Wheat Silage: Effect of Cultivar and Stage of Maturity on Yield and Degradability *in Situ*[†]

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Dry matter (DM) yields and degradability *in situ* of two wheat cultivars—an early-maturing, Bet Hashita (BH), and a late-maturing, Ariel (A), harvested and ensiled at four maturity stages, shooting, flowering, milk, and dough—were evaluated. The wheat was ensiled in minisilos for 90 days. The DM yields (t ha^{-1}) of A tended to be higher than those of BH at all maturity stages. Average neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents of both cultivars were lowest at the shooting stage and highest at flowering stage. Average NDF and ADF contents of A silages were higher than those of BH: 631 vs 582 g kg^{-1} DM and 378 vs 338 g kg^{-1} DM ($P < 0.05$), respectively. *In situ* DM degradability of BH was higher than that of A at all stages of maturity ($P < 0.05$). (average 27.1 vs 20.1%; $P < 0.05$), and it decreased significantly with maturity. *In situ* NDF degradability during 24 h of incubation decreased with maturity in both cultivars ($P < 0.05$) and was higher for BH than for A at the milk stage. Total degradable NDF yields tended to increase with maturity and to be higher in cultivar A. Therefore, A, harvested at a later ripening stage, is preferable to BH as a roughage crop for dairy cattle.

Keywords: *Wheat silage; maturity; in situ degradability*

INTRODUCTION

Wheat is the major crop for silage in Israel. It is usually grown in a double-cropping system on winter rain and harvested in spring, after which the land is cleared for summer crops. Research and development is aimed at finding the most promising cultivars in terms of yields, silage quality, and nutritive value. In the early-maturing cultivars, which are grown mainly for grain, the growth period is short and the ratio of grain to biomass is greater than in the late-maturing ones. This might have nutritional significance: the late-maturing varieties have a long vegetative growth period with a smaller grain to biomass ratio and, therefore, are superior as forage for ruminant feeding. In addition, harvesting later in spring avoids possible rainfall which disturbs silage making. On the other hand, in years of drought, the early-maturing varieties which make full use of the small amount of rain which does fall, might be advantageous.

Ashbell *et al*. (1985) reported that the largest changes in nutritive components of the whole wheat plant occurred between the flowering and milk stages of ripening. During that period, there was an increase in dry matter (DM) and water-soluble carbohydrate (WSC) contents, with no decrease in digestibility. Arieli and Adin (1994) found that wheat silage harvested at the flowering stage was superior to wheat silage harvested at the end of the milk stage, in terms of NDF digestibility and milk yields of lactating cows. It has also been reported that in grass silage, the NDF digestibility decreased with advancing maturity (Panditharatne *et al*., 1989). Garnsworthy and Stokes (1993) found that there was a decrease in the digestibility of energy, fiber, and crude protein (CP) during maturation of wheat for silage.

According to Weinberg *et al*. (1991, 1993), the milk-ripening stage is the optimal stage for silage making. At the flowering stage the DM content is too low and the wheat must be wilted before ensiling; NDF and ADF contents are highest and rumen degradability (after *in situ* rumen incubation for 48 h) is lowest. At the dough stage of maturity, yields are higher but the WSC content has decreased owing to starch accumulation in the grains and the DM content is too high to allow adequate compaction. Thus, conclusions on when to harvest wheat for silage remain contradictory.

The purpose of the current study was to compare yields and degradability characteristics of an early-maturing wheat cultivar (Bet Hashita) with those of a late-maturing cultivar (Ariel), during four stages of plant maturation.

MATERIALS AND METHODS

Early- and late-maturing Israeli wheat cultivars, Bet Hashita (BH) and Ariel (A), respectively, were used in this study. The two cultivars were grown in the Jordan valley experimental farm, under the same conditions (date of sowing, seed rate, fertilizer input, and agrochemical input). Whole wheat plants were harvested at four maturation stages: shooting, flowering, milk, and dough. The yield obtained at each stage was determined by weighing the forage harvested from 1 m^2, in six replicates. The wheat of each replicate was chopped to 10 mm and ensiled in 1.5 l glass jars, equipped with a special spring-loaded lid which permits gas release only (Weck, Germany). The wheat from the shooting and flowering stages was wilted for 24 h, to about 35% DM, before ensiling. The

[†] Contribution from the Agricultural Research Organization, The Volcani Center, Bet Dagan, Israel. No. 1588-E, 1995 Series.

