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Effects of traditional tenderization treatments on *Transversus abdominis* muscles obtained from Holstein carcasses

H. Benli[1#] & L.A. Tokgoz[1]

[1]Department of Food Engineering, Cukurova University, Adana, 01330, Turkey

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Abstract

The aim of this study was to evaluate the effects of traditional tenderization treatments on *Transversus abdominis* (TrA) muscles (inside skirts) of Holstein carcasses. The muscles were collected from carcasses of 12 healthy 18- to 22-month-old Holstein steers that had been subjected to similar care and nutrition programmes. A replicated 4 x 4 Latin square design was used to compare the effects of the treatments of blade tenderization, enzymatic tenderization, marination and control. Blade tenderization and enzymatic tenderization had statistically similar colour values to the control, whereas marination had negative effects on the colour of raw and cooked samples. Blade tenderization had the lowest mean Warner-Bratzler shear force value (37.88 N), whereas enzymatic tenderization had the second lowest value (42.87 N). In sensory evaluation, significant differences were observed when the samples cooked to an internal temperature of 82 °C. A simple ranking test indicated that the most preferred sample was obtained with the blade tenderization. Also, blade tenderization and then enzymatic tenderization had the highest scores for tenderness in sensory evaluation. Although Holstein cattle are known for superior milk production and may not be a suitable breed for high-quality meat production, the results indicated that blade tenderization and enzymatic tenderization could be used to improve the tenderness of TrA steaks from Holstein carcasses and use them better.

Keywords: blade tenderization, enzymatic tenderization, Holstein marination, *Transversus abdominis*
[#]Corresponding author: hbenli@cu.edu.tr

Introduction

Beef fajitas, which are prepared from the inside or outside skirt, are popular in the USA (Huerta-Montauti *et al.*, 2008). The inside skirt is removed from the interior portion of the abdominal wall of the hindquarter and contains only TrA muscle, whereas the outside skirt is separated from the short plate and consists of the diaphragm, which may or may not have the serous membrane (peritoneum) attached (Aus-Meat Limited, 2006; North American Meat Processors Association, 2007).

Some steakhouses and Mexican restaurants have been serving beef fajitas to their customers in Turkey and the demand has increased in recent years. However, most restaurants use cuts from beef loin or tenderloin to prepare fajitas, since the inside skirts, which are removed from the carcasses, are called 'liver meat' and are not marketed separately, but are often incorporated into ground meat. Tenderness was the most desired attribute for consumers when eating at home or in a restaurant, although beef palatability was affected by other factors, including juiciness and flavour (Sweeten & Recio, 1985; Recio *et al.*, 1988; Belew *et al.*, 2003). Traditional methods such as enzymatic tenderization, mechanical tenderization and marination can be used to improve the tenderness of beef cuts (Ashie *et al.*, 2002; Chang *et al.*, 2010). Papain, bromelain and ficin were the most commonly used plant enzymes for enzymatic tenderization of meat (Dransfield & Etherington, 1981). Mechanical tenderization, including blade tenderization, is an effective method of improving the tenderness of tougher meat cuts (Pietrasik & Shand, 2011), in which a set of needles or blades is used to cut through the muscle fibres and connective tissues (Maddock, 2008). Marination was reported to improve certain properties of meat, including aroma, taste and texture (Tomaszewska-Gras & Konieczny, 2012). Immersion of meat in salt and acid marination increased textural properties such as tenderness and juiciness (Chang *et al.*, 2010; Tobin *et al.*, 2012).

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Although demand for beef fajitas is increasing, high-quality beef production is limited in Turkey because of the use of unsuitable breeds for meat production, including indigenous breeds, Holstein and Brown Swiss. Since small-scale farmers are the main producers of beef in Turkey, their primary interest is milk production and cattle are raised mostly for both milk and beef (Serttas, 2010; Bozkurt & Dogan, 2016). The effects of traditional techniques, including mechanical tenderization, enzymatic tenderization and marination on meat quality, have been studied in the literature. However, the effects of these techniques on inside skirts (TrA) from Holstein steers have not been studied extensively. Thus, the aim of this study was to investigate the effects of some traditional tenderization treatments to improve tenderness and to better utilize TrA muscles from Holstein steers, which would otherwise be incorporated in ground meat.

