Indian Journal of Animal Sciences **90** (2): 254–258, February 2020/Article

Evaluating potential of wheat varieties at different phenological stages for silage production

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ABSTRACT

This study was aimed to evaluate the effects of variety, harvest stage and their interactions on nutritive profile, feed values and *in vitro* fermentation characteristics of whole crop wheat silage under Indian climate. Four wheat cultivars, sown in randomized block design with 3 replications, were harvested at the head and the milk stage and ensiled in low density polypropylene for 45 days. Results revealed significant effects of wheat cultivar, the harvest stage and its interaction on nutritive profile (CP, NDF, ADF, ADL), feed values (DM intake, Digestible DM, TDN, RFV, Flieg Score), *in vitro* potential (NGP, ME, OM digestibility) and fermentation characteristics (*p*H, lactic acid, ammonical nitrogen) while the variety affected acetic acid, harvest stage NDF digestibility and variety × harvest interaction effected butyric acid significantly. All wheat cultivars exhibited good ensiling characteristics at both phenological stages. However, the lowest ADF content and highest CP, digestible DM, RFV, NE_l values and Flieg Score indicated the variety PBW 725 at head stage as most promising for silage production under Indian conditions.

Key words: Harvest stage, Silage quality, Wheat variety

Wheat (*Triticum aestivum L.*), the main cereal crop in India, is cultivated on 30.6 million ha area during *rabi* season. In addition to grain source, wheat has also potential to be used as hay and silage for ruminants (Crovetto *et al.* 1998, Filya 2003, Weinberg *et al.* 2008). Moreover, wheat has been used as fodder for decades in USA, Australia, Argentina and many Mediterranean countries (Heuze *et al.* 2015). But in developing countries like India, use of whole plant wheat as hay or silage has not been attempted. Due to urbanization and changing feed habits of Indian population towards milk, meat and eggs, large sized population of livestock is required. Hence, there will be shortage of green fodder and dry fodder by 18.4 and 13.2%, respectively at the current growth up to year 2050 (IGFRI Vision 2050). To bridge demand and supply gap of forage resources, wheat silage can be one of the alternatives to feed ruminants.

No doubt, the whole crop wheat can provide good forage for ensiling (Filya *et al.* 2001). But the variation in ensiling process, feed values and fermentation characteristics of silage with wheat variety (Filya *et al.* 2001, Filya 2003) and phonological harvest stage (Crovetto *et al.* 1998, Nadeau 2007) are reported. Ashbell *et al.* (1985) also observed the changes in nutritive composition of wheat plant silage at different maturation stages. Keeping in view the future fodder scenario, a study was planned to evaluate the effects of different wheat cultivars at two phenological stages, the head and the milk stage on nutritive profile, feed values, *in vitro* potential and fermentation characteristics of whole crop wheat silage.

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MATERIALS AND METHODS

Locale of study and soil type: The study was carried out at Department of Animal Nutrition, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana (305452 N, 7548142 E, 230 m above sea level) in collaboration with KrishiVigyan Kendra, Booh (3111342 N, 7454542 E, 228 m above sea level) from November 2018 to March 2019. The soil of experimental area was loamy in texture with *p*H 8.6, electrical conductivity 0.13 m mohs/sec, medium in available nitrogen and phosphorus, and high in available potash.

Wheat cultivars and agronomic practices: Four wheat cultivars (PBW 725, Unnat PBW 343, HD 2967, HD 3086) were selected for study. The crop was sown during 2nd week of November, 2018 with happy seeder in standing stubbles of paddy without burning of paddy straw with row to row spacing of 22.5 cm in randomized block design with 3 replications. Seed rate was kept at 100 kg/ha. About 125 kg diammonium phosphate/ha was drilled at time of sowing and 250 kg urea/ha was applied in two equal splits, i.e. 125 kg/ha each before 1st and 2nd irrigation. Total three irrigations were applied to the crop. Rainfall received during the cropping season was 100.6 mm. Wheat crop was harvested for ensiling at two different development stages, i.e. 1st when the crop was at heading stage (head was fully emerged from the stem) and 2nd when the crop was at milk stage (kernel formation occurs) and ensiled individually for 45 days in low density polypropylene.

