan and Phipatanakul, 2009). Therefore, it might also be a dairy alternative for individuals with cow milk allergies, thus creating its own niche market.

CONCLUSIONS

This meta-analysis provides evidence that DMI along with dietary forage to concentrate ratio are two predictor variables with the greatest effects on milk yield of inter-species lactating dairy buffaloes. Milk production increased when DMI increased and it decreased in response to increasing forage proportion in the diets, indicating an importance role of concentrate supplementation for buffaloes to increase milk production. In addition, the magnitude response of buffaloes' species on nutrient content of diets varied whereas Murrah buffalo seemed to be more sensitive with changes in nutrient of feed, as observed on milk fat and milk protein content of this buffalo species.

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DATA AVAILABILITY STATEMENT

Availability of data and equipment used and analyzed during this study is available from the correspondence author on reasonable request.

CONFLICTS OF INTEREST

The authors declare that they have no conflict of interests.

NOVELTY STATEMENT

Dairy buffalo (*Bubalus bubalis*) is known as one of the important ruminants that contribute significantly to milk and meat production. However, there is scarcity of information on the nutritional requirements of dairy buffalo, specifically. Most of the feeding standards and recommendations for dairy buffalo are based on the exploration from dairy cattle data, which may not be accurate. Therefore, this study aims to explore the effect of concentrate and nutrient intake on the milk production of dairy buffalo, using meta-analysis techniques. This study will provide novelty statement how to improve the milk production of the dairy buffalo feed with proper nutrient based on the meta-analysis data.

AUTHORS CONTRIBUTIONS

Conceived and designed the experiment: FAAS, AFMA, MAAZ, HMZ, SZ, IEMJ, and MBIRA. Literature search and analyzed the data: FAAS, AFMA, MAAZ, HMZ, SZ, IEMJ, and MBIRA. Data interpretation and scientific discussion: HAH, SS, AJ, ANR, AI, MZAB, MZS, FAAS, AFMA, MAAZ, HMZ, SZ, IEMJ, and MBIRA. Writing the manuscript: FAAS, AFMA, MAAZ, HMZ, SZ, IEMJ, and MBIRA. All authors have read and approved the final manuscript.

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