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Effect of sun dry brewer spent yeast on chemical composition, in vitro digestibility, and ruminal degradation kinetics of wheat straw

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Abstract

Background Dry brewer spent yeast (DBSY) has high crude protein (CP) (43.2%) and metabolizable energy (14.3 MJ/kg) contents and it is an alternative animal feed for the improvement of the productive and reproductive performance of the animals. This study was conducted to evaluate the effect of DBSY on the chemical composition, in vitro digestibility, and in situ degradability of wheat straw (WS).

Methods Liquid brewer spent yeast (BSY) and water was mixed at a ratio of 1:5, respectively. The mixed debris soaked for 7 h in a 200-L plastic bucket. The water accumulated above the biomass was removed by tilting the container after the BSY was soaked in water. After three days of sun drying, DBSY was collected and removed with a scraper. The DBSY and wheat straw (WS) mixed uniformly. Different ratios of DBSY: WS (0:100, 10:90, 20:80, 30:70, 40:60, and 50:50, respectively, on a DM basis) were prepared. Based on these ratios, the experiment was subjected to a completely randomized design with six treatments comprising DBSY0, DBSY10, DBSY20, DBSY30, DBSY40, and DBSY50. Rumen liquor was collected from the three cannulated Boran-Friesian steers (42 months old and weighed 480 kg). The steers were fed natural pasture hay ad libitum supplemented with 2 kg concentrate per day/head. The sample was incubated in a test tube at 39 °C for 48 h with 10 ml of rumen fluid and 50 ml of buffer solution. The enzymatic digestion with acid pepsin solution was continued for another 48 h. Blank and standard samples were also incubated with buffered rumen fluid for correction and precision check-up of in vitro organic matter digestibility. Digestible organic matter in the dry matter (DOMD) was determined after drying and ashing the residues. The sample (3 g and 2 mm sieve size) with nylon bags (6.5 X 14 cm and 50 µm pore size) was entered sequentially and manually pressed deep into the liquid phase of the ventral sac of the rumen and incubated in the rumens (6, 12, 24, 48, 72, and 96 h) of three fistulated Boran × Holstein–Friesian steers. After removing the bags from the rumen, it was washed in running water for 20 min. The bags with residues were dried at 55 °C for 72 h in an air-forced oven, hot weighed, and finally, the residues recovered for further CP and neutral detergent fibre (NDF) analysis.

Results The highest ash, metabolizable energy, estimated digestible CP, DOMD, CP, Ca, P, Cu, Zn contents and the better DM, NDF, and CP ruminal degradability, and the lowest ($P < 0.01$) crude fibre, acid detergent fibre, NDF, K & Fe contents were observed in DBSY50 than the other DBSY inclusion level. In DBSY50, the potential degradability (PD)

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and effective degradability (ED) for DM of WS were improved by 52.22% and 56.17%, respectively. In DBSY50, PD and ED (NDF) in WS were increased by 60.34% and 65%, respectively. Similarly, in DBSY50, PD and ED (CP) of WS also improved by 54.20% and 63%, respectively.

Conclusion The inclusion of DBSY can improve the limited utilization of wheat straw, but this study should be verified with a feeding experiment to identify and recommend the most promising, economical and biological inclusion level of DBSY.

Keywords Dry brewery spent yeast, Nutritional Values, Rumen degradability, Wheat Straw