Ensiling and analytical procedures: Before ensiling, wheat cultivars were harvested at different harvest stages (Head and Milk stage) and wilted for 24 h down to about 30–35% DM. Wheat cultivars were chopped to approximately 1–3 cm particle length and were ensiled individually for 45 days in low density polypropylene bags in triplicate without adding any additive. After termination of fermentation process (after 45 days), silage bags were opened and representative sample were taken out from each bag, and divided into two parts. One part was used to prepare water extract and other part was dried. Weighed 25 g of fresh silage sample and churned it with 225 ml of lukewarm distilled water in a mixer. The extract was used to determine *p*H, lactic acid (Barker and Summerson 1941), volatile fatty acids and ammonical-N content. The samples were dried at 60°C, finely grounded and were analyzed for DM, CP and total ash (AOAC 2007) and other cell wall constituents (Robertson and Van Soest 1981). Feed values in terms of TDN, NE_l, DMI, RFV, RFQ were worked out (Schroeder 2004). Flieg Score (FS) for silages was worked out with equation suggested by Kilic (1986). The nutritional value of different wheat silages was assessed by *in vitro* gas production (IVGP) technique described by Menke and Steingass (1988).

*Statistical analysis:*The data were subjected to analysis of variance by using SPSS (2012) software version 20.0, taking wheat variety as one factor and their harvest stage as second factor. The means were tested for significant difference by using Tukey's b test. The statistical model used was:

$$Y_{ijk}= \mu+W_i+H_j+(W\times H)_{ij}+e_{ijk}$$

where, Y_{ijk}, the dependable variable (nutritive composition, feed values, fermentation characteristics etc.); μ, population mean; W_i, the effect of i^{th} wheat variety (PBW 343, HD 3086, HD 2967, PBW 725); H_j, effect of j^{th} harvest stage (Head and milk stage); W × H, effect of i^{th} wheat variety at j^{th} harvest stage; e_{ijk}, error. The data on harvest stages (head and milk stage) were subjected to pair t-test to observe effects.

RESULTS AND DISCUSSION

Nutritive values: The optimum dry matter (DM) content is critical for effective packing of fodder in the silo pit as well as for the growth of lactic acid bacteria (McDonald *et al.* 2002). DM content of crop varied (P<0.001) from 30.6% (HD 2967) to 34.7% (PBW 725) among different wheat cultivars at the time of ensiling which was within the range as described by McDonald *et al.* (1991). The nutrient composition of silages of wheat cultivar at different harvest stages has been given in Table 1. There were significant differences in the crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF), ash and organic matter (OM) contents between the harvest stages. Significance differences were also reported among the different wheat cultivars in terms of CP, NDF, ADF, ADL, OM and ash. Significant interactions between the wheat cultivars and the harvest stage were reported for all observed parameters except ADL. Crude protein was high in head stage and declined to a low level with advancing maturity, i.e. milk

Table 1. Nutritive composition of wheat cultivar silages at different harvest stages (% DM)

Parameter	CP	EE	NDF	ADF	ADL	Ash	OM
PBW 343							
Head stage	8.06^b	2.15^a	68.6^b	42.9^b	5.55^a	7.80^a	92.2^a
Milk stage	7.72^a	2.15^a	64.6^a	40.3^a	5.95^a	9.04^b	90.6^b
Mean	7.89^A	2.15^A	66.6^C	41.6^C	5.75^B	8.60^C	91.4^A
HD 3086							
Head stage	8.51b	1.90^a	64.5^a	36.3^a	4.45^a	7.7^a	92.3^b
Milk stage	7.25a	2.15^a	62.9^a	36.2^a	5.75^a	8.00^b	92.0^a
Mean	7.88^A	2.02^A	63.7^B	36.3^B	5.10^A	7.88^B	92.1^B
HD 2967							
Head stage	8.80^b	2.25^a	64.2^a	35.95^a	4.35^a	7.4^a	91.6^a
Milk stage	7.12^a	2.20^a	62.6^b	35.90^a	4.75^a	7.5^b	92.5^b
Mean	7.96^A	2.23^A	63.4^B	35.9^B	4.55^A	7.90^B	92.1^B
PBW 725							
Head stage	9.70^b	2.25^a	63.8^b	34.5^a	4.40^a	7.35^a	92.65^a
Milk stage	8.33^a	2.00^a	61.2^a	34.6^a	4.65^a	7.25^a	92.75^a
Mean	9.02^B	2.13^A	62.5^A	34.6^A	4.53^A	7.30^A	92.7^C
Statistics							
Wheat cultivar (W)	***	ns	***	***	**	***	***
Harvest stage (H)	***	ns	***	**	ns	**	**
W×H	***	ns	*	**	ns	***	***

