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Determination of yield nutrient contents and in vitro digestibility of some triticale varieties harvested at different maturity stages

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Abstract: The aim of this study was to determine the contribution of growth performance, nutrient content, and digestibility of different triticale varieties to ruminant diets and to indirectly assist farmers in feed production. The experiment utilized five triticale varieties. The study was designed as a randomized complete block design with split plots and three replications. The digestibility values were determined in vitro after 48 h of incubation using an Ankom Daisy II incubator. Rumen liquid was obtained from dairy cows slaughtered at the Yeşil Vadi Meat Integrated Facility. Nutrient values, in vitro dry matter digestibility, and yield traits of forages were measured. The highest levels of dry matter and organic matter were observed during the physiological maturity stage, followed by the dough and milk development stages ($p < 0.05$). The DM values in the milk, dough, and physiological maturity stages were 43.11%, 61.94%, and 91.41%, respectively ($p < 0.05$). The triticale varieties had the highest crude protein (CP) values during the milk development stage and the lowest values during the physiological maturity stage ($p < 0.05$). The highest dry matter digestibility (DMD) rates were observed in the physiological maturity stage across all varieties. The DMD rates for triticale varieties Alperbey, Tatlıcak 97, Karma 2000, Ümranhanım, and Mikham 2002 were 84.74%, 86.55%, 84.19%, 86.20%, and 85.10%, respectively. No significant differences in the amount of phytic acid content were found among the triticale varieties used in the study ($p > 0.05$). Therefore, it is believed that triticale varieties can provide highly digestible forage and grain feed for ruminants if the harvesting time is well managed.

Key words: Triticale, nutrient contents, phytic acid, in vitro digestibility, degradation rate

1. Introduction

The seasonal and geographical conditions of our country provide favorable conditions for agriculture and animal husbandry. However, it is observed that the products obtained from these areas are not produced in sufficient and expected quantities. This issue can be attributed to factors such as the low level of awareness among people engaged in agriculture and animal husbandry, insufficient production of raw materials for feed, an imbalance between supply and demand, and fragmented agricultural land [1] [1].

Continuous studies are conducted on feed, which is one of the most significant inputs in animal husbandry, to find ways of achieving the highest yield at the lowest cost. In our country, many animal husbandry enterprises, particularly those involved in small-scale agriculture and animal husbandry, use straw as roughage, barley, and pulp as concentrated feed due to their low cost. However, with this feeding method, the breed's characteristic yields cannot be sufficiently beneficial. In this case, both producers and the economic contributions of agriculture and animal husbandry to our country are negatively affected. It has been reported that increasing the production of forage grasses and legume forage crops would be beneficial both in meeting the country's feed requirements and in mitigating these negative effects.[2]

Triticale, a type of forage grasses, is a grain that yields more than wheat and barley in agricultural lands with insufficient rainfall, salty soil, and barren conditions. It also contains some minerals. Despite the increased production of triticale in both Türkiye and worldwide, its production still seems to be lower compared to that of other cereals[3] [2, 3].

[1]Turkish Statistical Institute (TÜİK) (2024). Animal production and harvest yield data [online] [Turkish]. Website https://data.tuik.gov.tr/Kategori/GetKategori?p=Tarim-111 [Accessed 20 January 2024]

[2]Çukurova Zootekni Derneği (2003). Türkiye Hayvancılığı; Hedef 2023-Sorunlar, çözüm yolları ve politika arayışları [online] [Turkish]. Website www.zootekni.org.tr/upload/File/Hayvanclk%20Rapor-Sonhali.pdf [accessed 20 January 2024].

[3]Food and Agriculture Organization of the United Nations (2024). Food and agriculture data [online]. Website http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor [accessed 20 January 2024]

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Harvesting feed sources at different stages of development has been reported to affect nutrient levels, digestible quantities, and various processing patterns [4, 5]. In this context, it has been revealed that harvesting triticale at various developmental stages offers advantages over other grain products in terms of digestibility and nutrient content [6, 7].

It was stated that triticale contains phytic acid, which has antinutritional properties. Factors such as climate, region, irrigation, soil characteristics and season affect the amount of phytic acid in grains [8, 9]. It is known that ruminant animals can digest phosphorus in phytic acid due to the microorganisms in their stomachs [10]. Therefore, triticale varieties are a type of grain that offers high yields as a feed crop for livestock farms with marginal agricultural lands.

This study aims to determine the growth performance, nutrient content, and digestible ratios of triticale cultivars suitable for climatic and agricultural land conditions that are less favorable for other grain products. It also aims to evaluate their contribution to feeding ruminant animals, thereby indirectly enhancing the productivity of farmers.