Materials and Methods

Samples of TrA muscles were obtained from a local slaughterhouse in the district of Havutlu in Adana, Turkey (36°55'02.9' N 35°21'04.5' E). The samples were collected from carcasses of 12 healthy 18- to 22-month-old male Holstein steers subjected to similar care and nutrition programmes. The inside skirts (Institutional Meat Purchase Specification 121D) were removed with knives by a professional butcher in the slaughterhouse after evisceration and held in chilled storage (0-4 °C) for 24 hours. Then, the muscles were vacuum packaged individually and transported to the laboratory in an insulated container in 30 min. The samples were then used in the experiments within 1 hour. The slaughterhouse was visited on three days to obtain samples from four beef carcasses at each visit.

The treatments consisted of control, blade tenderization, enzymatic tenderization and marination. Randomly selected Latin square designs were used for three replications (Kaps & Lamberson, 2004). In these designs, each treatment was applied to 12 samples (a total of 48 samples) to collect the data. For the application of the treatments, control samples were placed in a 1 L rectangular glass container and stored at 4 °C for 24 hours until cooked on a clam-shell-type electrical grill (Grill Comfort, Tefal, France). For blade tenderization, the samples were placed in a container and stored until 5 min before cooking. Then the samples were treated twice with a hand-held tenderizer (Jaccard Supertendermatic 48-Blade Tenderizer, USA), once horizontally and once rotated 90 °, and cooked on the electrical grill. A commercial ready-to-use papain solution (0.1%), which is available in Turkish markets, was used according to the manufacturer's instructions for enzymatic tenderization (Marinado-Meat Tenderizer, Yönsan Food, Istanbul, Turkey). Again, the samples were placed in a container and stored until 15 min before cooking. Then the samples were covered with the papain solution for 15 min and cooked on the grill. For marination, a brine mixture of 2.5% salt and 0.2 M acetic acid (Merck, Darmstadt, Germany) was prepared. Samples were similarly placed in a container, covered with the brine and stored at 4 °C for 24 hours (Chang *et al.*, 2010). The samples were then placed on the grill for cooking. A handheld thermometer (Verth, Type K Thermometer, Taiwan) was used to monitor the internal temperature of each sample. All samples were cooked to an internal temperature of 71 °C (AMSA, 2015).

After tenderization, slurries were prepared by blending 10 g raw sample with 90 ml distilled water for 60 seconds. Then pH values were taken with a calibrated pH meter (S220, Mettler-Toledo, LLC, Columbus, OH, USA) (Ockerman, 1985). The moisture contents were determined by oven drying (Memmert, Universal Oven Tech., Germany) at 100 °C for 18 hours (AOAC, 2000). Ash contents were established with a muffle furnace (Protherm, PLF 130/45, Turkey) at 600 °C. The samples were left in the furnace for a minimum of 24 hours. They were then removed and placed in a desiccator for 1 hour. The final weights of the samples were then recorded to calculate ash contents (AOAC, 2000). After tenderization, samples were weighed before and after cooking to 71 °C. Percentage differences between the initial and cooked weights were calculated to determine the cooking loss values (AMSA, 2015).

Colour measurements of the samples were taken with a Konika Minolta colorimeter (CR-400, Minolta C., Ramsey, NJ, USA) equipped with a 8 mm aperture and calibrated with the settings of illuminant D-65 and 2° observer on a standard white tile (Y = 93.7, x = 0.3157, y = 0.3323). Five random readings of L* (lightness), a* (redness), and b* (yellowness) were taken on inner surfaces before and after cooking. These formulas were used to calculate hue and chroma, arctangent (b*/a*) and $\sqrt{(a^{*2} + b^{*2})}$ (Calnan *et al.*, 2016).