Harvest means within each wheat cultivar having different superscript small letters are significantly different, Wheat cultivar means with different superscript capital letters are significantly different, *Significant at P<0.05, **Significant at P<0.01, ***Significant at P<0.001, stage. The results are in agreement with findings of Filya (2003) who also reported decrease in CP content with maturity in tested cultivars.

Moreover, protein in fresh wheat at all maturation stages is in bound form while ratio of free amino acids increases on ensiling (Ashbell *et al.* 1985). Crude protein ratio ranged between 7.88 to 9.02% for different wheat cultivars. While the highest (P<0.001) value was obtained in cultivar PBW 735, the cultivars PBW 343, HD 3086 and HD 2967 showed CP ratios statistically similar to that of PBW 725. The cell wall fractions, i.e. NDF and ADF ratio, which are digestibility indicators of silage, varied significantly. Depending on the cultivars, NDF concentration varied from 62.5 to 66.6% and ADF content from 34.6 to 41.6%, however, the lowest values with respect to both characteristics were observed from cultivar PBW 725 and the highest values were obtained in cultivar PBW 343. The values obtained in this study agreed with those of Crovetto *et al.* (1998) for similar stage. Moreover, the higher NDF concentration at head stage was because of more mature plants containing grains filled with starch which diluted the NDF concentration in the whole plants. The ADF contents also showed tendency to decrease but with no statistical significance (P=0.053). However, significant rise in ADF content at milk stage was obvious with development of the lignocellulose complex in mature plants.

Feed values: The effects of wheat cultivars, the harvest stage and the variety × harvest interactions were significant except digestible DM and NE_L, which remained indifferent between the harvest stages (Table 2). Dry matter intake varied between 1.80 to 1.92% with the highest value for the silage from cultivar PBW 725 and the lowest value cultivar PBW 343. The energy content of feedstuffs expressed in terms of total digestible nutrient (TDN, %) or net energy lactation (NE_l, Mcal/kg) and was higher (P<0.001) for PBW 725 as compared to other wheat cultivars, which attributed towards their significantly lower ADF content. With increase in lignin content of forage, energy content decreased. The lowest values for TDN (58.7%), NE_l (1.32 Mcal/kg), digestible DM (56.8%), relative feed value (RFV; 79) and relative forage quality (RFQ; 1.89) were observed in PBW 343 wheat cultivar. The RFV is used to compare DM intake and digestible DM (Kilic 2010) qualities of similar forages. The RFV of PBW 725 wheat cultivar was higher (92.2; P<0.000) in comparison to other wheat varieties because of their lowest ratio of NDF to ADF content. With regards to Flieg Score, silages from almost all of the wheat cultivars were of high quality and ranged from 71.5 to 104.3 with the highest value in the silage of cultivar PBW 725 and the lowest one in that of the cultivar HD 2967. Likewise, Kilic (2010) also reported similar values for NE_l, digestible DM, RFV and Flieg Score for whole plant wheat silage in his study.

In vitro *potential:* Table 3 shows the *in vitro* potential of the wheat cultivars at different harvest stage. The harvest stage and the variety × harvest interactions had significant effect on net gas production (NGP), NDF digestibility (NDFD), OM digestibility (OMD) and ME among different wheat silages however the effects of variety obtained in terms of NGP, OMD and ME only. The decreasing order of ME content among different wheat cultivars was PBW 725, HD 2967, HD 3086 and PBW 343. The NGP (ml/g/24 h),

