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Full Length Research Paper

The relationship between excreta viscosity, starch digestibility and metabolizable energy of wheat and barley in adult cockerels

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This experiment was conducted to determine the relationship between excreta viscosity, nitrogen corrected apparent metabolizable energy (AMEn) and stich digestibility of eighteen and sixteen varieties of wheat and barley, respectively, in adult cockerels by conventional addition method (CAM) in adult cockerels for 7 day.Based on these results, very significant (P<0.0001) effect of wheat varieties on excreta Viscosity, starch digestibility and MEn in adult cockerels was observed. The highest excreta Viscosity, 1.77 (cps), MEn (13.85 MJ/kg) and starch digestibility (98.97 %) were shown for Shiraz, Akbari and Chamran varieties respectively. Also, the lowest amounts of excreta viscosity, 1.36 (cPs), MEn (9083 MJ/Kg) and starch digestibility (85.78 %) was had for Dez, Pishtaz and Shiraz varieties respectively. Results showed that excreta viscosity amounts was significantly influenced by the sixteen varieties of barley (P<0.001), whereas wheat MEn and starch digestibility were not significantly affected. The highest amount of excreta viscosity (3.01 cPs) was belonging to variety 1 and the lowest (1.65 cPs) were belonged to variety 13. There was a negative linear relationship between the excreta viscosity and MEn, and Vis and starch digestibility of wheat varieties. In this regard, when excreta viscosity was increased, the MEn and starch digestibility was reduced. Also, regression analysis of wheat samples gave correlation coefficients of 0.29 and 0.19 for relationship between excreta viscosity and MEn, and excreta viscosity and starch digestibility, respectively.There was a weak linear relationship between the excreta viscosity and MEn, and viscosity and starch digestibility of barley varieties. In this regard, when excreta viscosity was increased, the MEn and starch digestibility was reduced. Also, regression analysis of wheat samples gave correlation coefficients of 0.02 and 0.008 for relationship between excreta viscosity and MEn, and excreta viscosity and starch digestibility, respectively. Experiment indicated that viscosity obtained of non-starch polysaccharide (NSP) contents of wheat caused to reduce amount of ME and starch digestibility as compared with barley.

Keywords: Excreta viscosity, starch digestibility, metabolizable energy, cereals.

INTRODUCTION

It is now well established that the nutritional value of wheat for poultry may vary considerably (Mollah et al., 1983; Scott et al., 1998; McCracken and Quintin, 2000). The nutritional value is affected by both variety and environment, but the intrinsic factors in wheat that cause varying nutritional value are not yet completely established. Also, barley is the preferred grain for cultivation in many areas in the world due to its resistance to drought and ability to mature in climates

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with a short growth season. Using wheat and barley for poultry has however been limited by the considerable amounts of fiber contained in the grain (Svihus and Gullord, 2002). Under these circumstances, the utilization of wheat and barley in broiler formulation requires an adequate knowledge of their nutritive value. The nutritive values of wheat and barley are mostly defined by their energy value (AMEn). The AME content of a raw material depends mostly on its chemical composition and on the availability of its nutrients to the animal. Research through years has tried to identify the factors that influence cereals, specially wheat and barley, AMEn in an attempt to obtain an adequate prediction equation for AMEn of them. However, despite the efforts, no very high correlation between AMEn and physico-chemical properties in wheat and barley has been established (Wiseman 2000; Steendfeldt, 2001). For example, Classen et al. (1995) found a negative relationship between viscosity and wheat AMEn ($r = -0.7$, $P< 0.05$), whereas Austin et al. (1999) failed to find such a correlation. Huyghebaert and Schoneor (1999) positively corrected starch content to AMEn ($r = 0.7$, $P< 0.01$) but this was not supported by Skiba et al (2003). Additionally, most previous studies on wheat have been confined to physic-chemical parameters, specially, starch and/or non starch polysaccharides (NSP), (Choct and Annison, 1990; McCracken and Quinitin, 2000; Svihus and Hetland, 2001).

Starch is the most abundant nutrient in broiler diets, often comprising ~40% of the diet and more than half the metabolisable energy intake (Svihus, 2011). Despite this prominent role, starch has not received much attention by nutritionists generally and poultry nutritionists specifically before the early eighties, presumably because of a widespread belief that starch is more or less completely digested by broilers independent of starch source. Moran (1982), for example, concluded in his review that digestion of starch is seldom a problem. Starch is the major yielding components of cereals. Therefore, any variability in their content or digestibility would influence the AMEn value of cereals. Although it is generally assumed that starch is well digested by broiler chickens (Longstaff and MacNab, 1986), some researches have shown wheat starch digestibility to range from 80 to 90% when fed in situ to broiler chickens (Mollah et al., 1983; Rogel et al., 1987). Rogel et al. (1987) reported that starch isolated from wheat's from low AMEn were 100% digested by broiler chickens. Therefore, it seems that the observed variability in starch digestibility is linked to other factors different that starch per se. Maisonnier S, et al., (2001) he was concluded that the low apparent digestibility of starch observed with wheat's could not be attributed only to intestinal viscosity and that other factors appear to be implicated in the low digestibility observed with the wheat. The current study was carried out to assess the variation in nutritional value of wheat and barley varieties across locations and determine the relationship between viscosity, AMEn and starch digestibility of wheat and barley.

