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Meta-analysis of the effect of feeding live yeast (*Saccharomyces cerevisiae*) on feeding behaviour and lactation performance, rumen fermentation, and rumen microbiota in dairy cattle

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Abstract The objective of this meta-analysis was to analyze the effect of feeding live yeast (*Saccharomyces cerevisiae*) on feed intake (FI), lactation performance (LP), rumen fermentation (RF), and rumen microbiota (RM) in dairy cattle. We performed a literature search using the Boolean search approach with MeSH keywords, including live yeast, *Saccharomyces cerevisiae*, *S. cerevisiae*, feed intake, lactation, performance traits, rumen, fermentation, microbiota, and cattle. Twenty-five (25) articles published contained at least data on feed intake, lactation performance or milk production parameters, rumen fermentation or digestibility, and rumen microbiota measured for experiments involving dairy animals have been selected. Microsoft Excel performed data extraction and organization, and statistical analysis was performed using SPSS. Few studies have observed a negative impact of the LY on the FI (8%), LP (12%), RF (4%), and RM (8%), but the majority of the selected studies reported a positive impact of adding LY (FI: 36%, LP: 52%, RF: 52% and RM: 40%). Cows supplemented with LY showed a marginal decrease in feeding rate; min/d (0.13 vs. 0.14; P = 0.65), interval between meals; min (142.1 vs. 1603, P = 0.09), meal size; kg of DM/meal (3.4 vs. 3.8, P = 0.09), meal duration; min/meal (32.5 vs.35.3, P = 0.39), lying boots; no/d (9.5 vs. 9.6, P = 0.83), eating boot; bout/day (80.7 vs. 8.26, P = 0.24), and lying time; min/d (671.1 vs. 697.5, P = 0.51). However, LY increases feeding duration; min/d (232.0 vs. 226.6, P = 0.65), meal frequency; meal/d (9.0 vs. 7.8, P = 0.07), rumination; min/d (570.3 vs. 344.9, P = 0.08), and meal criterion with significance; min (20.0 vs. 25.8, P = 0.04). Meta-regression of the covariate effect shows that using live yeast products in the cattle diet significantly increased the Lactation Performance (P = 0.001) and Feed Intake (P = 0.001). However, it enabled a higher average ruminal Fermentation (P = 0.005) and microbiota (P = 0.003). Furthermore, the timing of live yeast culture before calving could influence the performance and ruminal parameters, especially the microbiomes (P = 0.006). A little increase in milk yield (1.4kg/day) and lower SCS（somatic cells score (2.76) were observed in LY. This meta-analysis indicated feeding live yeast (*Saccharomyces cerevisiae*) could improve feeding behaviour, animal performance, and herd productivity (milk and rumen health). However, further research is required to study its effect on feed intake and rumen microbiota in dairy cattle.

Keywords: yeast supplementation, *Saccharomyces cerevisiae,* feed intake, animal performance, rumen health, dairy cattle

1. Introduction

The cattle industry has expanded and picked up pace throughout the years. Providing food with sufficient amounts of energy, protein, vitamins, and minerals can result in increased yields. Adding chemicals to meals that alter rumen function is another option for increasing animal productivity (Sartori et al 2017); as a result, usually, dairy cows are exposed to multiple stressors during their life, especially during the periparturient period and lactation. The effect of these stressors negatively influences productive and reproductive performance. Moreover, stress may affect metabolism and immune functions. Severe or chronic stress disrupts homeostasis, altering biological processes and predisposing animals to several pathologies (Horst et al 2021).

Antibiotic supplements are subject to government regulation in the European Union and elsewhere. Digestive disorders created by high-grain diets and lack of adequate fiber from forages are the main responsible of subacute ruminal acidosis syndrome, which negatively affects performance and results in substantial economic losses to farmers (Elghandour et al 2022). This situation has led many farmers to switch to less harmful animal feed (Oliveira et al 2019). Yeasts have also been demonstrated to modulate rumen pH and reduce the risk of acidosis by regulating lactate-producing and lactate-utilizing bacteria(Salah Hamed 2022). A microbial strain like S. cerevisiae presents a rich

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supply of nutrients including peptides, vitamins, organic acids, and cofactors that rumen bacteria might require(Salah Hamed 2022). Milk characteristics and milk yield were not affected by the treatment. Adding yeast products to cattle diets is a widespread practice around the world. Milk production (MP), milk fat (MF), and milk protein (MP) output from nursing dairy cows are predicted to rise as a result of yeast product effects on the rumen microbial community, resulting in changes in ruminal VFA production (Putnam et al 1997). Some research suggests that DMI is increasing (Dann et al 2000), while others indicate it is decreasing (Schingoethe et al 2004). Many studies have investigated the effects of feeding yeast products to dairy cows during lactation; however, the results have been inconsistent. A trend in output or no significant variations in milk production were detected (Wang et al 2001).

Before determining whether to utilize these yeast products, dairy farmers, veterinarians, and nutritionists need more information about how they affect milk production. A type II statistical mistake, or the inability to detect a real treatment effect in a study, might result from a lack of statistical power (Freiman et al 2019). When multiple small studies have been conducted at different study sites by various researchers using different study designs, and when analyzed separately, may not offer unambiguous evidence of benefit, meta-analysis has been proposed as a technique to produce relevant summary estimates of effect (Lean and Rabiee 2011). Various yeast products are used, presumably contributing to the observed heterogeneity in response to supplementation. There is a wide variety of products on the market, each with its unique mechanism of action.

Some features of feeding behaviour were affected by LY supplementation. Meal size decreased quadratically (3.2, 3.5, and 2.9 kg DM, respectively). However, intervals between ruminating bouts decreased linearly (122, 96.5, and 90.7 min, respectively) with increasing dosage of LY chewing time per kg of NDF increased linearly (71.6, 71.3, and 81.6 min/kg, respectively) with increasing LY dosages. The expected net energy during lactation of the diet rose by 5.2%, from 1.72 Mcal/kg of DM for 0 g of LY to 1.81 Mcal/kg for 1 g of LY (Perdomo et al 2020). Feeding 1 g of LY/d to heat-stressed cows increased ECM yield and efficiency of feed conversion into ECM, improved diet digestibility, and increased ruminal fluid pH; these responses could be attributed to either direct effects of LY on ruminal microbial activity or to changes in feeding behaviour that enhanced the digestion of heat-stressed cows (Perdomo et al 2020).