Table 2. Feed values of wheat cultivar silages at different harvest stages

Parameter	DMI, % B.wt.	DDM	TDN	RFV	RFQ	NE_L, M cal/kg	FS
PBW 343							
Head stage	1.75^a	55.5^a	57.8^a	75.2^a	1.80^a	1.30^a	100.7^b
Milk stage	1.86^b	57.5^a	59.6^b	82.8^b	1.98^b	1.34^b	87.0^a
Mean	1.80^A	56.8^A	58.7^A	79.0^A	1.89^A	1.32^A	93.8^C
HD 3086							
Head stage	1.86^a	60.6^a	62.4^a	87.4^a	2.07^a	1.41^a	105.2^b
Milk stage	1.91^a	60.7^a	62.5^a	89.7^a	2.13^a	1.41^a	52.9^a
Mean	1.88^B	60.6^B	62.4^B	88.6^B	2.10^B	1.41^B	77.6^B
HD 2967							
Head stage	1.87^a	60.89^a	62.67^a	88.2^a	2.09^a	1.41^a	90.1^b
Milk stage	1.92^b	60.93^a	62.7^a	90.5^a	2.15^b	1.42^a	52.8^a
Mean	1.89^{BC}	60.9^B	62.7^B	89.4^B	2.11^B	1.42^B	71.5^A
PBW 725							
Head stage	1.88^a	62.0^a	63.7^a	90.4^a	2.14^a	1.44^a	105.6^b
Milk stage	1.96^b	61.9^a	63.6^a	94.1^b	2.23^b	1.44^a	103.0^a
Mean	1.92^C	60.9^C	63.6^C	92.2^C	2.18^C	1.44^C	104.3^D
Statistics							
Wheat cultivar (W)	***	***	***	***	***	***	***
Harvest stage (H)	**	ns	*	**	***	ns	***
W×H	*	*	**	**	**	**	***

Harvest means within each wheat cultivar having different superscript small letters are significantly different, Wheat cultivar means with different superscript capital letters are significantly different, *Significant at P<0.05, **Significant at P<0.01, ***Significant at P<0.001.

Table 3. *In vitro* potential of wheat cultivar silages at different harvest stages

Parameter	NGP ml/g	NDFD (%)	OMD (%)	ME (MJ/kg)
PBW 343				
Head stage	194.0^{b}	43.7^{a}	58.5^{a}	8.07^{b}
Milk stage	177.0^{a}	41.1^{a}	57.8^{a}	7.63^{a}
Mean	185.5^{A}	42.4	58.2^{A}	7.85^{A}
HD 3086				
Head stage	202.0^{b}	46.0^{b}	62.8^{b}	8.19^{b}
Milk stage	184.5^{a}	36.0^{a}	57.8^{a}	7.78^{a}
Mean	193.3^{B}	41.0	60.3^{B}	7.98^{B}
HD 2967				
Head stage	206.0^{b}	49.7^{b}	65.2^{b}	8.43^{b}
Milk stage	190.9^{a}	38.6^{a}	58.4^{a}	7.94^{a}
Mean	198.5^{C}	44.2	61.8^{C}	8.18^{C}
PBW 725				
Head stage	201.0^{b}	45.7^{b}	61.3^{a}	8.37^{a}
Milk stage	194.0^{a}	39.5^{a}	60.1^{a}	8.06^{a}
Mean	197.5^{C}	42.6	60.7^{BC}	8.21^{C}
Statistics				
Wheat cultivar (W)	***	ns	***	***
Harvest stage (H)	***	**	**	***
W×H	**	*	**	***

Harvest means within each wheat cultivar having different superscript small letters are significantly different, Wheat cultivar means with different superscript capital letters are significantly different, *Significant at P<0.05, **Significant at P<0.01, ***Significant at P<0.001,

Table 4. Fermentation characteristics of wheat cultivar silages at different harvest stages (% DM)

Parameter	*p*H	LA	AA	BA	AN, % TN
PBW 343					
Head stage	4.15^{a}	6.44^{b}	1.84^{a}	0.055^{a}	3.88^{a}
Milk stage	4.42^{b}	6.28^{a}	1.73^{a}	0.026^{a}	5.51^{a}
Mean	4.29^{AB}	6.40^{B}	1.78^{C}	0.04^{B}	4.69^{C}
HD 3086					
Head stage	4.25^{a}	6.26^{a}	1.16^{a}	0.00^{a}	2.31^{a}
Milk stage	4.41^{b}	6.04^{a}	1.20^{a}	0.04^{a}	2.84^{a}
Mean	4.33^{AB}	6.15^{B}	1.18^{A}	0.02^{B}	2.58^{A}
HD 2967					
Head stage	4.38^{a}	6.09^{b}	1.08^{a}	0.031^{a}	2.34^{a}
Milk stage	4.41^{a}	5.13^{a}	1.18^{a}	0.036^{a}	3.16^{a}
Mean	4.40^{B}	5.61^{A}	1.13^{A}	0.03^{B}	2.75^{A}
PBW 725					
Head stage	4.24^{a}	6.01^{a}	1.51^{a}	0.00^{a}	2.51^{a}
Milk stage	4.27^{a}	5.70^{a}	1.59^{a}	0.00^{a}	4.58^{b}
Mean	4.25^{A}	5.85^{A}	1.55^{B}	0.00^{A}	3.54^{B}
Statistics					
Wheat cultivar (W)	**	***	***	*	**
Harvest stage (H)	**	**	ns	ns	*
W×H	**	**	ns	*	*