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S0021-8561(96)00336-6 CCC: $14.00

Table 1. Agronomical Data of the Wheat Cultivars Harvested at Four Stages of Maturity

cultivar	stage of maturity	growth period (d)[a]	date of harvest	wheat DM g kg^{-1}	wheat DM yield ton ha^{-1}
Bet Hashita	shooting	101	28.2.93	189^{e}	6.4^{f}
	flowering	111	10.3.93	246de	8.2^{e}
	milk	134	2.4.93	280^{cd}	11.3^{d}
	dough	146	14.4.93	355^{bc}	15.2^{b}
Ariel	shooting	111	10.3.93	173^{e}	8.4^{e}
	flowering	126	25.3.93	199^{e}	9.3^{e}
	milk	141	9.4.93	291^{cd}	13.0^{c}
	dough	160	28.4.93	432^{b}	16.4^{b}
	SEM			22.9	0.39

[a] Emergence to harvesting. [b−f] Within a column, figures followed by different superscripts are significantly different ($P < 0.05$).

Table 2. Chemical Composition (g kg^{-1} DM) of the Wheat Silages of Bet Hashita (BH) and Ariel (A) Cultivars at Different Stages of Maturity

	chemical composition (g kg^{-1} DM)								
	shooting		flowering		milk		dough		
cultivar	BH	A	BH	A	BH	A	BH	A	SEM
DM	347^{bc}	343^{bc}	302^{e}	319^{d}	357^{b}	328^{cd}	348^{bc}	405^{a}	6.3
CP	160^{a}	151^{a}	125^{b}	109^{c}	106^{c}	94^{d}	88^{d}	71^{e}	3.3
Ash	112	125	105	111	105	106	94	105	2.0
NDF	566de	584^{cd}	604^{bcd}	664^{a}	627^{abc}	655^{ab}	533^{e}	620^{abc}	16.0
ADF	327^{cd}	325^{cd}	360^{b}	404^{a}	355^{bc}	406^{a}	312^{d}	378^{ab}	10.5
ADL	71^{d}	66^{d}	91^{bc}	70^{d}	89^{c}	84^{c}	100^{ab}	109^{a}	2.6
pH	4.72^{a}	4.36^{bc}	4.55^{ab}	4.63^{a}	4.03^{d}	4.32^{bc}	4.25^{cd}	4.69^{a}	0.08

[a−e] Within a row, figures followed by different superscripts are significantly different ($P < 0.05$). BH = Bet Hashita, A = Ariel.

jars were stored at 25 °C for 90 days. After the ensiling period the silages were treated as described in the following paragraph.

Analytical Procedure. Dry matter (DM) of the crops and silages was determined by oven drying for 48 h at 60 °C. All samples were ground sufficiently finely to pass through a 1.0 mm screen. Ash content was obtained in a muffle oven after 3 h at 550 °C. Crude protein (CP) was determined by the Kjeldahl method. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined according to Goering and Van Soest (1970). Rumen degradability of the various silages was measured by the *in situ* procedure of Mehrez and Orskov (1977), as described by Arieli *et al.* (1989). Since these workers also found that *in situ* degradability test performed with cows that were fed entirely different rations did not result in differences in degradability of a large number of feedstuffs, all dacron bag incubations in the present study were carried out in triplicates, in one cow, as follows: Air-dried milled samples were placed in 7 × 12 cm bags made of dacron, pore size 10−40 mm, which were inserted into the rumen of a fistulated Israeli-Holstein lactating cow, that was fed a total mixed ration comprising (on DM basis) 20% wheat silage, 10% vetch hay, and 70% concentrates. The feed was provided for *ad libitum* intake. The dacron bags were incubated in the rumen for 3, 6, 9, 12, 24, 36, 48, and 72 h, after which they were removed and were immediately rinsed with cold tap water in a washing machine. Disappearance at zero incubation time was evaluated in bags immersed in water at 39 °C for 1 h (Arieli *et al.*, 1989). Percentage of residual DM was determined after drying the bags overnight at 105 °C. NDF degradability was measured only in bags incubated for 24 h, which in our experience is highly correlated with effective degradability of NDF. Three bag replicates were prepared per sample. Accordingly, there were 18 replicates per maturity stage (six jars × three replicates). These values were used in the calculation of the degradability kinetic.