Background

Brewer-spent yeast (BSY) is the second largest but the least used by-product of feed from the brewing industry commonly used as feedstuff for pigs, ruminants, poultry, and fish (Huige 2006). As a by-product in the manufacture of beer and wine, spent yeasts are increasingly used not only as animal feed additives but as valued and fairly inexpensive nutrition products (Rakowska et al. 2017). It is a source of protein (40–56%, DM basis) and B-complex vitamins, nucleic acids, and minerals (Tacon and Metian 2009). Brewer's yeast slurry is an effective animal diet and increases the fat and total solid contents of cow milk (Wijerathna et al. 2020). Active BSY is used in ruminant nutrition to improve feed efficiency and performance and, at the same time, to prevent health disorders (McAllister et al. 2011). Yeast-fermented with corn dust and cassava pulp at different ratios (40:60, 20:80, and 0:100%) and ensiled for 15 days improve the nutritive value and in vitro rumen fermentation characteristics (Lunsin et al. 2020). Yeast waste can be replaced with soybean meal and had no negative effect on gas kinetics, rumen fermentation and *in- vitro* DM & OM digestibility (Cherdthong et al. 2018). The addition of yeast and yeast-containing substances boosts the animals' growth performance and health benefits (Shurson 2018). The inclusion of liquid BSY (up to 30%) in the cassava silage can increases the chemical composition and decrease in-vitro gas production of a feed (Kamphayae et al. 2017). Similarly, the use of BSG (20%) in corn silage boost *in-vitro* DM digestibility and fermentation quality (Dai et al. 2022, and Kim et al. 2015). Instead of fish meal and soybean meal, pigs are given a diet that contains some BSY, which promotes growth and feed conversion (Bo et al.2020). The replacement of BSY with corn gluten meal (25%) improves growth performance, carcass and internal organ characteristics of broiler chickens (Ciurescu et al. 2021). An optimal range of inclusion and substitution of soybean meal with dry BSY in C. gariepinus feed is between 1 and 14% of DM (Solomon et al. 2017). Low DM content, which impedes transport, storage, and preservation, is the primary limiting issue for the efficient use of BSY, but it can be remedied by drying (Terefe 2022). This study aimed to investigate the effects of DBSY inclusion on WS chemical composition, in vitro digestibility, and in situ degradability.

Materials and methods

Description of study area

The experiment was carried out at Holetta agricultural research center, which is located 29 km west of Addis Ababa, Ethiopia. The center is located at 9° 03′28.82″ E latitude and 38° 30′17.59″ E longitude at an elevation of 2400 m above sea level. The average annual rainfall in the area is 1144 mm, while the average daily temperature ranges from 6 to 21 °C.

Sample preparation and experimental design

Liquid brewer spent yeast was collected from the Heineken brewery industry, in Ethiopia. Brewer spent yeast (BSY) was inactivated (80 °C) in the factory and the hot BSY was collected with plastic buckets (400 L) and transported by car to the research center. It was stored for approximately 12 h and allowed to cool before being mixed in 1:5 ratios with water, respectively. The mixed materials were kept in plastic buckets. The buckets were placed in a fixed location and given time for the biomass (residues) to settle in the material's foundation. The water that had accumulated on top of the biomass was easily removed after the BSY had been soaked in water for 7 h by tilting the buckets. The floor was properly cleaned; the biomass was poured over it and exposed to the sun for three days to dry. The DBSY was collected and removed with a scraper. The wheat straw (WS) and DBSY were mixed uniformly. Different ratios of DBSY: WS (0:100, 10:90, 20:80, 30:70, 40:60, and 50:50 respectively, on DM basis) were prepared. Based on these ratios, the experiment was subjected to a completely randomized design with six treatments comprises: DBSY0, DBSY10, DBSY20, DBSY30, DBSY40, and DBSY50.

Chemical analysis

The DBSY & WS samples were ground in a 1 mm sieve size and analysed at the Holeta agricultural research center in animal nutrition and soil and plant laboratories. The samples and residues after *in-situ* dry matter (DM)

degradability were analysed through a standard procedure of (AOAC 1990) for DM, crude protein (CP), crude fibre, and ash. The fiber fractions (neutral detergent fiber, acid detergent fibre, and lignin) were analysed by the procedures of Van Soest et al. (1991). Macro (Ca, P, Na, and Mg) and micro minerals (Cu, Fe, Mn, and Zn) of the feed were analysed through flame and atomic absorption spectrophotometer procedure (AOAC 1990).

The digestible crude protein (DCP) of the feed was calculated by using the following formula (Church and Pond 1982).