2. Material and method

In the study, five triticale varieties were used. The triticales were harvested at three different periods—milk stage, dough stage, and physiological maturity stage—5 cm above the soil level, by hand mowing due to the small area. At milk stages, the first substances to accumulate in the endosperm are proteins, while starch is almost absent in young endosperm cells aged 3–5 days. Approximately half of the proteins present in the grain during this period are derived from those formed in the stems and leaves and subsequently transported to the grain after fertilization. These proteins accumulate in the grain and form a honeycomb-like network tissue within the endosperm cells. During this stage, the grain reaches its maximum volume. By the end of this stage, which lasts until 20 to 25 days after fertilization, the grain's water content is approximately 60% and the interior has the consistency of boza. During the dough stages, after the moisture content in the grain drops below 60%, protein accumulation ceases, and the accumulation of starch increases rapidly. During this stage, starch particles fill the protein networks formed in the fattening tissue during the milk stage. This results in a reduction in the grain's volume, and the nutrient takes on a waxy consistency. By the end of this stage, nutrient accumulation in the grain ceases, the moisture content drops to approximately 40%. At this stage, the top leaf blade of the plant turns yellow, while the leaf sheath remains green and the upper node is must. This period lasts between 10 and 25 days, depending on the rainfall and temperature of the season. Physiologic maturity, also known as the hard dough stage, occurs after the accumulation of nutrients in the grain stops (dough). During this stage, the maturation of the accumulated substances continues. This period is called the period of physiological maturity. This period can last 2–3 days in arid and hot regions and 5–10 days in humid coastal regions. At the end of the period, the grain develops the characteristics of a seed. Some opinions suggest that the grain's moisture content at the end of physiological death is approximately 33–18.5%. After physiological death, the grain loses only water.

The experiment was designed with three replicates planted in parcels divided into random blocks. The dry matter digestibility of these triticale varieties, which were harvested by hand, were determined using in vitro method. Additionally, the nutrient content of these products was analyzed and is presented in Table 1.

The study utilized the hexaploid triticale varieties Alperbey, Mikham 2002, Karma 2000, Tatlıcak 97, and Ümranhanım. The seed amount was calculated at 22 kg/da. During planting, 15 kg/da of diammonium phosphate (DAP) fertilizer was applied. Worm fertilizer was applied twice.

In vitro dry matter (DM) digestion values were determined using an Ankom Daisy II incubator (Ankom Technology, Macedon, NY, USA) according to the method reported by Tilley and Terry [11] and modified by Marten and Barnes [12]. The samples were placed in F57 filter bags.

Rumen fluid was collected from Holstein cows that had been fed a dry period ration and subsequently slaughtered at the Yeşil Vadi Meat Integrated Facility due to orthopedic disorders. The obtained rumen fluid was quickly transported to the laboratory in thermos containers filled with hot water and was used after being filtered through cheesecloth under CO_2 gas.

The incubated feeds were prepared by grinding them to a particle size of 2 mm after drying. Feed samples, weighing 0.25 g each, were placed into F57 filter bags, with two parallel used for each jar. Additionally, two empty, tared F57 filter bags were incubated, and weight corrections were made based on their weights at the end of the incubation period. The mouths of the filter bags are sealed using a heat sealer.

The prepared filter bags were left to incubate for 48 h in the Ankom Daisy D200 device. At the end of the incubation, the pouches were removed from the solution, and the contaminated feed particles were removed by rinsing the fountain with cold tap water to prevent microbial activity. The pouches were then washed under running water until the water became clear (approximately 15 min) and dried in an oven at 65 °C for 24 h. After the dried pouches were stored in a desiccator briefly, their weight was recorded by weighing.

Table 1. Nutrient contents of Alperbey, Mikham 2002, Karma 2000, Tatlıcak 97 and Ümranhanım varieties.

Stages	Varieties of triticale	DM	Ash	OM	CP	EE	ADF	NDF
MS, DM%	**Tatlıcak 97**	42.55	9.78	90.32	12.93	2.29	34.25	63.55
	Karma 2000	45.50	7.28	92.72	12.37	2.22	33.99	64.24
	Alperbey	44.71	8.48	91.52	17.90	2.24	30.79	60.84
	Ümranhanım	41.17	8.34	91.66	15.35	2.30	32.54	61.77
	Mikham 2002	41.61	7.73	92.27	16.70	2.22	34.88	64.54
DS, DM%	**Alperbey**	65.98	8.39	91.61	10.74	2.06	30.64	62.01
	Tatlıcak 97	58.27	6.02	93.98	9.03	2.10	31.10	60.25
	Karma 2000	64.11	7.17	92.83	10.81	2.04	31.57	62.12
	Ümranhanım	59.35	5.97	94.03	11.69	2.11	33.76	62.56
	Mikham 2002	61.99	6.63	93.37	10.58	2.03	29.01	56.90
PMS, DM%	**Alperbey**	91.39	3.48	96.52	8.77	1.88	4.00	23.55
	Tatlıcak 97	91.13	3.03	96.97	8.52	1.90	3.32	14.40
	Karma 2000	90.91	4.44	95.56	9.82	1.85	3.86	16.01
	Ümranhanım	91.87	3.72	96.28	9.19	1.92	3.35	14.88
	Mikham 2002	92.26	2.15	97.85	9.48	1.84	3.28	13.00

MS: milk stage, DS: dough stage, PMS: physiological maturity stage, DM: dry matter, OM: organic matter, CP: crude protein, EE: ether extract, ADF: acid detergent fiber, NDF: neutral detergent fiber.