To determine Warner-Bratzler shear force values, the samples were cooked to 71 °C (AMSA, 2015) and then chilled overnight in a refrigerator at 4 °C. Five round core samples (1.27 cm in diameter) were removed parallel to the longitudinal orientation of the muscle fibres. Warner-Bratzler shear force values were determined with an automated testing machine (Model TA–XT Plus, Stabile Microsystems, England) equipped with a Warner-Bratzler knife and a guillotine block (TA-7, Stabile Microsystems, England). The assay parameters consisted of pre-test speed (3.0 mm/s), test speed (1.0 mm/s) and post-test speed (3.0 mm/s). Texture profile analyses (TPA) were done with a texture analyser (Model TA–XT Plus, Stabile Microsystems, England) after cooked (71 °C) samples had been chilled in a refrigerator at 4 °C for 2 hours, as De Huidobro *et al.* (2005) practised. For texture assessment, five 1 x 1 x 1 cm-cubic sub-samples were

prepared from each sample and compressed axially in a double compression cycle (75% of their initial height) parallel to the direction of fibres (50 kg load cell and crosshead pre-test speed 3.0 mm/s, test speed 1.0 mm/s, and post-test speed 3.0 mm/s).

A simple ranking test was used to choose the most preferred sample in sensory evaluation (Meilgaard *et al.*, 1999). After treatment, the samples were cooked to 71 °C (medium) in the morning session and to 77 °C (well done) and 82 °C (very well done) in the afternoon session on a clam-shell-type electrical grill (North American Meat Processors Association, 2007). The sensory evaluation was conducted to three degrees of doneness because a majority of the panelists stated that the samples that were cooked to 71 °C were underdone for their taste. The samples were cut at 2 x 2 cm for the sensory evaluation. Forty panellists from the Department of Food Engineering at Cukurova University participated, including graduate students and staff members (25 women and 15 men, all between 20 and 35 years old). Panellists were served four tenderized samples in random order and instructed to assign rank 1 to the most preferred sample and 4 to the least preferred. In addition, the panellists were asked to evaluate the samples for appearance, colour, flavour, taste, tenderness, juiciness and overall acceptability. They ranked each attribute on a 9-point hedonic scale (1 = very much disliked to 9 = very much liked) (Meilgaard *et al.*, 1999).

In this study, the effects of the treatments on TrA muscles were compared using three replications of a 4 x 4 Latin square design. The muscle samples were collected from four carcasses in each slaughterhouse visit for one replication of the 4 X 4 Latin square. Then, each TrA muscle was divided into four pieces to obtain different portions (location) for the application of the treatments. Steer and location were the extraneous sources of the variation that were aooutned for as rows and columns in the Latin squares. A randomly selected Latin square design was used for each replication (Kaps & Lamberson, 2004; Ott & Longnecker, 2001). The data were analysed with SPSS software version 20 (IBM Inc., Armonk, New York, USA). The UNIANOVA procedure was used to conduct the analysis of variance for the replicated Latin square design. The design statement included square, steer (square), location (square), and treatments as independent variables. Square represented the replications of Latin square design, steer represented the beef carcasses, location represented the portions obtained by dividing TrA muscles, and treatments represented the tenderization treatments used in the study. The POSTHOC statement (Tukey) was used to compare treatment means (Kaps & Lamberson, 2004).

To analyse the sensory evaluation data, the rank sums were calculated for each sample. Then a nonparametric analysis was performed using a Friedman-type rank test. The nonparametric analogue to Fisher's LSD for rank sums was used to determine which of the samples differed significantly (Meilgaard *et al.*, 1999).

Results and Discussion

Average pH values of TrA samples ranged from 4.56 to 6.04 after treatment (Table 1). There were significant differences among these values. Marination produced a lower pH value than blade tenderization, enzymatic tenderization and control (P <0.05). Similarly, Aktas *et al.* (2003) used various concentrations of lactic acid and citric acid to marinate *Longissimus dorsi* muscles from beef carcasses. Marination decreased pH values of the samples significantly, and acid type and concentration had significant effects. There were no significant differences among moisture contents after treatments (Table 1). The average moisture contents were between 72.84% and 74.29%. Average ash values of the samples – ranging from 0.79% to 1.12% – were significantly different after tenderization (Table 1). Marination resulted in the highest ash content among the treatments since a brine mixture of 2.5% salt and 0.2 M acetic acid was used. There were significant differences among average cooking loss values of the samples after cooking to 71 ºC on an electrical grill (Table 1). The cooking loss values were between 24.09% and 33.54%. Enzymatic tenderization caused higher (P <0.05) cooking loss, whereas blade tenderization, marination and control samples produced similar amounts. Papain, which is produced from the latex of the papaya plant *(Carica papaya)* is a cysteine protease enzyme. Since papain can degrade connective tissue and myofibrillar proteins over a range of pH (5–8) and at a high optimal temperature (65 °C) (Bekhit *et al.*, 2014), enzymatic tenderization with a papain solution might have caused a higher cooking loss value. Akpan and Omojola (2015) also reported that cooking loss rose when the concentration of papain enzyme for injecting the beef samples was increased.