$$\text{DCP}\ (\text{g}) = 0.929 * \text{CP}\ (\text{g/kg}) - 3.48$$

In vitro dry matter digestibility

The DM digestibility of the feed was determined using the two-stage Tilley and Terry (1963) method. Rumen liquor was collected and transported into the laboratory using thermos flasks and pre-warmed to 39 °C before the daily meal of the three cannulated Boran-Friesian steers. The steers were 42 months old and weighed 480 kg. The steers were fed natural pasture hay (6% CP, on DM basis) ad libitum supplemented with 2 kg concentrate mixture (19.86% CP, DM basis) per day/head. The sample (0.5 g) was incubated in a test tube at 39 °C for 48 h with 10 ml of rumen fluid and 50 ml of buffer solution. After the microbiological digestion, the enzymatic digestion with acid pepsin solution (i.e. 5 ml per tube) was continued for another 48 h. Blank and standard samples were also incubated in duplicate with buffered rumen fluid for correction and precision check-up of *invitro* organic matter digestibility. Digestible organic matter in the dry matter (DOMD) was determined after drying and ashing the residues. Estimated Metabolizable energy (EME) was calculated by using the formula (McDonald et al. 2002):

$$\text{EME}\ (\text{MJ/kg}) = 0.16 * \text{g DOMD/kg DM}$$

In situ degradability

The rumen degradability of the feeds was evaluated by Orskov and McDonald's (1979) procedure. Duplicated samples (2 mm) were weighed (3 g) and entered in nylon bags (6.5 X 14 cm with 50 µm pore size) and incubated in the rumens of three fistulated Boran × Holstein–Friesian steers. The steers were 42 months old and weighed 480 kg. The steers were fed natural pasture hay (6% CP) ad libitum and two kg concentrate mixture (19.86% CP) feed every day, half in the morning and the rest half in the afternoon (8 A.M, and 4 P.M, respectively). The steers were housed in individual pens and provided water *adlibitum*. The two nylon bags per sample were entered sequentially and manually pressed deep into the liquid phase of the ventral sac of the rumen and incubated for 6, 12, 24, 48, 72, and 96 h. After removing the bags from the rumen and washed them in running water for 20 min. The washing losses were determined in duplicate by weighing nylon bags with 3 g feed and then soaking them in tap water for 30 min. The nylon bags with residues were dried at 55 °C for 72 h in an air-forced oven, hot weighed and finally, the residues were recovered for further CP and NDF analysis. Ruminal DM, CP, and NDF degradability (%) were calculated as the difference of DM, CP, and NDF (g/kg DM) in the residues and original samples.

DM degradability (%) was calculated by

$$= \frac{((BW + S1) - (BW + RW))}{S1 * DM} * 100$$

where: BW = Bag weight (g), RW = Residue weight (g), S1 = Sample weight (g), DM = Absolute dry matter (%) of the original sample

CP degradability (%) was calculated by

$$= \frac{CP\ in\ the\ feed - CP\ in\ the\ residue}{CP\ in\ the\ feed} * 100$$

NDF degradability (%) was calculated by

$$= \frac{NDF\ in\ the\ feed - NDF\ in\ the\ residue}{NDF\ in\ the\ feed} * 100$$

Statistical analysis

The model used for laboratory data was a completely randomized design, Yij = µ + Fi + eij where: Yij = response variable, µ = Overall mean, Fi = i^{th} feed (yeast ratio) effect, and eij = random error. In situ DM, CP, and NDF degradability trials were fitted into the exponential models of Orskov and McDonald (1979) as: P = a + b (1—e^{-ct}); where; P = disappearance of DM, CP, and NDF in the rumen at time t; a = the washing loss fraction; b = the insoluble but slowly degradable fraction; c = the rate at which the "b" fraction degraded (in % h^{-1}). Similarly, the effective degradability of DM, CP, and NDF were calculated by the equation of Orskov and McDonald (1979) as ED = a + b[c / (c + k)], Where; k = the rumen outflow rate. Data from all trials were subjected to analysis of variance using the general linear model procedures of the statistical analysis system, version 9.3 (SAS 2014). Mean separations were made using the analysis of the least significant differences at $p \leq 0.05$.