Calculations and Statistical Analysis. An overall analysis of variance, involving variety, maturity, and incubation times, showed highly significant interactions of all orders. Therefore, separate nonlinear regression analyses were carried out on time, using the SAS (1985) NLIN procedure, for each variety and maturity combination (Orskov and McDonald, 1979). Data were fitted to the exponential: $P = a + b(1 - e^{-ct})$, where P = degradation after t hours and a, b, and c were calculated for each variety and ripeness combination by an iterative, minimal least square program using Marquard procedure. The effective degradability (d) of DM was calculated using those three constants and the estimate rate of particulate outflow from the rumen (k = 4% h^{-1}): $d = a + [(bc)/(c + k)]$. The significance of the differences between treatments was evaluated by Duncan's multiple range test.

RESULTS

Agronomical data of the wheat cultivars at harvest are given in Table 1. There was an average of 14 days difference between the early- and late-maturing cultivars with regard to ripening stages. Dry matter content increased with maturity in both cultivars, with A reaching a higher DM content at the dough stage than BH ($P < 0.05$). The DM yields (t ha^{-1}) of the late-maturing cultivar A also tended to be higher than those of the early-maturing cultivar BH, at the same physiological stages.

The chemical composition (g kg^{-1} DM) of the silages at harvest and at the four stages of maturity is given in Table 2. CP content decreased during maturation from an average of 156 g kg^{-1} at shooting to 80 g kg^{-1} at the dough stage ($P < 0.05$), and it tended to be lower in A than in BH. Ash contents of both cultivars ranged from 94 to 125 g kg^{-1} DM. Average NDF and ADF contents of BH cultivar were lowest at the dough stage, highest NDF at the milk stage of maturity and for ADF at flowering. In A they were lowest at the shooting stage and highest at the flowering and milk stages. In general, the average NDF and ADF contents of A silages were higher than those of BH: 631 vs 582 g kg^{-1} ($P < 0.05$) and 378 vs 338 g kg^{-1} ($P < 0.05$), respectively.

In situ DM degradability of BH and A at successive stages is presented in Figure 1, and fitted exponential constants for DM degradability are given in Table 3. The degradability of BH was higher than that of A at all stages of maturity (Figure 1). Average DM solubility (a) of BH was higher than that of A (41.2 vs 36.7%; $P < 0.05$). Highest DM solubility was obtained in both cultivars at the dough stage. Average DM potentially degradable fraction (b) of BH was higher than that of

Table 3. Fitted Exponential Constants (*a*, *b*, *c*) for Dry Matter Degradability of Bet Hashita (BH) and Ariel (A) Wheat Cultivars at Different Stages of Maturity[a]

stage of maturity	cultivar	*a* (% of DM)	*b* (% of DM)	*c* (% h^{-1})	R^2	SE	*a* + *b* (% of DM)
shooting	BH	41.2^y	31.4^x	0.031^{yz}	0.989	0.88	72.6
	A	35.8^z	25.4^y	0.048^x	0.978	1.40	61.2
flowering	BH	34.1^z	33.8^x	0.027^{yz}	0.976	0.97	67.9
	A	33.7^z	19.3^z	0.039^{xy}	0.966	1.82	53.0
milk	BH	40.0^y	26.2^y	0.024^{yz}	0.973	0.83	66.2
	A	35.0^z	17.1^z	0.028^{yz}	0.973	1.19	52.1
dough	BH	49.3^x	16.9^z	0.028^{yz}	0.950	1.07	66.2
	A	42.1^y	18.5^z	0.020^z	0.930	1.35	60.6
	SEM	1.13	0.71	0.005			

[a] *a* = DM solubility, *b* = ruminal DM degradability, *c* = rate of ruminal DM dissolution. BH = Bet Hashita. A = Ariel. $^{x-z}$ Within a column, figures followed by different superscripts are significantly different ($p < 0.05$).