The method developed by Talamond et al. and modified by Ledesma et al. was used to determine the phytic acid content. The principle of the method is that phytic acid and $FeCl_3$ form a ferric phytate complex, with ammonium thiocyanate applied as a colorimetric agent [13]. The results were obtained using a spectrophotometer (Shimadzu UV-1701; Shimadzu Corporation, Kyoto, Japan).

Green grass yield was calculated by weighing the products obtained from 1 m^2 area during the milk and dough stages, and the results were scaled to a 1-da area. The dry matter yield, digestible dry matter yield, and crude protein yield of each triticale per unit area were then calculated by multiplying the dry matter, dry matter digestibility, and crude protein content of the product.

Phytic acid was calculated using the formula: Phytate-P (mg) / 100 g sample = Fe (μg) × 15 / sample weight (g).

The DM, ash, organic matter (OM), EE, ADIN-N, and CP contents of the samples used in the experiment were analyzed using AOAC analysis system [14]. The neutral detergent fiber (NDF) was determined according to Van Soest and Robertson [15], acid detergent fiber (ADF) was determined according to Goering and Van Soest [16].

The data obtained from the experiment were analyzed using analysis of variance with the Statistical Analysis Software (SAS) [17], and the differences between the means were determined using the Duncan test [18].

3. Results and discussion

The grass yields of the triticale varieties used in the study, according to the vegetation period, are presented in Table 2. The grass yield of all five triticale types we used was affected by the vegetation period. Except for the Ümranhanım variety, the highest grass yield was observed during the milk stage and the lowest physiological maturity stage. For the Ümranhanım variety, the highest grass yield occurred during the milk and dough stages, with the lowest yield at the physiological maturity stage.

The green grass yield obtained from the triticale in the study of Alp [19] was between 1205.7 and 1490.9 kg/da, while the dry grass yield was between 273.75 and 393.25 kg/da. In Kavut et al.'s study [20], the green grass yield was reported to be between 4884 and 7522 kg/da. Kara et al. [21] reported that the green grass yield was between 2150 and 2286 kg/da, and the dry hay yield was between 1335 and 1427 kg/da. Kaplan et al. [22] reported that the green grass yield was between 3805 and 4746 kg/da, and the dry grass yield was between 1277 and 1737 kg/da. The green grass yield of the triticale varieties in the study is higher than that reported by Alp [19] and Kara et al. [21], but lower than that reported by Kavut [20] and Kaplan et al. [22]. Hay yield is higher than that reported by Alp [18]. However, it is similar to the results reported by Kara et al. [21] and Kaplan et al. [22]. It is known that differences in

Table 2. Feed yields of triticale varieties used in the study according to vegetation period, kg/da DM.

	Milk stage	Dough stage	Physiological maturity stage	p
Alperbey	3240.67^{c} ± 307.91	2213.17^{b} ± 71.64	1367.33^{a} ± 79.81	0.001
Tatlıcak 97	3358.50^{c} ± 354.51	2363.00^{b} ± 102.36	1332.44^{a} ± 56.62	0.001
Karma 2000	3154.33^{c} ± 269.59	2283.17^{b} ± 48.71	1500.72^{a} ± 62.26	0.001
Ümranhanım	2925.67^{b} ± 203.32	2504.33^{b} ± 73.16	1281.94^{a} ± 33.55	0.001
Mikham 2002	3412.33^{c} ± 105.79	2640.83^{b} ± 89.81	1450.17^{a} ± 49.00	0.001

$^{a, b, c}$: Different letters in the same row indicate statistical difference ($p < 0.05$).

grass yield vary according to genotype, soil, fertilization, temperature, and rainfall.

The CP yield of the triticale varieties used in the study, based on the vegetation periods, is presented in Table 3. It is observed that vegetation periods are significant for CP yield in all cultivars except Mikham 2002 and Alperbey. In the milk stage, Tatlıcak 97 has the highest CP yield, while Karma 2000 has the lowest. In the dough stage, Tatlıcak 97 has the highest CP yield, Mikham 2002 has the lowest. In the physiological maturity stage, Karma 2000 has the highest CP yield, whereas Ümranhanım has the lowest.