Table 1 Chemical composition of wheat straw and dry brewery spent yeast

Feeds	Parameters (g/kg DM)								EME(MJ/kg DM)
	DM	Ash	CP	CF	NDF	ADF	ADL	DOMD	
WS	923	67	56	425	756	507	56	432.4	6.91
DBSY	935	12.5	432	151	75.4	13.2	5.2	894.5	14.31
	Macro minerals(g/kg DM)					Micro minerals (mg/kg DM)			
	Ca	P	K	Mg	Na	CU	Fe	Zn	Mn
WS	5.28	0.82	11.52	1.25	0.12	4.23	188	19.56	37.05
DBSY	6.74	4.93	1.84	1.72	0.23	19.45	117	115	37.30

DM Dry matter, *CP* Crude protein, *NDF* Neutral detergent fibre, *CF* Crude fibre, *ADF* Acid detergent fibre, *ADL* Acid detergent lignin, *DOMD* Digestible organic matter in the dry matter, *EME* Estimated metabolizable energy, *WS* Wheat straw, *DBSY* Dry brewer spent yeast

Table 2 Chemical composition (g/kg DM) and metabolizable energy (MJ/Kg DM) of wheat straw mixed dry yeast

Inclusion level	DM	Ash	CP	CF	NDF	ADF	ADL	DOMD	EDCP	EME
DBSY0	923.8	66.0^{d}	54.5^{f}	420.8^{a}	761.9^{a}	503.0^{a}	57.5^{a}	431.9^{f}	504.0^{f}	6.91^{f}
DBSY10	928.3	73.3^{c}	97.0^{e}	386.1^{b}	688.9^{b}	459.7^{b}	51.0^{b}	482.6^{e}	548.9^{e}	7.73^{e}
DBSY20	928.0	74.5^{c}	134.1^{d}	340.3^{c}	616.4^{c}	410.0^{c}	43.5^{c}	524.0^{d}	590.3^{d}	8.39^{d}
DBSY30	928.4	76.9^{bc}	169.1^{c}	301.1^{d}	549.7^{d}	361.2^{d}	41.0^{d}	570.5^{c}	635.4^{c}	9.13^{c}
DBSY40	934.3	79.0^{ab}	211.4^{b}	261.8^{e}	480.2^{e}	312.8^{e}	35.9^{e}	619.3^{b}	678.0^{b}	9.91^{b}
DBSY50	936.8	81.5^{a}	241.9^{a}	218.6^{f}	419.6^{f}	260.7^{f}	30.4^{f}	663.5^{a}	720.3^{a}	10.62^{a}
SEM	0.27	0.10	0.29	0.27	0.31	0.18	0.11	0.19	0.09	0.08
P –value	0.06	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Mean values in the rows without common letters are significantly different at ($p < 0.05$)

DBSY0, DBSY10, DBSY20, DBSY30, DBSY40 and DBSY50 mixture ratios of DBSY:WS at 0:100, 10:90, 20:80, 30:70, 40:60 and 50:50 respectively, on dry matter basis

DM Dry matter, *CP* Crude protein, *NDF* Neutral detergent fibre, *CF* Crude fibre, *ADF* Acid detergent fibre, *ADL* Acid detergent lignin, *DOMD* Digestible organic matter in the dry matter, *EDCP* Estimated digestible crude protein, *EME* Estimated metabolizable energy, *SE* standard error of means, *DBSY* dry brewery spent yeast

Results

Chemical composition

The nutritional composition of sun-dried brewery spent yeast (DBSY) and wheat straw (WS) before mixing is presented in Table 1. The DBSY had a higher CP (432 g/kg DM) but lower ADF, NDF &CF content than WS. Table 2 provide information on the chemical composition of WS and DBSY mixtures feed. The total ash, CP, DOMD, EDCP, and ME contents were increased ($P < 0.05$) with an increasing level of DBSY, whereas all other components were decreased ($P < 0.01$) as increased the level of DBSY. It was found that adding DBSY (50%) to WS boosted CP content by 74.47%.

Macro and micro minerals

The macro minerals (Ca, P, and K) were significantly increased ($P < 0.001$) as the level of DBSY was increased in the mixture feed but, the other macro minerals (Mg and Na) were not significantly affected as the proportion of DBSY increased in the mixture feed. Except for manganese (Mn), the contents of micro minerals (Cu, Fe, and Zn) were significantly decreased ($P < 0.001$) as the proportion of DBSY increased in the mixture of the feed (Table 3).

Dry matter degradability

Table 4 shows ruminal DM degradability parameters (a, b, c, PD, and ED) of the DBSY and WS mixture feeds. The highest ($P < 0.01$) DM degradability parameters were observed in DBSY50 as compared to the other DBSY inclusion level. In the inclusion level of DBSY50, the PD and ED (DM) of WS were improved by 52.22% and 56.17%, respectively. Similarly, as the DBSY inclusion level and incubation period of the feed increased, the ruminal DM degradation kinetics also increased (Fig. 1).