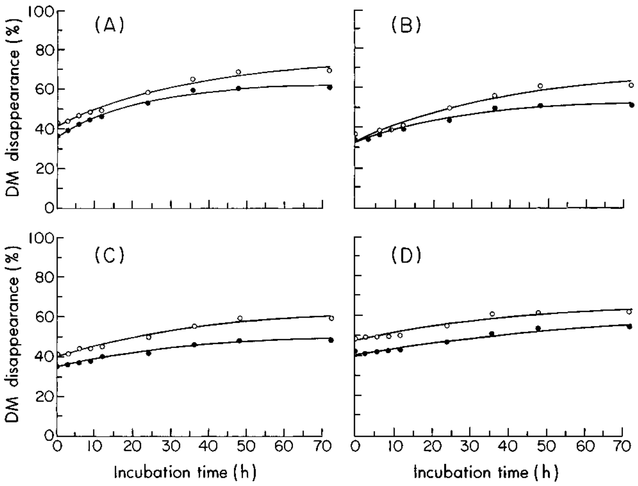

Figure 1. *In situ* dry matter disappearance curves of Bet Hashita (○) and Ariel (●) cultivars silages, harvested at shooting (A), flowering (B), milk (C), and dough (D) maturity stages.

A (27.1 vs 20.1%; $P < 0.05$), and it decreased significantly with maturity. The rate of ruminal DM degradability (*c*) tended to decrease with maturity; a significant decrease in *c* with maturity was obtained only in A. The average combined value of DM solubility plus DM potentially degradable fraction (*a* + *b*) of BH was higher than that of A (68.2 vs 56.7%; $P < 0.05$).

Values for *in situ* DM and NDF degradabilities of BH and A cultivars, during 24 h of incubation, and their calculated degradable yields (t ha^{-1}) are given in Table 4. NDF degradability decreased with maturity in both cultivars ($P < 0.05$) and was higher for BH than for A, at the milk stage. Degradable yields of DM and NDF were increased with maturity, and no significant differences between cultivars were found at all maturity stages.

DISCUSSION

In Israel, the proportion of roughages in the ration for dairy cattle is quite low (25−30%). Roughages are incorporated in rations of dairy cattle in the minimal amounts that are required for the ordinary metabolic and physiological functioning of the rumen. Since wheat silage is the main roughage, it is important to use cultivars which produce high yields of digestible NDF.

Arieli and Adin (1994) reported that when the late-maturing cultivar A, harvested and ensiled at mid-flowering stage, was compared with that harvested and ensiled at the milk stage, the DM yield increased by 30%, but no differences between the two silages in chemical composition and in *in situ* effective degradability of DM were found. However, NDF effective degradability *in situ* was higher for the early harvest than for the late harvest. Dairy cows given the early-harvested wheat silage produced more milk of lower fat concentration. This was attributed by Arieli and Adin (1994) to the improved NDF digestibility. This means that, for dairy cattle feeding, cultivars which are at early stage of maturity at harvest are preferred.

In the present study, wheat DM yields and degradabilities were determined for a wider range of harvesting dates and for two wheat cultivars. The late-maturing variety A had in similar physiological stages higher DM yields throughout the entire growth period than the early-maturing variety BH (Table 1). The nutritional value of the cell-wall components decreased with maturity of both cultivars; this was apparent from a significant increase in ADL and decrease in CP content (Table 2). This was more so in the late-maturing cultivar A than in BH. These parameters are probably related to the age of the plants (days of growth) and not to the actual stage of maturity. Economical considerations should take into account that the growth period of the late-maturing cultivar A is longer, and if intrapolated and compared by days of growth, the DM yields of A at 111, 134, and 146 days are 8.4, 11.4, and 13.9 t ha^{-1}, respectively. This is equal to or even lower than the respective yields of BH (Table 1).