Harvest means within each wheat cultivar having different superscript small letters are significantly different, Wheat cultivar means with different superscript capital letters are significantly different, *Significant at P<0.05, **Significant at P<0.01, ***Significant at P<0.001, AN-Ammonical nitrogen, TN-Total nitrogen.

OMD (% DM) and ME (MJ/kg) were observed to be the highest for HD 2967 and PBW 725 wheat silages. Harvest stage considerably determined the ME content of a silage and this variation in ME values was due to decreasing trends of NGP, CP and ether content of silage of different cultivars from head to milk stage. However, the NDF digestibility (% DM) was similar in different cultivars. Maturity at harvest has the greatest influence on digestibility. The silages prepared from head stage were found to be more digestible than those made from crop harvested at the milk stage which is in line with the findings of earlier studies (Weinberg *et al.* 2008). Higher digestibility of NDF and OM at head stage is an indicator of higher cell wall digestibility due to less linking between lignin and polysaccharides. However ME values were slightly lower as observed by Kilic (2010) which might be due to variation in stage of harvest, ether content and net gas production among different cultivars.

Fermentation characteristics: Wheat cultivar, the harvest stage and its interaction effects on *p*H, lactic acid and ammonical nitrogen were significant (Table 4). The acetate content by the variety and butyric acid concentration by the variety as well as variety × harvest interactions were significant. Fermentation characteristics of cereal silage varied among maturity stages of plants because of higher DM content and changes in the chemical composition of the plants as they develop (Cherney *et al.* 1982). The *p*H of silage ranged from 4.25 to 4.40 which agreed with the findings of Filya (2003). Similarly, lactic acid content ranged from 5.85 to 6.40% on DM basis. Under anaerobic conditions, fermentation of water soluble sugars in forages to organic acids is mainly responsible for decline in *p*H and lactic acid content (Borreani *et al.* 2018). A low *p*H resulted in the optimum production of lactic acid to inhibit the growth of unwanted microorganisms such as *Clostridia* and *Enterobacteria*. In current study, the *p*H and lactic acid levels were within the range of good quality silage as described by McDonald *et al.* (1991).

Acetic acid, which has the biggest impact on aerobic stability ranged from 11.3 to 17.8 g/kg DM for different cultivars and fell within the normal range (10.8–18.4 g/kg DM) advisable for good silages (Muck 2010). Butyric acid is undesirable in good quality silage because of its negative influence on animal health and nutritive quality. In tested wheat silages, the determined butyric acid remained undetectable or detected at very low level which indicated good fermentation process. Langston *et al.* (1958) stated that high quality silage is characterized by low NH_3-N concentration. In present study, ammonia-N content representing destruction of nitrogenous compounds varied from 2.58 to 4.69% of total nitrogen in different wheat silages which indicated that good quality fermentation took place during ensilage.

All wheat cultivars exhibited good ensiling characteristics at both phenological stages of maturity. However, improved nutritive profile, better feeding values, higher *in vitro* potential and good fermentation characteristics at head stage projected PBW 725 and HD 2,967 cultivars as more recommendable. But lowest ADF content and highest CP, digestible DM, RFV, NE_l values and Flieg Score showed that PBW 725 has better potential for ensiling at head stage given conditions.

REFERENCES

AOAC. 2007. *Official Methods of Analysis*. 18th Edition. Association of Analytical Chemists, Gaitherburg, Arlington, VA.

Ashbell G, Theune H H and Sklan D J. 1985. Ensiling whole wheat at various maturation stages: Changes in nutritive ingredients during maturation and ensiling and upon aerobic exposure. *Journal of Agricultural and Food Chemistry* **33**: 1–4.