Neutral detergent fibre degradability

Table 5 shows the degradability of NDF and its parameters such as a, b, c, PD, and ED in different DBSY and WS mixture ratios. The highest NDF degradability parameters (a, b, c, PD, and ED) ($P < 0.01$) were observed in DBSY50 and it improves the PD and ED (NDF) of the WS by 60.34% and 65%, respectively. Likewise, as the

Table 3 Macro and micro minerals contents of wheat straw mixed with dry brewery spent yeast

Inclusion levels	Macro minerals(g/kg DM)					Micro minerals (mg/kg DM)			
	Ca	P	K	Mg	Na	CU	Fe	Zn	Mn
DBSY0	5.30^{f}	0.89^{f}	11.57^{a}	1.30	0.17	4.28^{f}	188.05^{a}	19.61^{f}	37.10
DBSY10	5.48^{e}	1.28^{e}	10.60^{b}	1.35	0.18	5.80^{e}	180.95^{b}	29.15^{e}	37.13
DBSY20	5.62^{d}	1.65^{d}	9.63^{c}	1.39	0.19	7.32^{d}	173.85^{c}	38.70^{d}	37.15
DBSY30	5.74^{c}	2.05^{c}	8.67^{d}	1.44	0.20	8.85^{c}	166.75^{d}	48.24^{c}	37.18
DBSY40	5.88^{b}	2.51^{b}	7.70^{e}	1.74	0.46	10.62^{b}	159.90^{e}	58.04^{b}	37.45
DBSY50	6.06^{a}	2.93^{a}	6.73^{f}	1.79	0.48	12.14^{a}	152.80^{f}	67.58^{a}	37.48
SEM	0.04	0.04	0.05	0.18	0.18	0.18	0.18	0.18	0.18
P-value	0.001	0.001	0.001	0.34	0.65	0.001	0.001	0.001	0.53

Mean values in the rows without common letters are significantly different at ($p < 0.05$)

DBSY0, DBSY10, DBSY20, DBSY30, DBSY40 and DBSY50 mixture ratios of DBSY:WS at 0:100, 10:90, 20:80, 30:70, 40:60 and 50:50 respectively, on dry matter basis

SEM standard error of mean, *DBSY* Dry brewery spent yeast

Table 4 Ruminal dry matter degradation kinetics of wheat straw mixed with dry brewery spent yeast

Inclusion levels	a	b	c	PD	ED
DBSY0	7.65^{f}	26.29^{f}	0.024^{bc}	33.94^{f}	23.23^{f}
DBSY10	12.16^{e}	34.10^{b}	0.016^{d}	46.26^{e}	29.18^{e}
DBSY20	17.81^{d}	33.01^{c}	0.016^{d}	50.82^{d}	33.85^{d}
DBSY30	23.96^{c}	31.81^{e}	0.021^{c}	55.77^{c}	39.89^{c}
DBSY40	29.83^{b}	32.79^{d}	0.025^{b}	62.62^{b}	48.18^{b}
DBSY50	36.04^{a}	35.00^{a}	0.032^{a}	71.04^{a}	53.01^{a}
SEM	0.06	1.24	0.0001	2.45	3.21
P -value	0.05	0.001	0.01	0.05	0.001

Mean values in the rows without common superscripts are different at ($p < 0.05$)

DBSY0, DBSY10, DBSY20, DBSY30, DBSY40 and DBSY50 mixture ratios of DBSY:WS at 0:100, 10:90, 20:80, 30:70, 40:60 and 50:50 respectively, on dry matter basis

[a] Soluble fraction

[b] insoluble but slowly degradable fraction

[c] Degradation rate constant of the b fraction

PD Potential degradability, *ED* Effective degradability (at 0.02), *SEM* Standard error of the mean

Table 5 Ruminal NDF degradation kinetics of wheat straw mixed with dry brewery spent yeast