NDF and ADF concentrations in BH silage were highest at the milk stage, whereas in the late-maturing A variety, the NDF and ADF concentrations in the flowering, milk, and dough silages were similar and they were higher than those in BH (Table 2). Results reported by Weinberg *et al.* (1993) confirm that NDF and ADF concentrations in the early-maturing cultivar were lowest at the dough stage. Accordingly, if a wheat crop is grown in order to obtain the highest NDF yield, it is important to evaluate the nutritional value of late-maturation cultivars at the dough stage as well as at the flowering and milk stages.

The highest DM yields were obtained at the dough ripening stage in both wheat varieties (Table 1). The increase in DM yield from flowering to milk and from milk to dough was approximately 40% in both varieties. However, DM degradability of BH was higher than that of A (Figure 1, *a* + *b* in Table 3), owing to its lower NDF content (Table 2) and higher DM solubility (*a* in Table 3). In both varieties, the highest DM solubility was obtained at dough, which can be attributed to the increasing grain to biomass ratio, with progress toward the dough stage, which was much greater in BH than in A (Leshem *et al.*, 1994). As a result, effective

Table 4. Effective DM Degradability and NDF Degradability at 24 h Incubation *in Situ* and Calculated Degradable DM and NDF Yields of Bet Hashita and Ariel Wheat Cultivars at Different Stages of Maturity

				degradable yields (t ha^{-1})	
cultivar	stage of maturity	EDMD[e] (%)	NDFD (%)	DM	NDF
Bet Hashita	shooting	54.9[a]	39.8[a]	3.5[e]	1.5[d]
	flowering	47.7[b]	32.0[b]	3.9[ed]	1.6[d]
	milk	49.8[b]	31.2[b]	5.6[c]	2.2[bc]
	dough	56.3[a]	29.7[b]	8.6[a]	2.4[ab]
Ariel	shooting	49.6[b]	37.4[a]	4.2[d]	1.8[cd]
	flowering	43.2[c]	32.0[b]	4.0[ed]	2.0[bcd]
	milk	42.0[c]	25.4[c]	5.5[c]	2.2[bc]
	dough	48.3[b]	29.3[bc]	7.9[b]	3.0[a]
	SEM			0.19	0.07

[a–d] Within a column, figures followed by different superscripts are significantly different ($P < 0.05$). [e] EDMD = effective DM degradability. NDFD = NDF degradability.

degradable DM yields were similar for both cultivars, at each maturity stage (Table 4).

Differences between varieties and between maturation stages in NDF degradability, which were large at shooting, disappeared at dough (Table 4). Since NDF content (g kg^{-1}) at dough ripening stage, especially degradable NDF, was higher in A, total degradable NDF yields tended to increase with maturity and to be higher in A at dough stage (Table 4). Arieli and Adin (1994) also found that in the A variety the degradability of NDF was higher at the flowering than at the milk stage. The higher milk yield that was obtained from cows fed silage of flowering wheat than from those fed silage of wheat at the milk ripening stage was attributed by them to the higher NDF degradability. The results of the present study indicate that the NDF degradability of A at the dough stage was not lower than that at flowering, whereas the yields of degradable NDF at the dough stage were the highest of the entire growth period.