An important aspect of live yeast (*Saccharomyces cerevisiae*) inclusion in the diets of ruminants is improved animal productivity. Including yeasts in ruminant diets may alter rumen microbes and their metabolites and promote a favorable intestinal microflora by increasing the population of beneficial microorganisms. According to DeVries and Chevaux (2014), dairy cows' dietary habits can change when live yeast is supplemented. The minimum intermeal time was shortened with yeast supplementation (20.0 vs. 25.8 min), resulting in a tendency for cows to eat more frequently (9.0 vs. 7.8 meals/d) and smaller meals (3.4 vs. 3.8 kg/meal). Additionally, cows given yeast tended to ruminate longer (570.3 vs. 544.9 min/d) (DeVries and Chevaux 2014). According to Moallem et al (2009), when LY was supplemented to cows under heat stress, the daily dry matter intake was 2.5% higher in the LY group compared to the control group (24.7 and 24.1 kg, respectively). Comparing the LY group to the control group, the daily average milk output of the LY group was 1.5 kg (4.1%) higher (37.8 vs. 36.3 kg, respectively) (Moallem et al 2009). The percentages of milk fat and protein did not change significantly, although the LY group's fat production was higher than that of the control group. In the LY group, the fat-corrected milk 4% was 2.0 kg (6.1%) more than in the control group (34.8 vs. 32.8 kg, respectively) (Moallem et al 2009). When dairy cows were provided LY supplements during the hot season, the rumen environment benefited in a way that boosted the intake of dry matter, raising efficiency and production (Moallem et al 2009).

According to Nasiri et al (2018), feeding dairy cows exposed to high ambient temperatures of LY positively impacts reproductive parameters such as hormonal profile, ovarian follicular dynamics, and reproductive success. In cows fed diets enriched with yeast, plasma IGF concentrations following dietary therapy were more significant (P = 0.05). On day 60 after delivery, cows fed diets supplemented with yeast had higher average plasma concentrations of glucose (48.3 vs. 41.0 mg/dL) and insulin (0.90 vs. 0.23 U/mL) than cows fed diets without LY supplementation (Nasiri et al 2018). The plasma concentrations of E-17β at estrus (P = 0.016) and P4 on day 10 of the estrous cycle (P = 0.021) were also higher in cows that had received yeast supplements. In addition, yeast supplementation led to the production of more prominent ovulatory follicles (18.4 vs. 17.2 mm in diameter; P < 0.01) and a 2.6-day reduction in the length of the estrous cycle (P = 0.05). Days open were shorter, and more pregnant cows were present at 120- and 150-days post-partum in cows fed yeast-supplemented diets as compared to diets without yeast (P < 0.01) (Nasiri et al 2018). Larger ovulatory follicles, shorter estrous cycles, higher plasma levels of IGF-I, E-17β, and P4, and increased reproductive performance were all seen in cows fed diets enriched with yeast (Nasiri et al 2018).

Beneficial microbes compete for nutrients and attachment sites with pathogens, thereby reducing the growth of harmful microbes in the rumen. Yeasts enhance animal development and average weight gain by improving nutrient digestion and absorption. The physiological effects of yeast cultures are not caused by the presence of living yeast but rather by the fermentation by-products produced by yeast during fermentation. The rumen fermentation results in a chemical change that modulate the development of particular rumen bacteria and protozoa (Callaway and Martin 1997). According to DeVries and Chevaux (2014),

yeast-supplemented cows exhibited lower mean ruminal temperatures (38.4 vs. 38.5°C) and spent less time with rumen temperatures above 39.0°C (353.1 vs. 366.9 min/d), which may indicate improved rumen pH conditions. The lameness score of multiparous cows under heat stress was only minimally impacted by feeding a *S. cerevisiae* yeast culture(Bruno et al 2009). Additional benefits include a healthy gut with a concomitant increase in animal productivity, nutrient digestion, absorption, and general animal welfare. Yeast probiotics are a viable alternative to antibiotics to improve animal welfare (Anee et al 2021). Supplementing lactating dairy cows with LY improved meal patterns, including more frequent meals that were smaller and occurred closer in time together. Cows fed LY ruminate longer and have fewer spells of high rumen temperature. Despite selecting more against the most extended, fibrous diet particles, yeast-supplemented cows had better milk fat content and output (DeVries and Chevaux 2014). In early lactation dairy cows, supplementation with Saccharomyces cerevisiae may improve reproductive characteristics. According to AIlbrahim et al (2010), feeding *Saccharomyces cerevisiae* did not affect the energy status of lactating dairy cows with high or low BCS (body condition score) at calving, but it did improve serum insulin concentration, the preovulatory peak of oestradiol, and the size of the first ovulatory follicle in the early post-partum (PP) period.

To quantify the effects of live yeast supplementation on intake, rumen fermentation, and milk production, Desnoyers et al (2009) conducted a meta-analysis of the literature on the topic. Thirteen papers were reviewed using laboratory-grown yeast as the experimental organism. The vast range of findings may be attributable to differences in the production method and the reactivity of particular yeast products within various herd production systems. The goal of this meta-analysis was to analyze the effect of feeding live yeast (*Saccharomyces cerevisiae*) on feed intake (FI), lactation performance (LP), rumen fermentation (RF), and rumen microbiota (RM) in dairy cattle by rigorously analyzing available data**.**

The study aims to evaluate the live yeast additive in cattle performance by studying the four different parameters simultaneously. These parameters are milk production, feed intake, rumen fermentation, and rumen microbiota. The study shows a significant improvement in feed intake, milk production, rumen fermentation, and rumen microbiota**.**

2. Materials and Methods

2.1. Research design

This research aims to analyze the effect of feeding live yeast (Saccharomyces cerevisiae) on feed intake (FI), lactation performance (LP), rumen fermentation (RF), and rumen microbiota (RM) in dairy cattle.

2.2. Data collection

Data collection was performed by following the PRISMA guidelines (Figure 1). We completed the literature search using the Boolean search approach and searching key terms in a well-recognized electronic research database, i.e., "PubMed, Elsevier, Scopus, Web of Science, Science Direct, and Google Scholar database." The Mesh keywords include live yeast, *Saccharomyces cerevisiae*, *S. cerevisiae*, feed intake, lactation, performance trait, rumen, fermentation, microbiota, and cattle. We applied a filter of publications in English-language having full texts from 2015 to 2022 to include the latest data and updated outcomes. Selected papers contained at least data on feed intake, lactation performance or milk production parameters, rumen fermentation or digestibility, and rumen microbiota measured for experiments involving dairy animals.

Additionally, studies must have reported results of at least one of the production outcomes of interest. After completing the final searches, duplicate articles were removed from the collection. Then an inclusion/exclusion procedure was carried out based on the following inclusion criteria: (1) randomized controlled studies, (2) publications in journals that have been subjected to peer review, (3) testing of products comprising only commercial yeast ptoduct, and (4) access to the information in English. In addition, the research included in the articles must have been carried out on lactating dairy cows (5) and have sufficient statistical reporting. They need to have employed (6) a parallel-group design (as opposed to a crossover design). They need to have (7) published the findings of at least one of the production outcomes (milk yield, dairy milk index, and milk composition) together with a measure of variation (standard error or standard deviation). After screening for eligibility, 25 studies were selected for this meta-analysis (Table 1).