Inclusion levels	a	b	c	PD	ED
DBSY0	4.25^{e}	16.00^{c}	0.017^{bc}	20.25^{f}	10.12^{f}
DBSY10	5.42^{e}	21.50^{b}	0.019^{b}	26.92^{e}	14.92^{e}
DBSY20	9.78^{d}	21.30^{b}	0.034^{a}	31.08^{d}	21.23^{d}
DBSY30	15.75^{c}	23.20^{b}	0.017^{bc}	38.95^{c}	23.54^{c}
DBSY40	19.62^{b}	24.60^{ab}	0.013^{c}	44.12^{b}	26.69^{b}
DBSY50	22.36^{a}	28.70^{a}	0.005^{d}	51.06^{a}	29.10^{a}
SEM	1.06	2.24	0.0001	2.65	3.21
P -value	0.001	0.05	0.001	0.05	0.001

Mean values in the rows without common superscripts are different at ($p < 0.05$)

DBSY0, DBSY10, DBSY20, DBSY30, DBSY40 and DBSY50 mixture ratios of DBSY:WS at 0:100, 10:90, 20:80, 30:70, 40:60 and 50:50 respectively, on dry matter basis

PD Potential degradability, *ED* Effective degradability (at 0.02), *SEM* Standard error of the mean

[a] soluble fraction

[b] insoluble but slowly degradable fraction

[c] degradation rate constant of the b fraction

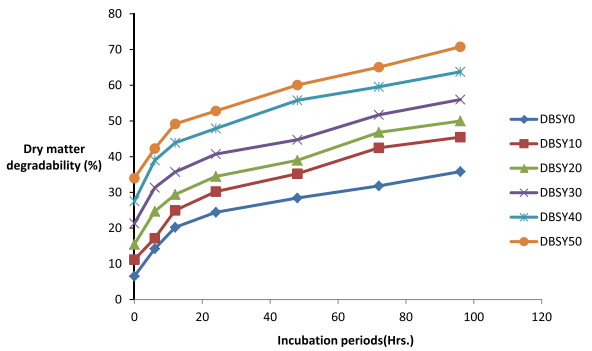

Fig. 1 Ruminal dry matter degradability of wheat straw &dry brewery spent yeast ratio

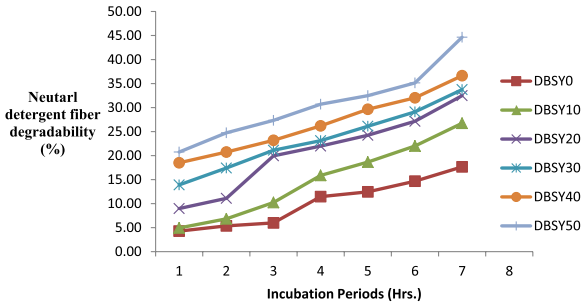

Fig. 2 Ruminal neutral detergent fiber degradability of wheat straw &brewery spent yeast ratio

Table 6 Ruminal crude protein degradation kinetics of wheat straw mixed with dry brewery spent yeast

Inclusion levels	a	b	c	PD	ED
DBSY0	5.30^{f}	24.68^{e}	0.029^{ab}	29.98^{f}	17.42^{f}
DBSY10	8.10e	33.92^{b}	0.025^{c}	42.02^{e}	23.36^{e}
DBSY20	13.30^{d}	33.15^{c}	0.024^{c}	46.45^{d}	27.98^{d}
DBSY30	19.26^{c}	31.93^{d}	0.026^{bc}	51.18^{c}	33.98^{c}
DBSY40	26.24^{b}	31.83^{d}	0.031^{a}	58.07^{b}	42.32^{b}
DBSY50	30.47^{a}	34.99^{a}	0.027^{abc}	65.46^{a}	47.04^{a}
SEM	0.78	0.68	0.001	1.23	1.54
P -value	0.001	0.001	0.001	0.001	0.001

Mean values in the rows without common superscripts are different at ($p < 0.05$)

DBSY0, DBSY10, DBSY20, DBSY30, DBSY40 and DBSY50 mixture ratios of DBSY:WS at 0:100, 10:90, 20:80, 30:70, 40:60 and 50:50 respectively, on dry matter basis

PD Potential degradability, *ED* Effective degradability (at 0.02), *SEM* standard error of the mean, mean