The determination of optimal harvesting time is affected by three factors: NDF yield, NDF degradability, and ensiling properties. The highest degradability of fiber was obtained at shooting (Table 4), but yields of degradable NDF of BH and A at this stage were only 63 and 60%, respectively, of those at dough stage. In countries where roughage prices are low, the fiber degradability at shooting would not be an important factor in the considerations of when to harvest wheat for silage. However, in Israel and other places where roughages are expensive, yields of degradable fiber, should be considered. At the dough stage, digestible nutrients in addition to digestible NDF derive from the starch accumulated in grains, which could be supplied in concentrates rather than by more expensive roughage. Therefore, the decision on optimal ripening stage at which to harvest wheat for silage should take into account the difference in the yields of digestible NDF and the cost of additional starch between milk and dough stage as compared with the grain cost. It can be assumed that the degradable DM yield (Table 4) includes degradable NDF, starch (mainly toward the dough stage), and soluble nutrients. Accordingly, the additional NDF yield of 0.2 t ha^{-1} in the BH cultivar, from milk to dough, was accompanied by an additional 3.0 t ha^{-1} of degradable DM (1:15 ratio), whereas in A, during the same period, an additional 0.8 t ha^{-1} of degradable NDF was accompanied by only 2.4 t ha^{-1} of additional degradable DM (1:3 ratio). Yield of digestible DM and NDF per hectare will impact economic performance of dairy farm. Therefore, the late-maturing variety A, harvested at a later ripening stage, is preferable. Some of the advantages observed for cultivar A over BH were not significant, and it might be beneficial to have even later maturing cultivars that would exhibit these advantages more clearly.

LITERATURE CITED

Arieli, A.; Adin, G. Effect of wheat silage maturity on digestion and milk yield in dairy cows. *J. Dairy Sci.* **1994**, *76*, 237–243.

Arieli, A.; Bruckental, I.; Smoler, E. Prediction of duodenal nitrogen supply from degradation of organic and nitrogenous matter in situ. *J. Dairy Sci.* **1989**, *72*, 2532–2539.

Ashbell, G., Theune, H. H.; Sklan, D. J. Ensiling whole wheat at various maturation stages: Changes in nutritive ingredieents during maturation and ensiling and upon aerobic exposure. *J. Agric. Food Chem.* **1985**, *33*, 1–4.

Garnsworthy, P. C.; Stockes, D. T. The nutritive value of wheat and oat silages ensiled on theree cutting dates. *J. Agric. Sci. Cambridge* **1993**, *121*, 233–240.

Goering, H. K.; Van Soest, P. J. Forage fiber analysis. *Apparatus, Reagents, Proceeding and Application*; U.S. Department of Agriculture, Handbook No. 379, 1970, pp 1–10.

Leshem, Y.; Kreevack, G.; Dvash, L.; Chefer, Y.; Berkovitz, S. High quality wheat silage from late maturing varieties. *Hassadeh* **1994**, *74*, 1171–1172, 1194 (in Hebrew).

Mehrez, A. Z.; Orskov, E. R. A study of the articifial fiber bag technique for determining the digestibility of feed rumen. *J. Agric. Sci. Cambridge* **1979**, *88*, 645–650.

Orskov, E. R.; McDonald, I. The estimation of protein degradability in the rumen from incubation measurements weighted according to rate passage. *J. Agric. Sci. Cambridge* **1979**, *92*, 499–503.

Panditharatne, S.; Allen, V. G.; Fontenot, J. P.; Jayasuriya, M. C. Effect of stage of growht and chopping length on digestibility and palatability of Guinea 'A' 1005–1009. *J. Anim. Sci.* **1988**, *66*, 1005–1009.

SAS. *SAS User's Guide: Statistics, Version 5*; SAS Institute: Cary, NC, 1985.

Weinberg, Z. G.; Ashbell, G.; Hen, Y.; Harduf, Z. Ensiling whole wheat for ruminant feeding at different stage of maturity. *Anim. Feed Sci. Technol.* **1991**, *32*, 313–320.

Weinberg, Z. G.; Ashbell, G.; Azrieli, A.; Bruckental, I. Ensiling peas, ryegrass and wheat with additives of lactic bacteria (LAB) and cell wall degrading enzymes. *Grass Forage Sci.* **1993**, *48*, 70–78.

Received for review May 21, 1996. Revised manuscript received November 25, 1996. Accepted December 18, 1996.[⊗]

JF960336L

[⊗] Abstract published in *Advance ACS Abstracts*, February 15, 1997.