2.3. Statistical analysis

We used Microsoft Excel (version 2016) to retrieve raw data and process it to create secondary data. The IBM SPSS (version 25) for Windows was used to export the secondary data and conduct the statistical and meta-analysis. The yeast effect was first tested as a co-variable according to the level of yeast supplementation expressed and then qualitatively (control vs. yeast). Normalized residuals [i.e., the disparity between the examined parameter's projected and measured value, split by the residuals' standard deviation (SD)] were generated to evaluate the model's ability to fit the input. Every potentially influencing factor's impact on this gradient was examined using either one-factor ANOVA for qualitative variables or linear regression for quantitative parameters. The regression intercept was set at zero if it did not substantially deviate from zero on the first analysis. The primary statistical model applied to the data was:

$$Yijk = \mu + YEAST_i + EXP_j + E_{ijk}$$

where Y_{ijk} = observations, μ = overall mean, $YEAST_i$ = fixed effect of yeast, EXP_j = fixed effect of experiment j, and E_{ijk} = random residual error.

We took estimations of variability from the manuscripts if the chosen research did not measure the variation of the desired outcomes. The estimates for standard error (SE) and standard deviation (SD) were computed using the divergence between the means and the number of animals involved for each experiment, whether the trial only provided a Z-statistic or P-value. A simulated sample means and a variation modification for the linked findings were estimated in publications with complicated data structures, like those that included multivariate regression. It was achieved by creating a synthesized point effect using a fixed-effects meta-analysis of the report's linked results. The variance inflation parameter was used to determine the deviation for the synthetic point effect. The articles utilized to determine the synthetic treatment effect were not included in the final meta-analysis since they were applied to calculate the fixed-effect prediction equation. A *P*-value of ≤ 0.05 was considered significant, and the P-value that produced the smallest (most conservative) estimate of the overall treatment effect was selected for the calculation of the SE.

2.4. Ethical review statement

No data were collected from humans or animals directly by the authors; however, the research was conducted in adherence to the Declaration of Helsinki.

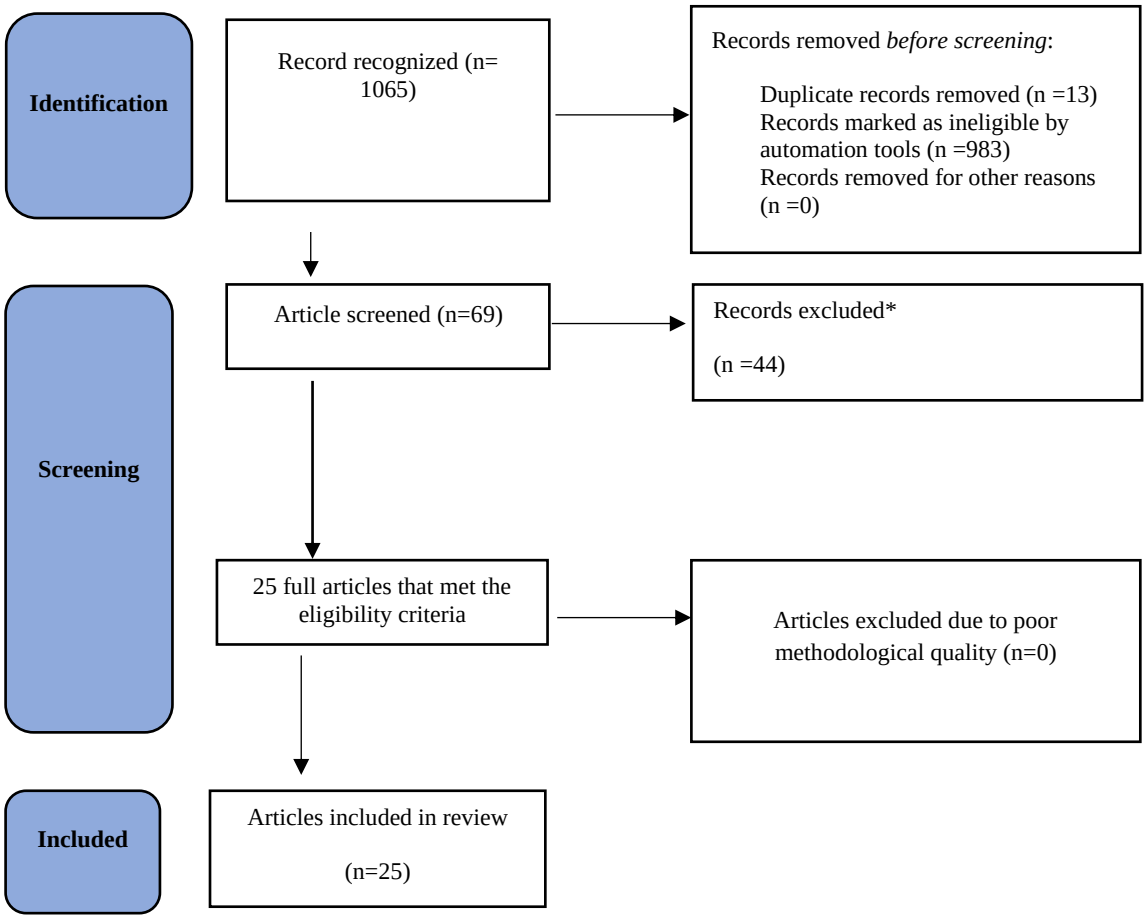

Figure 1 PRISMA flowchart illustrating the literature review process. **Records excluded due to unavailability of sufficient data.

3. Results

Twenty-five (25) studies met the database inclusion criteria. The summary of those studies included in the meta-analysis and the citations are presented in Table 1. The effects of the supplementation of live yeast products in the diet of dairy cattle on FI, LP, RF, and RM are presented in Table 2. According to some studies, the supplementation of yeast products to the diet of dairy cattle has a positive effect on the FI (n=9; 36.0%), LP (n=13; 52%), RF (n=13; 52%), and RM (n=10; 40.0%). Many studies reported that LY did not alter the FI profile (n=8; 32%), LP (n=5; 20%), and RF (n=3; 12%). Surprisingly three studies (8%) observed a negative impact of the LY on the FI and LP of cattle, one study (4%) reported a negative effect of adding LY on the RF, and two studies (8%) found a negative association of adding LY on RM in cattle (Figure 2a-2d). However, Table 2 shows that the overall positive impact of adding LY has been reported by the majority of the selected studies (FI: 36%, LP: 52%, RF: 52%, and RM: 40%) as compared to the adverse outcomes (FI: 8%, LP: 12%, RF: 4% and RM: 8%).

Table 1 Studies included in the meta-analysis.