Table 1 pH, moisture, ash, cooking loss values of *Transversus abdominis* samples after tenderization

Tenderization treatments	pH	Moisture, %	Ash, %	Cooking loss, %
Blade tenderization	6.03 ± 0.04^{a}	73.99 ± 1.24	0.85 ± 0.03^{a}	28.46 ± 1.13^{b}
Enzymatic tenderization	6.01 ± 0.02^{a}	73.40 ± 0.99	0.83 ± 0.03^{a}	33.54 ± 1.71^{a}
Marination	4.56 ± 0.09^{b}	74.29 ± 1.09	1.12 ± 0.06^{b}	28.24 ± 2.15^{b}
Control	6.04 ± 0.03^{a}	72.84 ± 2.03	0.79 ± 0.06^{a}	24.09 ± 0.80^{b}

[a,b] Within a column, values with a common superscript did not differ with probability $P < 0.05$

The highest L* value was produced by marination, whereas blade tenderization had the lowest L* value before cooking (Table 2). The results were consistent with studies indicating that organic acid treatment increased L* values of fresh beef cuts (Stivarius *et al.*, 2002; Sawyer *et al.*, 2009). However, there were no significant differences among L* values of samples after cooking to 71 °C. Cooking of fresh and uncured meat causes myoglobin denaturation, producing a dull-brown interior, which may explain similar L* values for the treatments after cooking to the present study (Suman *et al.*, 2016). Blade tenderization had the highest a* values of 13.09 before cooking, whereas marination caused the lowest a* values of 5.79 and 5.82 ($P < 0.05$) before and after cooking. There were no significant differences among b* values of the samples before cooking. However, marination caused the lowest b* value of 6.74 ($P < 0.05$) after cooking. Stivarius *et al.* (2002) indicated that ground beef produced from trimmings treated with acetic acid (5%) tended to be less red and contained less oxymyoglobin. In addition, myoglobin was reported to be less stable for thermal treatments at lower pH values (less than 5.4) in meat (Suman *et al.*, 2016). Marination had the highest hue values of 37.14 and 49.18 ($P < 0.05$) before and after cooking (Table 2). Lower hue values indicated that the colour of the meat samples was closer to red, which was considered favourable for fresh meat (Calnan *et al.*, 2016). Blade and enzymatic tenderization had the lowest numerical hue values before cooking. Marination decreased the chroma value, whereas blade tenderization increased it slightly (13.79 before cooking ($P < 0.05$). Similarly, marination produced the most faded sample with a value after cooking. In the current study, marination seemed to have more effect on the colour of raw and cooked samples compared with the control, since blade tenderization and enzymatic tenderization produced statistically similar values to the control.

Table 2 Colour values of raw and cooked *Transversus abdominis* samples after tenderization

	Tenderization treatments			
Colour value	Blade tenderization	Enzymatic tenderization	Marination	Control
Raw L*	44.84 ± 1.31^{b}	47.13 ± 0.63^{ab}	49.81 ± 0.84^{a}	47.16 ± 1.49^{ab}
Raw a*	13.09 ± 0.83^{a}	11.38 ± 0.52^{b}	5.79 ± 0.20^{c}	11.94 ± 0.69^{ab}
Raw b*	4.20 ± 0.36	3.75 ± 0.54	4.49 ± 0.36	4.53 ± 0.49
Raw hue	17.94 ± 1.26^{b}	17.57 ± 1.80^{b}	37.14 ± 1.38^{a}	20.85 ± 2.02^{b}
Raw chroma	13.79 ± 0.85^{a}	12.05 ± 0.64^{b}	7.35 ± 0.36^{c}	12.86 ± 0.71^{ab}
Cooked L*	42.99 ± 1.33	42.95 ± 1.31	45.93 ± 1.61	42.73 ± 1.20
Cooked a*	8.48 ± 0.29^{a}	8.09 ± 0.29^{a}	5.82 ± 0.46^{b}	8.73 ± 0.57^{a}
Cooked b*	7.66 ± 0.49^{ab}	8.03 ± 0.44^{ab}	6.74 ± 0.49^{b}	8.61 ± 0.38^{a}
Cooked hue	41.74 ± 2.03^{b}	44.49 ± 1.61^{b}	49.18 ± 1.08^{a}	44.97 ± 1.54^{ab}
Cooked chroma	11.51 ± 0.39^{a}	11.45 ± 0.42^{a}	8.92 ± 0.65^{b}	12.31 ± 0.59^{a}