Barker S B and Summerson W H. 1941. The colorimetric determination of lactic acid in biological material. *Journal of Biology and Chemistry* **138**: 535–54.

Borreani G, Tabacco E, Schmidt R J, Holmes B J and Muck R E. 2018. Silage review: Factors affecting dry matter and quality losses in silages. *Journal of Dairy Science* **101**: 3952–79.

Cherney J H and Marten G C. 1982. Small grain crop forage potential: I. Biological and chemical determinants of quality and yield. *Crop Science* **22**: 227–31.

Crovetto G M, Galassi G, Rapetti L, Sandrucci A and Tamburini A. 1998. Effects of stage of maturity on nutritive value of whole crop silage. *Livestock Production Science* **55**: 21–32

Filya I, Sucu E and Karabulut A. 2004. The effect of *Propionibacterium acidipropionici*, with or without *Lactobacillus plantarum*, on the fermentation and aerobic stability of wheat, sorghum and maize silages. *Journal of Applied Microbiology* **97**: 818–26.

Filya I. 2003. The effect of *Lactobacillus buchneri*, with or without homofermentative lactic acid bacteria, on the fermentation, aerobic stability and ruminal degradability of wheat, sorghum and maize silages. *Journal Applied Microb*iology **95**(5): 1080–6.

Heuze V, Tran G and Baumont R. 2015. Wheat forage. Feedipedia, a programme by INRA, CIRAD, AFZ and FAO. 14:25 https://www.feedipedia.org/node/363

IGFRI Vision 2050: Indian Grassland and Fodder Research Institute, Jhansi, Uttar Pradesh, India

Kilic A. 1986. *Silo feed* (Education, learning, application). Bilgehan Publisher, Barnoa.

Kilic U. 2010. Nutritive values of whole crop wheat hay and silage and effect of microbial inoculants on in vitro gas production. *Journal Applied Research* **37**: 67–71.

Langston C W, Irvin H, Gordon C H, Bouma C, Wismani H G, Melin C G and Moore L A. 1958. Microbiology and Chemistry of Grass silage. *Technical Bulletin* 1187. Washington, USA.

McDonald P, Greenhalgh J, Edwards R A and Morgan C A. 2002. *Animal Nutrition* (6th Ed.). Pearson, Prentice Hall, Addison-Wesley Longman Ltd, England.

McDonald P, Henderson A and Heron S. 1991. *The Biochemistry of Silage*. 2nd edn. Chalcombe Publication, 13 Highwoods Drive, Marlow Bottom, Marlow, US.

Menke K H and Steingass H. 1988. Estimation of energetic feed value obtained by chemical analysis and *in vitro* gas production using rumen fluid. *Animal Research and Development* **28**: 7–55.

Moon N J, Eli L O and Sudweeks E M. 1981. Fermentation of wheat, corn and alfalfa silages inoculated with *Lactobacillus acidophilus* and *Candida* spp. at ensiling. *Journal of Dairy Science* **64**: 807–13.

Muck R E. 2010. *Silage additives and management issues*. Proceedings of Idaho Alfalfa and Forage Conference, Best Western Burley Inn, Burley, Idaho, US. 1–17.

Nadeau E. 2007. Effects of plant species, stage of maturity and additive on the feeding value of whole crop cereal silage. *Journal of Science and Agriculture* **87**: 789–801.

Robertson J B and Van Soest P J. 1981. The detergent system of analysis and its application to human foods, pp. 123–58. *The Analysis of Dietary Fiber in Foods*. Eds. James W P T and Theander O J . Marcel Dekker Inc., New York.

Schroeder J W. 2004. *Silage fermentation and preservation*. NDSU Extension Service. North Dakota State University Fargo, North Dakota 58105.

SPSS. 2012. *Statistical Packages for Social Sciences*. Version 20, SPSS Inc., Illinois, USA.

Weinberg Z G, Chen Y and Solomon R. 2009. The quality of commercial wheat silages in Israel. *Journal of Dairy Science* **92**: 638–34.

Woolford G M, Bolsen K K and Pearl L A. 1982. Studies on aerobic deterioration of whole crop cereal silages. *Journal of Agricultural Science* **98**: 529–35.