Reference*	Location	NA*	TLYC*	FI	LP	RF	RM
1.	Pennsylvania State University	45	After	Data Available	Data Available	Data Available	Data Available
2.	Iran	172	Both	Data Available	Data Available	Data Unavailable	Data Unavailable
3.	Brazil	40	After	Data Available	Data Available	Data Available	Data Available
4.	Virginia	24	Before	Data Unavailable	Data Available	Data Available	Data Unavailable
5.	Czech Republic	50	After	Data Available	Data Available	Data Available	Data Unavailable
6.	Virginia	24	Before	Data Available	Data Available	Data Available	Data Unavailable
7.	Japan	16	After	Data Available	Data Available	Data Available	Data Available
8.	University of Florida	50	After	Data Available	Data Available	Data Available	Data Available
9.	Spain	25	Before	Data Unavailable	Data Available	Data Unavailable	Data Unavailable
10.	Iowa State University	12	After	Data Unavailable	Data Available	Data Unavailable	Data Unavailable
11.	Spain	25	Both	Data Available	Data Available	Data Unavailable	Data Available
12.	Data Unavailable	-	Both	Data Available	Data Available	Data Available	Data Available
13.	South America	4	Before	Data Available	Data Available	Data Available	Data Unavailable
14.	The Pennsylvania State University	48	After	Data Available	Data Available	Data Available	Data Unavailable
15.	Columbus	12	After	Data Available	Data Available	Data Available	Data Unavailable
16.	Egypt	80	After	Data Available	Data Available	Data Unavailable	Data Unavailable
17.	Data Unavailable	-	Both	Data Available	Data Unavailable	Data Unavailable	Data Available
18.	Canada	84	After	Data Unavailable	Data Available	Data Available	Data Available
19.	Data Unavailable	-	Data unavailable	Data Unavailable	Data Unavailable	Data Unavailable	Data Available
20.	University of Alberta	20	After	Data Unavailable	Data Unavailable	Data Unavailable	Data Available
21.	University of Bari	40	Before	Data Available	Data Unavailable	Data Available	Data Unavailable
22.	Tunisia	16	Before	Data Available	Data Available	Data Available	Data Unavailable
23.	Brookings, South Dakota	40	Before	Data Available	Data Available	Data Available	Data Available
24.	Finland	4	After	Data Available	Data Available	Data Available	Data Available
25.	Agriculture Research Center, Egypt	24	Before	Data Available	Data Unavailable	Data Available	Data Available

*Supplemental details of these references are detailed in the appendix. NA: Number of animals involved in the study. TLYC: Timing of live yeast culture regarding calving.

Table 2 Descriptive frequencies of effects of using yeast-derived products on animal performance and ruminal parameters (n=25).

Variables	FI		LP		RF		RM	
	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Data Unavailable	6	24.0	4	16.0	8	32.0	12	48.0
Positive Impact	9	36.0	13	52.0	13	52.0	10	40.0
No Impact	8	32.0	5	20.0	3	12.0	1	4.0
Negative Impact	3	8.0	3	12.0	1	4.0	2	8.0
Total	25	100.0	25	100.0	25	100.0	25	100.0

Meta-regression of the covariate effect shows that using live yeast products in the cattle diet significantly increased Lactation Performance (t=6.828; *P* = .001) and Feed Intake (t=5.754; *P* = .001). However, it enabled a higher average ruminal Fermentation (t=4.560; *P* = .005) and Microbiota (t=3.347; *P* = .003; Table 3). A difference in the timing of live yeast culture or treatment has been observed. Some studies have incorporated live yeast into the diet before calving, i.e.,

in non-lactating cattle, while others have tested it after calving on lactating cattle. The association of the timing of live yeast culture with feed intake, lactation performance, rumen fermentation, and rumen microbiota has been analyzed and presented in Table 4. The results show that the timing of live yeast culture could influence the performance and ruminal parameters, especially the microbiomes (P = 0.006).