[a,b] Within a row, values with a common superscript did not differ with probability $P < 0.05$

Table 3 presents the data for Warner-Bratzler shear force values of TrA samples. There were significant differences among average shear force values, which ranged from 37.88 N to 50.99 N. Blade

tenderization had the lowest (P <0.05) mean shear force value (37.88 N), whereas the second lowest value was determined in the enzymatic tenderization samples (42.87 N). Control and marination samples had the highest shear force values of 49.93 N and 50.99 N, respectively. Mechanical tenderization was reported to improve tenderness of meat cuts (Pietrasik & Shand, 2011). Similarly, Obuz *et al.* (2014) reported that blade tenderized *Longissimus lumborum* steaks from culled Holstein cows had shear force value of 33.13 N, whereas control steaks had the value of 41.46 N. Pietrasik and Shand (2011) examined the effects of moisture enhancement, enzyme treatment, and blade tenderization on beef *semimembranosus* steaks. Blade tenderization and enzyme injection were both reported to increase tenderness of the steaks. Likewise, King *et al.* (2009) reported that blade tenderization and increased ageing time and temperature were effective in improving tenderness of beef *Longissimus lumborum* and *Gluteus medius* steaks, although greater improvements were obtained with blade tenderization compared with the other treatments. Moreover, Recio *et al.* (1988) reported that beef skirt steaks from mature carcasses could be utilized for fajita meat with appropriate mechanical tenderization.

Table 3 Warner-Bratzler shear force and texture profile analysis values of *transversus abdominis* samples following tenderization

Tenderization treatments	Shear force, N	Hardness, N	Cohesiveness	Chewiness	Resilience
Blade tenderization	37.88 ± 2.52^{b}	115.84 ± 6.47^{a}	0.54 ± 0.01^{a}	0.43 ± 0.05^{a}	0.19 ± 0.01^{a}
Enzymatic tenderization	42.87 ± 5.41^{ab}	96.79 ± 4.75^{b}	0.48 ± 0.02^{b}	0.27 ± 0.03^{b}	0.16 ± 0.01^{b}
Marination	50.99 ± 5.81^{a}	120.38 ± 7.42^{a}	0.52 ± 0.02^{ab}	0.38 ± 0.04^{a}	0.18 ± 0.01^{ab}
Control	49.94 ± 4.44^{a}	111.03 ± 6.14^{ab}	0.53 ± 0.02^{a}	0.37 ± 0.04^{ab}	0.19 ± 0.01^{a}

[a,b] Within a column, values with a common superscript did not differ with probability P <0.05

In texture profile analysis (TPA) of the samples, the enzymatic tenderization had the lowest hardness value of 96.79 N (P <0.05) whereas the second lowest value was measured in the control (Table 3.). Even though marination caused a numerically higher hardness value, there were no significant differences between marination (120.83 N) and blade tenderization (115.84 N). Similarly, Roslan *et al.* (2019) studied effects of four enzymatic tenderization treatments (water, papaya leaf juice, papaya leaf powder, and commercial meat tenderizer) on the *Pectoralis major* muscle of spent chicken and reported that papaya leaf powder improved tenderness. Enzymatic tenderization had the lowest cohesiveness value of 0.48, whereas blade tenderization and control had the highest values of 0.54 and 0.53, respectively (P <0.05). Similarly, enzymatic tenderization had the lowest chewiness value of 0.27 (P <0.05), whereas blade tenderization and marination had the highest values (0.43 and 0.38). In addition, the lowest resilience value of 0.16 (P <0.05) was produced by enzymatic tenderization, whereas blade tenderization and control had the highest values (0.19 and 0.19). Resilience values indicated that how well the tenderized TrA samples regained their original heights after deformation (Yuca *et al.*, 2019). Texture profile analysis revealed that enzymatic tenderization should also be considered to improve the tenderness of TrA samples, since papain can degrade connective tissue and myofibrillar proteins and might have caused deformation in the structural integrity of the samples. Similarly, Schenkova *et al.* (2004) indicated that papain treatment increased the tenderness of bovine muscle significantly compared with the control samples after high pressure treatment.