[a] Soluble fraction

[b] Insoluble but slowly degradable fraction

[c] Degradation rate constant of the b fraction

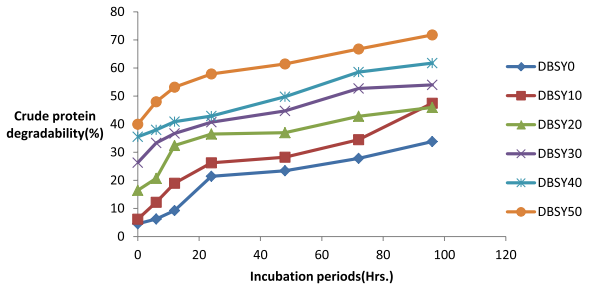

Fig. 3 Ruminal crude protein degradability of wheat straw &dry brewery spent yeast ratio

incubation period and DBSY inclusion level increased, the rate of NDF degradability was also increased (Fig. 2).

Crude protein degradability

The ruminal CP degradability and its parameters such as a, b, c, PD and ED in the different ratios of DBSY and WS are shown in Table 6. The highest CP ruminal degradability parameters (a, b, c, PD and ED) ($P < 0.01$) were observed in DBSY50 and it improves the PD and ED (CP) of the WS by 54.20% and 63%, respectively. As incubation period increased, CP disappearance in the rumen also increased (Fig. 3).

Discussion

Brewery-spent yeast is a desirable ingredient for feed items to increase the nutritional value of the diet because it has high crude protein, minerals, and vitamins (Jaeger et al. 2020). In contrast to the current finding, Chollom et al. (2017) reported lower CF (4.3%), P (0.82%), Ca and Fe composition but approximately similar CP (38%) content in DBSY. Similarly, lower concentrations of Cu (0.22 mg/100 g DM), Fe (3.67 mg/ 100 g DM), Zn (9.96 mg/100 g DM), and Mn (0.15 mg/100 g DM) were reported in DBSY (Jacob et al. 2019). The fibre content of BSY includes ADF (18 g/kg DM) and NDF (62 g/kg DM) reported by Ciurescu et al. (2021) is not comparable with this finding. When DBSY inclusion levels in the WS increased, the fibre fractions (CF, NDF, and ADF) declined but CP and DOMD increased. This finding is consistent with a study by Kamphayae et al. (2017), who found that adding up to 30% liquid BSY to cassava enhances CP content while lowering in vitro gas and keeping fermentation quality such as pH, NH3-N/TN, lactic acid bacteria, volatile fatty acid, and IVDMD. To boost the actual CP content, brewers' grains and rice distillers' by-products ensiled with cassava root are also crucial (Inthapanya and Preston 2016). This finding is supported by the finding of Cherdthong et al. (2018), who suggested that BSY may substitute soybean meal in concentrate diets without affecting in vitro DM and OM digestibility. Using BSY for animal feed would help to reduce environmental pollution. Supplemental craft yeast reduced the amount of methane generated by the fermentation of the bovine and caprine rumen (Pszczolkowski et al. 2016). Cows fed supplementary yeast have better CP digestion (Wohlt et al. 1991). For beef cattle feed, adding yeast (4 g) enhanced the digestibility of DM, OM, and CP (Phesatcha et al. 2021). The buffalo bulls supplemented with yeast culture (Levucell SC20) at a rate of 0.25 g per head per day had no impact on the DM intake (Kumar et al. 2011). The digestibility of CP in the sheep was improved by feeding the two yeast products (inactivated or dried) at a rate of 5 g h^{-1} day^{-1} (Ghoneem and Mahmoud 2014). Although it tended to enhance starch digestibility and quantitatively increased DM & OM digestibility, supplementing beef heifers with yeast (active and killed dried yeast) did not affect apparent total tract nutrient digestibility (Vyas et al. 2014). Supplementing yeast culture to buffalo calves is important to balance Ca & P composition in the animal (Kumar et al. 2011). This finding is supported by Cherdthong et al. (2018), who claimed that BSY may replace soybean meal in concentrate diets without affecting gas dynamics or rumen fermentation. Additionally, after incubating the animal diets for 24 h, the live yeast significantly boosts the DM degradability (by 4.6%) (de Poppi et al. 2021). An *in-vitro* gas generation can be reduced by adding liquid BSY (up to 30%) to the cassava silage (Kamphayae et al. 2017). The fermentation properties and DOMD of the feed were improved by the contribution of the Saccharomyces cerevisiae yeast culture (Maamouri and Ben Salem 2021). Dairy cows receiving yeast supplements performed better throughout lactation in diets