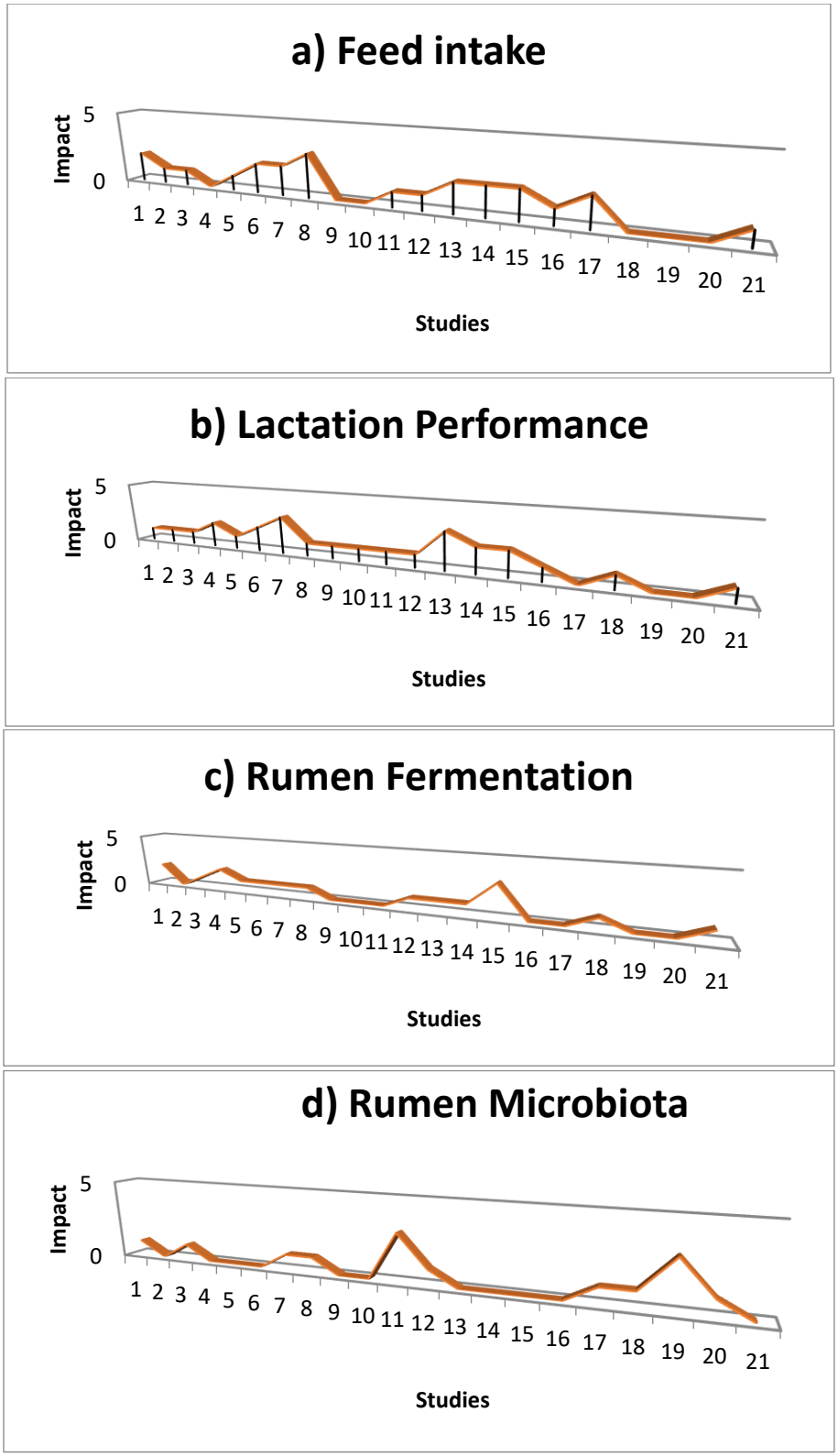

Figure 2 Effect of LY on different parameters. a) shows the effect of LY on FI b) shows the effect of LY on LP c) shows the effect of LY on RF d) shows the effect of LY on RM Studies with impact zero (0) mean no data was available for this parameter, one (1) shows a positive effect, two (2) show no effect or normal function and impact three (3) is the negative effect of LY.

Meta-regression of the covariate effect shows that using live yeast products in the cattle diet significantly increased Lactation Performance (t=6.828; *P* = .001) and Feed Intake (t=5.754; *P* = .001). However, it enabled a higher average ruminal Fermentation (t=4.560; *P* = .005) and Microbiota (t=3.347; *P* = .003; Table 3). A difference in the timing of live yeast culture or treatment has been observed. Some studies have incorporated live yeast into the diet before calving, i.e., in non-lactating cattle, while others have tested it after calving on lactating cattle. The association of the timing of live yeast culture with feed intake, lactation performance, rumen fermentation, and rumen microbiota has been analyzed and presented in Table 4. The results show that the timing of live yeast culture could influence the performance and ruminal parameters, especially the microbiomes (*P* = 0.006).

Table 3 Meta-regression of the covariate effect on feed intake, lactation performance, rumen fermentation, and rumen microbiota.

	N*	Mean	SD	SEM	t	SMD	95% CI of the Difference Lower	95% CI of the Difference Upper	*P*-value
Feed Intake	25	1.1429	.91026	.19863	5.754	1.14286	.7285	1.5572	.001
Lactation Performance	25	1.2381	.83095	.18133	6.828	1.23810	.8599	1.6163	.001
Rumen Fermentation	25	.8095	.81358	.17754	4.560	.80952	.4392	1.1799	.005
Rumen Microbiota	25	.6667	.91287	.19920	3.347	.66667	.2511	1.0822	.003

*N: number of studies. SD: standard deviation. SEM: standard error of the mean. t:t test. SMD: standard mean difference. CI: confidence interval.

Table 4 Association of Timing of Live Yeast Culture with feed intake, lactation performance, rumen fermentation, and rumen microbiota.

Source	df	MS.	F	*P*-value
FI.	1	.263	.797	.385
LP.	1	.820	2.483	.135
RF.	1	.086	.262	.616
RM	1	3.280	9.928	.006

df: degrees of freedom, MS: Mean Square, F: F-statistic.

The analysis revealed that adding live yeast to a high-concentrate feed had no discernible impact on total BW, ADG, or FCR (Table 5). As a possible indication of a smoother transition to the high-energy diet administered throughout the gaining phase, saccharomyces treatment boosted DM consumption, especially within the first weeks of fattening. Although there was no significant difference between both groups' final body weight gain, it was lower in the cattle fed with LY (738) than in the C (741). Due to their higher calorie consumption, yeast-feeding cattle often require less growing time to attain their ideal completing state. The weight and dressings of these cattle carcasses were comparable to others. However, the proportion of good-rated carcasses for conformation rose after yeast supply. The delivery of LY reduces the feed intake, but there is no discernible difference. However, the LY group's mean feed conversion ratio (FCR) was lower (Table 5).

A little increase in milk yield (1.4kg/day) of LY cattle was observed than those in the Control group cattle (38.7kg/day vs. 37.3kg/day). Still, treatment had no significant effect on lactation and digestibility parameters except CP (*P* = 0.01) and NDF (*P* = 0.08). The SCS in LY was also found to be lower (2.76) as compared to the Control group (3.03). Table 5 shows that the ruminal pH, NH3-N, and propionate levels of the LY and control groups did not differ significantly (*P* > 0.05); however, the acetate level tended to be higher in the LY-supplemented group. Few interactions were found, which suggests that LYC had a small part in reducing the unfavorable reactions of cows to NO_3 administration. Figure 3-6 shows the graphical representations of live yeast's association with feed intake, lactose performance, ruminal digestibility, and composition.

In addition to a very significant chi-squared test of Q (*P* = 0.008), the analysis of LP revealed a high degree of heterogeneity (I^2 = 11.952%; Table 6). Since it compares the heterogeneity within the collection of studies to the within-study variation, the analysis for heterogeneity is crucial in meta-analysis. The null hypothesis that all the studies have the same effect size is tested using the chi-squared test of Q. The ratio of real heterogeneity or study variation to the overall variance of observed effect estimates is known as the I^2 statistic. A high I^2 indicates that the variance of the individual research results is more (or more varied) than anticipated. It might not be suitable to merge the studies for an average impact if there is too much variety since it could mean that more than one outcome is being examined. Changes in breed characteristics, such as those between Jersey and Holstein, the type of diet provided, how it was delivered, or the time of lactation may be to blame for the variation in therapeutic efficacy.

Table 5 The effectiveness of adding yeast to feed on cattle performance.