Kaplan et al. [23] reported that triticale yields were between 67.59 and 114.15 kg/da during the milk and dough stages. Kaplan et al. [22] reported the CP yield of triticale in their study as 108–153 kg/da during the milk stage. Our CP yield results were higher than those reported by Kaplan et al. [22]. This difference is attributed to the higher CP% rate in the triticale varieties used in our study compared to those in other studies.

The in vitro dry matter digestion of the triticale varieties used in the study, according to their vegetation periods, is presented in Table 4. In vitro DMD, vegetation periods were found to be significant for all triticale varieties used in the study. As the DM% content of the triticale varieties increased in parallel with the development periods of the plants, the DMD also increased. The highest DMD rate across all varieties was observed at the stage of physiological maturity.

Kaplan et al. [22] reported the DMD yields of triticale during the milk stage ranged from 56.48% to 62.92% in their study. Denek and Deniz [24] reported the DMS rates of 81.04%, 81.72%, and 84.17% for wheat, rye, and triticale grains, respectively. The DMS rates at the physiological maturity stage in the study were higher than those reported by Denek and Deniz [24]. Conversely, the DMS at the milk stage was lower than that reported in the study of Kaplan et al. [22]. It is thought that the low DMS rates during the milk and dough stages are due to high ADF and NDF rates, as well as antinutritional factors such as phytic acid.

The phytic acid contents of the triticale varieties used in the study are presented in Table 5. There was no significant difference in the phytic acid amount among the triticale varieties used in the study. Gupta et al. [25] reported phytic acid amounts in wheat, rye, and barley as 1.14–3.91, 0.54–1.46, and 0.38–1.16 g/100 g, respectively. Hídvégi and Lásztity [26] reported phytic acid amounts in wheat

Table 3. CP yield of triticale varieties used in the study according to the vegetation period, kg/da DM.

	Milk stage	Dough stage	Physiological maturity stage	p
Alperbey	173.52 ± 11.36	158.47 ± 9.87	148.22 ± 8.37	0.123
Tatlıcak 97	181.82^{a} ± 10.40	236.16^{b} ± 6.74	157.92^{a} ± 17.60	0.001
Karma 2000	124.46^{a} ± 7.99	158.24^{ab} ± 6.54	172.71^{b} ± 13.71	0.011
Ümranhanım	174.18^{b} ± 11.46	110.98^{a} ± 11.77	102.99^{a} ± 5.78	0.001
Mikham 2002	134.22 ± 7.25	108.24 ± 7.24	127.28 ± 7.43	0.061

$^{a, b, c}$: Different letters in the same row indicate statistical difference ($p < 0.05$).

Table 4. In vitro DMD of triticale varieties used in the study according to the vegetation period, DM%.

	Milk stage	Dough stage	Physiological maturity stage	p
Alperbey	37.01[a] ± 0.98	37.15[a] ± 4.79	84.74[b] ± 0.75	0.001
Tatlicak 97	30.23[a] ± 2.66	31.23[a] ± 3.26	86.55[b] ± 0.44	0.001
Karma 2000	36.95[a] ± 4.89	35.72[a] ± 3.35	84.19[b] ± 0.69	0.001
Ümranhanım	34.30[a] ± 2.74	38.31[a] ± 3.42	86.20[b] ± 0.24	0.001
Mikham 2002	31.11[a] ± 2.28	38.90[a] ± 3.00	85.10[b] ± 1.03	0.001

DMD: dry matter digestibility.
[a, b, c]: Different letters in the same row indicate statistical difference ($p < 0.05$).

Table 5. The phytic acid content of triticale varieties used in the study, g/100g*.

Alperbey	Tatlıcak 97	Karma 2000	Ümranhanım	Mikham 2002	p
0.96 ± 0.05	1.12 ± 0.07	1.03 ± 0.06	0.99 ± 0.03	1.00 ± 0.05	0.265

*: It was obtained from the physiological maturity stage grains of the triticale varieties.

and barley as 0.72–0.93 and 0.97 g/100 g, respectively. Egli et al. [27] reported the amount of phytic acid in wheat, rye, and triticale as 1.03, 1.01, and 1.29 g/100 g, respectively. The amount phytic acid in triticale in the study was found to be similar to that in other studies.

4. Conclusion

As a result, it is thought that the triticale varieties used in the study are highly productive in terms of DM, OM, CP nutritional values, and digestibility. This is particularly true in climates and agricultural conditions that are adverse to other cereal crops. These varieties can be utilized as forage and grain feed for ruminant animals. Additionally, further studies should be conducted, and both breeding and feed resources should be supported.

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Conflict of interest
The authors declare that they have no conflicts of interest.

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