with high or low starch; the mechanisms underlying these effects may include increased rumen pH, fiber digestion, microbial N synthesis, and a decrease in the acute phase (Dias et al. 2018). However, other than an increase in the molar proportion of butyrate, adding yeast supplements to the diet had no positive effects on ruminal fermentation (Bennett et al. 2021). Neither the in situ rumen degradability of DM nor the rumen fermentation characteristics were impacted by the addition of inactivated yeast (50 g) to the ruminant diet (Metwally et al. 2015). Dietary yeast supplements are a popular feed additive in ruminant diets because they can improve animal health and output by altering the rumen microbiota and fermentation (Baker 2021). Similar to this finding, live yeast can increase NDF degradability (by 10.3%) after animal diets have been incubated for 24 h (de Poppi et al. 2021). Live yeast supplementation can help fiber-degrading bacteria and increase fiber digestibility in grazing animals (Sousa et al. 2018). Saccharomyces cerevisiae can stabilize rumen pH and increase fibre degradation and cellulase activity (Ding et al. 2014). Similarly, white rot fungi improve the rumen degradation of oil palm fronds (Hassim et al. 2012). The addition of live and autoclaved yeast cultures can stimulate the ruminal fermentation of the feed (Oeztuerk et al. 2009). The addition of BSG (25–50%) to maize for silage improves fermentation quality and stability against aerobic deterioration (Koc and Coskuntuna 2003). However, direct feeding of yeast products to animals does not affect fibre digestion or microbial CP flow (Robinson et al. 2016). Supplemental BSY reduced the amount of methane produced by bovine and caprine rumen fermentation (Pszczolkowski et al. 2016). Yeast supplementation (4 g) increased DM, CP, and OM digestibility in beef cattle (Phesatcha et al. 2021). Similar to this finding, using yeast-fermented de-hulled rice as a protein source is improves nutrient degradability and in vitro rumen fermentation (Totakul et al. 2020). Live yeast supplementation also improves the NDF degradability of various animal feeds (corn, oat, alfalfa, and tropical grass) (de Poppi et al. 2021) and increases the digestibility of DM, CP, NDF, and OM in beef cattle diets (Phesatcha et al. 2021). However, live yeast supplementation does not have a significant effect on dairy cow performance, rumination time, or rumen pH, and there was no evidence of its benefits (Ambriz-Vilchis et al. 2017).

Conclusion

Chemical composition of WS is improved through the addition of DBSY by increasing total ash, CP, DOMD, Ca, P, Cu, & Zn concentrations while decreasing those of other micro minerals (K & Fe) and fibre components (CF, NDF, ADF &ADL). The ruminal degradation kinetics of DM, CP & NDF was also increased with increasing the proportion of DBSY in the mixture feed. From this study, it can be concluded that inclusion of DBSY (20 to 50%) in the WS has shown better improvement in terms of chemical composition and rumen degradability. However, to identify the most promising economical and biological level of DBSY inclusion, this study has to be verified with feeding trials.

Abbreviations

ADF	Acid detergent fibre
AOAC	Association of official agricultural chemists
BW	Bag weight
BSG	Brewery spent gain
BSY	Brewery spent yeast
CF	Crude fibre
CP	Crude protein
DCP	Digestible crude protein
DOMD	Digestible organic matter in the dry matter
DBSY	Dry brewery spent yeast
DM	Dry matter
NDF	Neutral detergent fibre
ED	Effective degradability
OM	Organic matter
EME	Estimated metabolizable energy
PD	Potential degradability
IVDMD	Invitro dry matter digestibility
RW	Residue weight
SAS	Statistical analysis system
WS	Wheat straw

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Author contributions

GT, GK: Conceived and designed the experiments; Performed the experiments; Contributed reagents, materials, analysis, Tools or data; Wrote the paper. MD, DF, AK, BM, and MW and YH: Analysed and interpreted the data, materials, analysis tools, wrote the paper.

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Availability of data and materials

The data set used /analysed during the current study is available from the corresponding author on reasonable request.

Declarations

Consent for publication

Not applicable.

Competing interests

The authors declared that they have no competing interest.

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