Parameters	Treatment		SMD*	*P*-value
	C	LY.	(95% CI)	
Feed Intake and feeding behavior*				
Eating (bout/day)	8.26	8.07	0.13	0.24
Feeding time, min/d	226.6	232.0	11.47	0.65
Feeding rate, kg/min	0.14	0.13	0.0089	0.54
Meal criterion, min	25.8	20.0	2.31	0.04
Meal frequency, meals/d	7.8	9.0	0.57	0.07
Interval between meals, min	160.3	142.1	9.85	0.09
Meal size, kg of DM/meal	3.8	3.4	0.21	0.09
Meal duration, min/meal	35.3	32.5	3.02	0.39
Rumination, min/d	544.9	570.3	13.17	0.08
Lying bouts, no./d	9.6	9.5	0.43	0.83
Lying time, min/d	697.5	671.1	38.19	0.51
Body weight (BW; kg/day)	1.7	1.79	0.47	0.024
Mean BW (kg/day)	1.4	1.8	0.25	0.003
Initial BW (kg, 0-95 days)	443	442	68.47	0.7
Mid-BW (kg, 0-95 days)	607	612	78.96	0.19
Final BW (kg, 0-95 days)	741	738	22.9	0.65
Dry Matter intake (DMI; kg/d)	10.5	12	0.31	0.56
Neutral Detergent Fiber (NDF; kg/d)	8.01	7.86	0.26	0.62
Feed Conversion Rate (FCR)	6.01	5.87	0.03	0.4
Lactation performance				
Milk Yield (kg/d)	37.3	38.7	0.89	0.10
FCM kg/d	36.3	38.2	0.90	0.07
Energy-Corrected Milk (ECM; kg/d)	35.2	37.2	0.94	0.04
Milk fat (%)	3.30	3.42	0.97	0.27
Milk protein (%)	2.73	2.80	0.07	0.08
Lactose (%)	4.84	4.86	0.18	0.33
Somatic Cells Score (SCS)	3.03	2.76	0.63	0.55
Ruminal Digestibility				
DMI kg/d	20.0	19.7	0.76	0.49
DM digestibility %	59.0	64.0	8.5	0.46
OM digestibility %	73.6	76.0	4.9	0.2
CP digestibility %	65.1	68.8	0.47	<0.01
NDF digestibility %	29.6	41.6	40.5	0.08
Starch	18.1	32.3	78.5	0.56
Total gas (ml)	63.7	64.3	2.9	0.5
metabolized energy (kcal)	1919	2419	576	0.4
volatile fatty acids (mmol/syringe)	1.27	1.33	0.004	0.2
Ruminal composition				
PH	6.28	6.33	0.041	0.35
Lactate (mM)	1.39	0.20	0.35	0.05
Short-chain fatty acids (mM)	110.3	125.4	0.96	0.06
Acetate (mM)	60.58	62.15	0.567	0.05
Propionate (%)	26.5	25.6	0.79	0.67
Nitrogen Ammonia (NH3 –N; mg/dL)	15.36	13.05	0.232	0.42
Acid-soluble protein (µg/mL)	33.4	37.0	0.18	0.78

*Feed intake in control was Mixed ration. Feed intake in the LY group was Mixed Ration+5g/day Saccharomyces cerevisiae. SMD: Standard Mean Difference. C: control group.

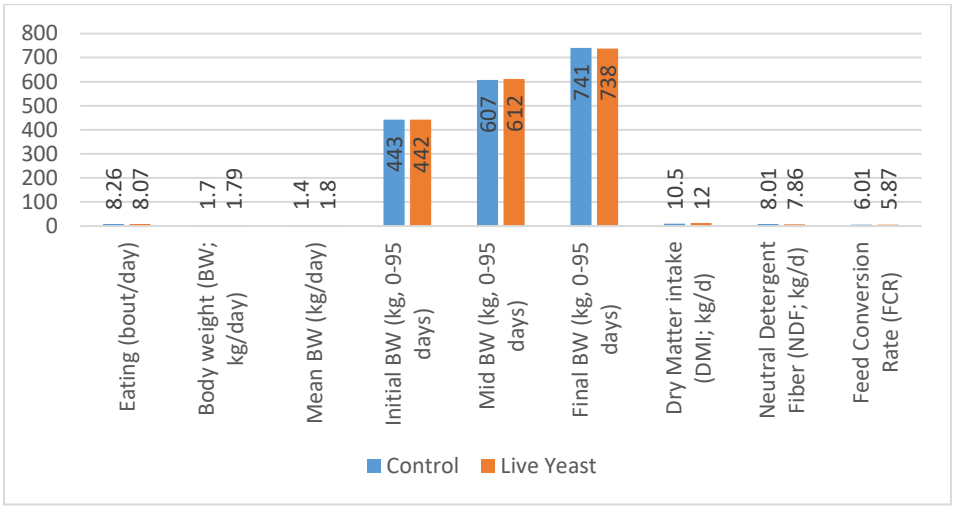

Figure 3 Comparison of the impact of control versus live yeast on feed intake, i.e., Body weight: BW in kg/day, Dry Matter intake: DMI in kg/day, Neutral Detergent Fiber: NDF in kg/day, and Feed Conversion Rate: FCR, etc. in both groups.

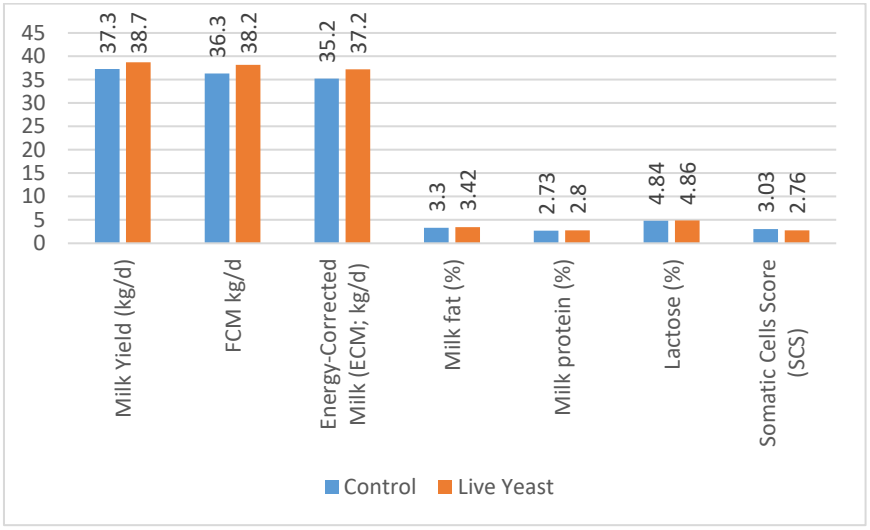

Figure 4 Comparison of the impact of control versus live yeast on lactation performance, i.e., daily milk yield in kg, Fat correction milk: FCM in kg/day, Energy correction milk: ECM in kg/day, percentage of milk fat, protein, and lactose, and the somatic cells score SCS in both groups.