Simple ranking test values of samples cooked to 71 °C, 77 °C, and 82 °C are presented in Table 4. There were no significant differences among the test values of the samples cooked to 71 °C and 77 °C, although blade tenderization and enzymatic tenderization were preferred to marination and control. A significant difference was observed when the samples were cooked to 82 °C. Blade tenderization was the most preferred sample, whereas the control was least preferred. Similarly, blade tenderization and ageing were reported to improve sensory panel tenderness of *Longissimus lumborum* steaks from culled Holstein cows (Obuz *et al.*, 2014).

Table 4 The rank sum values[1] of *Transversus abdominis* samples after tenderization

Tenderization treatment	Internal temperature of cooked product		
	71 °C	77 °C	82 °C
Blade tenderization	44	49	54[b]
Enzymatic tenderization	46	47	70[ab]
Marination	56	63	73[ab]
Control	54	51	83[a]

[1] Rank 1 was assigned to the most preferred sample, whereas rank 4 was assigned to the least preferred sample
[a,b] Within a column, values with a common superscript did not differ with probability $P < 0.05$

Table 5 presents sensory evaluation of the samples cooked to 82 °C, since there were no significant differences among treatments at 71 °C. Marination produced the lowest scores for flavour and overall acceptability when samples were cooked to 77 °C ($P < 0.05$) (data not shown). Significant differences among treatments were observed only for tenderness when samples were cooked to 82 °C. Control samples had the lowest score for tenderness, whereas blade tenderization had the highest score, with enzymatic tenderization and marination being intermediate ($P < 0.05$).

Table 5 Sensory attributes of *transversus abdominis* samples that had been cooked to 82 °C after tenderization

Sensory attributes	Tenderization treatments			
	Blade tenderization	Enzymatic tenderization	Marination	Control
Appearance	6.85 ± 1.51	6.71 ± 1.86	6.36 ± 1.78	6.46 ± 1.77
Colour	6.93 ± 1.76	7.00 ± 1.33	6.46 ± 1.57	7.00 ± 1.76
Flavour	6.59 ± 1.58	6.71 ± 1.69	6.18 ± 1.98	5.75 ± 1.81
Taste	6.63 ± 1.55	6.54 ± 1.49	5.96 ± 1.63	5.61 ± 1.82
Tenderness	7.37 ± 1.48[a]	7.07 ± 1.84[ab]	6.21 ± 1.75[ab]	5.93 ± 1.98[b]
Juiciness	7.00 ± 1.82	6.68 ± 1.81	6.50 ± 1.98	5.75 ± 1.99
Overall acceptability	6.93 ± 1.64	6.71 ± 1.72	6.25 ± 1.81	5.96 ± 1.71

[a,b] Within a row, values with a common superscript did not differ with probability $P < 0.05$

Conclusions

With the increased demand for beef fajitas in Turkey, further processing of the TrA from Holstein steers could provide an economical source . The results indicated that traditional methods of tenderization, including blade and enzymatic tenderization, could lead to better utilization of TrA muscles, even from unsuitable breeds such as Holstein. These treatments could add value to meat from these animals, particularly where high-quality beef production was limited and TrA muscles had been incorporated into ground meat because of concern over their tenderness.

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Authors' Contributions

Conceptualization, HB and LAT; methodology HB; validation, HB and LAT; formal analysis, HB and LAT; investigation, HB and LAT; resources, HB and LAT; data curation, HB; writing and original draft preparation, HB and LAT; writing, review and editing, HB; supervision, HB; project administration, HB and LAT; funding acquisition, HB. All authors read and agreed to the finalized version of the manuscript.

Conflict of Interest Declaration

The authors declare there is no conflict of interest.

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