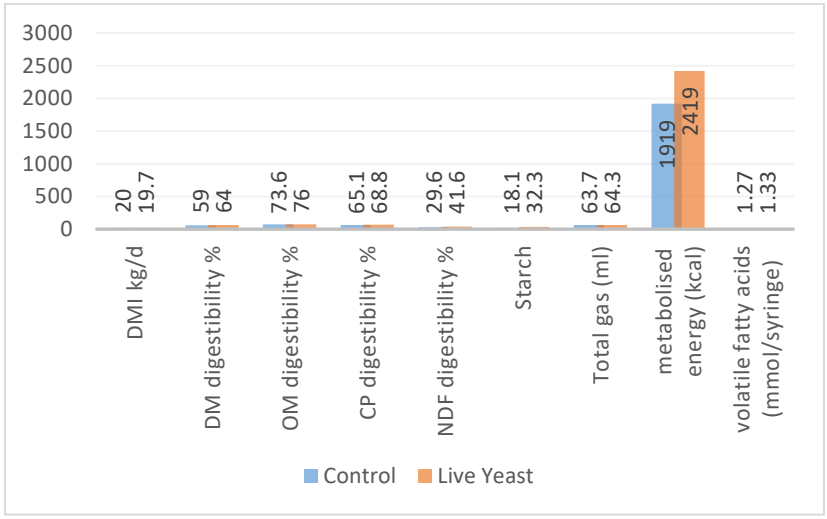

Figure 5 Comparison of the impact of control and live yeast on ruminal digestibility, i.e., Dry Matter intake: DMI in kg/day, percentage of Dry Matter digestibility: DM, Organic Matter digestibility: OM, crude protein digestibility: CP, Neutral Detergent Fiber: NDF, etc. in both groups.

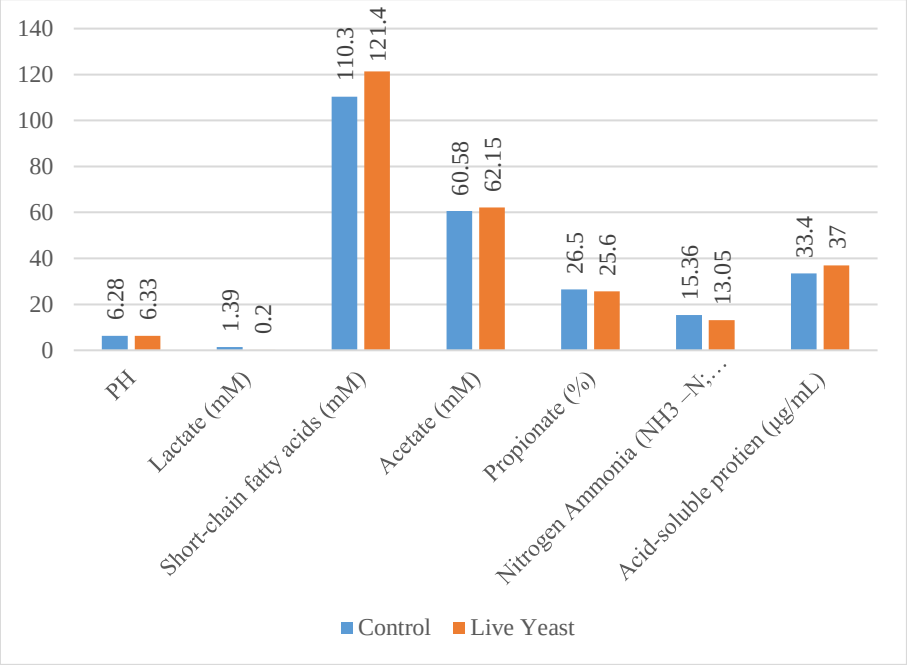

Figure 6 Comparison of the impact of control and live yeast on ruminal parameters, i.e., pH, lactate, short chain fatty acids and acetate, propionate percentage, nitrogen ammonia concentration: NH3-N, and acid soluble protein in both groups.

Table 6 Meta-analysis on the effect of live yeast on feed intake, lactation performance, rumen fermentation, and rumen microbiota.

Variables	N*	Treatment		Std. Deviation	RMSE	Heterogeneity I^2 (%)	*P*-value
		Control	LY				
FI	19	69.0	70.2	.91026	1.1429	4.714[a]	0.194
LP	20	1.32	1.24	.83095	1.2381	11.952[a]	0.008
RF	17	6.29	6.32	81358	.8095	11.190[a]	0.011
RM	13	94.4	96.6	.91287	.6667	6.000[b]	0.050

**N: No. of studies (out of 25). RMSE: Root Mean Square Error. Every study has reported at least one variable. a. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 5.3. b. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 7.0.*

4. Discussion

This meta-analysis examined how live yeast affects growth, fermentation in the rumen, milk production, quality, and feeding behavior. Responses to *Saccharomyces cerevisiae* products (SCP) supplementation were very different in the results of the various trials. This difference was lessened in the subgroup analysis by separating post-weaning and pre-weaning effects. Even after putting the diversity into groups based on the ressources, it gave, there was still much of it (LY and yeast fermentation products). We found that fermentation makes other things in addition to yeast. In one study, the FI and RF of cattle-fed LY decreased by 4.8%, while in two trials, the LP and RM of cows-fed LY went up by 9.5%. Figures 1–4 show how things turned out. The overall positive impact of adding LY has been reported by the majority of the selected studies (FI: 36%, LP: 52%, RF: 52%, and RM: 40%) as compared to the adverse outcomes (FI: 8%, LP: 12%, RF: 4% and RM: 8%). According to several data, providing live yeast (Saccharomyces cerevisiae) may have the capacity to change dairy cow feeding behavior patterns(DeVries and Chevaux 2014). Cows supplemented with LY tend to decrease feeding rate (0.13 vs. 0.14; *P* = 0.65), meal criterion (20.0 vs. 25.8, *P* = 0.04), the interval between meal (142.1 vs. 1603, *P* = 0.09), meal size (3.4 vs. 3.8, *P* = 0.09), meal duration (32.5 vs. 35.3, *P* = 0.39), lying boots (9.5 vs. 9.6, *P* = 0.83), eating boot (80.7 vs.8.26, *P* = 0.24), and lying time (671.1 vs. 697.5). In other hands, LY tend to increase feeding time (232.0 vs.226.6, *P* = 0.65), meal frequency (9.0 vs. 7.8, *P* = 0.07), and rumination (570.3 vs. 344.9, *P* = 0.08). In a study by Bach et al (2007), active dry yeast supplementation improved ruminal pH in a small sample of loose-housed lactating cows and changed cow feeding behavior. Yeast can scavenge oxygen from the rumen, hence improving the environment for the growth and activity of rumen anaerobic microorganisms. It can also boost rumen cellulolytic activity and nutritional digestion, especially in high-fiber diets (Salah Hamed 2022). Supplementing lactating dairy cows with live yeast improved meal patterns, including more frequent meals that were smaller and occurred closer together in time(DeVries and Chevaux 2014). Cows fed live yeast ruminate longer and have fewer periods of high rumen temperature. Despite selecting more against the most extended, fibrous diet particles, yeast-supplemented cows had better milk fat content and output(DeVries and Chevaux 2014).

Another study found that LY and yeast fermentation products had the same effect on ruminal fermentation in vitro (de Ondarza et al 2010). However, none of the studies compared the two in a way that was not direct. When dairy

calves were inoculated with pathogenic E. coli, it was discovered that adding yeast culture at 2% of the grain fed from 2 to 70 days of age increased neutrophil activity. Calves fed yeast culture had fewer days with moderate or watery diarrhoea, and the number of instances of fever per calf was similarly reduced(Salah Hamed 2022). LY reduced the dairy cows' rectal temperature and respiratory rate while increasing feed intake and milk performance. Live yeast increased fermentation in the rumen but did not affect fermentation in the hindgut. The microbiota in the rumen and hindgut were transformed by LY, with bacteria being enriched in the pathways of glucose, protein, and other substance metabolism (Li et al 2023). Overall, LY supplementation improved the microbiota and fermentation in the rumen and hindgut of dairy cows subjected to heat stress(Li et al 2023). According to Perdomo et al (2020), chewing time per kilogram of NDF increased linearly with increasing LY dosages (71.6, 71.3, and 81.6 min/kg, respectively). Dietary net energy during lactation increased by 5.2 percent, from 1.72 Mcal/kg of DM for 0 g of LY to 1.81 Mcal/kg for 1 g of LY (Perdomo et al 2020). Yeast has been shown in several studies to make milk production better, but the results have been mixed (Sousa et al 2018). The sentence suggests that, depending on which studies are looked at, we could draw either positive or negative conclusions about the effects of yeast supplementation on a specific parameter.

The authors have done everything they can to include all the necessary information about adding yeast to the diets of ruminants, but they cannot make any promises. Even though the data from the studies we looked at were very different, having so many sources helped us determine the yeast's most important effects. A meta-regression analysis of the covariate influence showed that adding live yeast products to cattle diets made them produce more milk (t=6.828; *P* = .001) and eat more feed (t=5.754; *P* = .001). Yuan et al (2015) similarly demonstrated quadratic dosage effects for prepartum feeding behavior, resulting in decreased meal size, meal length, and intermeal interval and increased meal frequency in cows receiving 30 and 60 g/d of LY supplementation. Even so, Table 3 shows that the microbiota and the average amount of fermentation in the rumen have improved (t=4.560, *P* = .005). For some research, information was only available in short summaries, posters, or messages. For other research, there were no publications at all. Findings that do not meet the significance threshold are rarely reported in abstracts, posters, and short presentations, which may add bias to the meta-analysis. There are a few possible reasons for this. Still, the most likely ones are publishing negative results that are not likely to change in the future or putting preliminary data in an abstract instead of a published scientific study.

Live strains of *Saccharomyces cerevisiae* have been shown to improve how well animals do and speed up how quickly fibers break down. When live yeast is added to the diet of livestock as a supplement, it enhances the activity of the rumen and lowers the redox potential because oxygen is taken away. Live *Saccharomyces cerevisiae* strains make it easier for animals to grow and for fibers to break down (Mosoni et al 2007; Marden et al 2008). Live yeast supplements are suitable for the rumen in several ways, such as speeding up fermentation in the rumen and lowering redox potential by removing oxygen. Because of this change, the pH of the environment has gone up because more of these growth elements (like organic acids and vitamins) are available, and the rumen microbiota can do well (Guedes et al 2008). Because of the lower occurrence of such health problems, the proportion of calves treated with anti-inflammatory and anti-diarrhoea products was lowered, as was the proportion of calves treated with antibiotics (for yeast culture compared with control). Because of the increase in income with calf value, net income was roughly $0.48 greater for calves fed with a yeast culture(Salah Hamed 2022). After 13 days, the mortality rate was significantly reduced with yeast culture. Yeast culture had a 6-fold lower mortality risk on day 13 than the control. According to Rossow et al (2018), day-to-day feeding, unpredictability in nutrients supplied, cow mobility between pens, and social interactions between cows in large pens (stress) mainly impact milk yield more than cows supplemented with LY production. No research has been done on the growth potential of DM and how well it breaks down in the rumen of tropical and subtropical forages. No matter what stage of lactation a dairy cow is in, different kinds of forage could speed up their decline. LY supplementation to dairy cows during the hot season improved the rumen environment, which increased dry matter intake and, as a result, production and efficiency (Moallem et al 2009).

The yeast's use of oxygen in the rumen can explain why NDF is easier to digest after being mixed with yeast because the cellulolytic microorganisms like *Fibrobacter succinogenes*, *Ruminococcus albus*, and *Ruminococcus flavefaciens* thrive (Moya et al 2009; Dias et al 2018). Yeast provides vitamins, amino acids, and organic acids, which are essential for the growth of ruminal bacteria and, by extension, the microbiota (Abd El-Ghani 2004). According to Ogunade et al (2019), some bacterial taxa that responded to treatment with a live *S. cerevisiae*-based additive had favourable correlations with metabolites involved in amino acid metabolism and biosynthesis, as well as energy substrate metabolism. Metabolism research has revealed that adding yeast to the rumen increases the number of microorganisms that break down amino acids and produce energy (Ogunade et al 2019).

Some evidence suggests that the higher number of protozoa in the rumen may have helped NDF break down better. Because ruminal microbes help each other during colonization and fiber digestion (Moya et al 2009) Stella et al (2007) also reported that an increase in the protozoa population makes it easier for NDF to be digested. The sentence suggests that, depending on which studies are looked at, you could draw either positive or negative conclusions about the effects of yeast supplementation on a

specific parameter. The authors have done everything they can to include all the necessary information about adding yeast to the diets of ruminants, but they can't make any promises. Even though the data from the studies we looked at were very different, having so many sources helped us determine the yeast's most important effects. Recent research suggests that yeast can impact metabolism, growth, and health. Because available energy is essential for immune activation, any change in metabolism or energy availability may influence immunological responses(Sanchez et al 2021).

5. Conclusions

Some studies observed a positive effect of the addition of yeast product in the diet of cattle on all the parameters, some did not find any effect, and only a few studies observed a negative impact. Analyses of selected studies showed that using live yeast products in the cattle diet significantly increased the LP and FI. However, it enabled a higher average RF and RM Furthermore, the timing of live yeast culture before calving could influence the performance and ruminal parameters, especially their gut microbiomes. A little increase in the daily milk yield, mean daily BW gain and lower SCS was also observed by adding LY. However, no notable increase in the final BW was observed. For many years, dietary supplementation has been utilized to promote animal growth, health, feeding behaviour, and production performance and decrease illness risk. Yeast and yeast products are a class of supplements with numerous uses in cattle production. These advantages include increased milk output and quality, weight gain, animal health, and immunity. Dairy producers can profit by boosting production and improving animal management and health. In conclusion, this meta-analysis indicated that feeding live yeast (*Saccharomyces cerevisiae*) could improve animal performance and rumen health. However, further research is required to study its effect on feed intake and rumen microbiota in dairy cattle**.**

Ethical considerations

Not applicable.

Conflict of Interest

We certify no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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