MATERIALS AND METHODS

Samples from 18 wheat, and 16 barley cultivars grown widely in Iran were obtained from the seed and plant institute, Karaj, Iran. Chemical composition (Dry matter, ash, crud protein (6.25 N), crud fiber, ether extract, gross energy, sugar and starch) content of barley and wheat were determine performed according to the standard Official Methods of Analysis of the Association of Official Analytical Chemists. Proximate analysis of cereal samples were determined by approved methods (AOAC 2000). Dry matter was determined by drying at 100 ^{o}C for 24h (AOAC 925.10). Ash was measured in a muffle furnace at 5000 ^{o}C for 18 h. Crude protein (6.25 N) in the samples was determined by the Kjeldahl methods (AOAC 984.13). Ether extract was extracted with diethyl ether by the Soxhlet method (AOAC 920.39). Gross energies of the diets and excreta were measured using a Parr adiabatic bomb calorimeter. The results are expressed on a dry weight basis.

For determine fecal viscosity 1 g sample with buffer solution were then centrifuged at 900 g for 10 minutes and viscosity of supernatants was measured in a digital, cone-plate viscometer (model LVTD-CP-40. Brookfield DVIII Engineering Laboratories, Inc.) at 25 ^{o}C at 50 RPM. The bioassay described by Yaghobfar and Boldaji (2002) was used to determine ME and starch digestibility. The experiment was conducted with mature Rhode Island Red (RIR) cockerels, using the conventional addition (CAM). The cockerels were individually housed in metabolic cages in a temperature-controlled room with 14 hours of light per day in both experiments. Each cage was fitted with an individual feeder and a nipple drinker. A total of 48 birds, drawn from a larger population, were used for in experiment. Between assays the birds were fed on maintenance diet and fresh water was available at all times. An aluminum tray was placed under each cage to allow droppings to be collected quantitatively. The CAM, period lasted 6 days: a 3-day pre-collection period and a 3-day collection period. Also, before the start of experiment, feed was withheld from all 48 birds for 24 h to ensure that no dietary residues remained in their alimentary tracts. In the CAM experiment, the duration of the feeding period was adjusted so that the adult cockerels voluntarily consumed all the samples they were

Table 1. The effect of wheat on Viscosity, metabolizable energy (MEn) and starch digestibility in adult cockerels.

Wheat varieties	Viscosity (cPs)	MEn (MJ/kg)	Starch Digestibility (%)
Alamout	1.69^{b}	11.65^{cd}	94.77^{d}
Bahar	1.41^{i}	12.82^{abc}	98.77^{a}
Darya	1.40^{i}	13.87^{a}	98.15^{ab}
Arta	1.45^{h}	13.63^{a}	97.61^{ab}
Akbari	1.47^{hg}	13.85^{a}	98.59^{a}
Dez	1.36^{j}	13.29^{ab}	98.83^{a}
Bam	1.50^{e}	12.98^{abc}	98.01^{ab}
Atrak	1.36^{j}	13.75^{a}	97.30^{abcd}
Shiraz	1.77^{a}	12.04^{bcd}	85.78^{e}
Pishtaz	1.59^{d}	9.83^{e}	96.95^{abcd}
Roshan	1.49^{efg}	13.30^{ab}	95.06^{cd}
Moghan	1.63^{c}	11.59^{cd}	97.68^{abc}
Niknejad	1.47^{fgh}	11.10^{cd}	86.95^{e}
Alvand	1.50^{ef}	12.75^{abc}	98.45^{a}
Shahryar	1.49^{efg}	12.74^{abc}	95.37^{bcd}
Pishgam	1.47^{fhg}	12.83^{abc}	96.36^{abcd}
Chamran	1.42^{i}	12.99^{abc}	98.97^{a}
Kavir	1.70^{b}	11.87^{cd}	97.60^{abc}
Mean	1.51	12.60	96.17
SEM	0.016	0.73	1.47
P-value	0.0001	0.0001	0.0001

offered. The samples of droppings voided during the 3-day after feeding were collected, weighed and frozen. Before analysis, the frozen samples were removed from the freezer, and placed in an oven, to be dried at 90°C for 16-h overnight. Samples of the ground excreta were assayed for gross energy by means of adiabatic oxygen bomb calorimeter and nitrogen by the Kjeldahl procedure (AOAC, 2000). The experiment was conducted on the basis of a completely randomized design, with 6 replicates. The mean values for each cereals input was determined for each replicate. Total intake of feed energy (IE) and nitrogen (IN) and droppings energy (FE+UE) and nitrogen (FN+UN) were measured for each bird, and results of experiment was evaluated by the formulae given below.

$$AME\ (MJ/kg) = [IE - (FE + UE)] / I$$
$$AMEn\ (MJ/kg) = [(IE - (FE + UE) - K\ (IN - (FN + UN)] / I$$

Starch digestibility

Feed consumption was monitored and excreta collected during 72 h of the feeding period. After collection, excreta were stored in the refrigerator. The excreta was dried at 90°C for 16-h overnight then weighed ground to a fine powder and sampled for starch analysis. The starch digestibility of the trial diets was calculated for each group of birds. The mean value for each cereal is reported.

RESULT AND DISCUSSION

The effect of wheat varieties on excreta viscosity, MEn and starch digestibility in adult cockerels were shown in Table 1. Based on these results, very significant ($P<0.0001$) effect of wheat varieties on excreta viscosity, starch digestibility and MEn in adult cockerels was

Table 2. The effect of barley varieties on Viscosity, metabolizable energy (MEn) and starch digestibility in adult cockerels

Barley varieties	Viscosity (cPs)	MEn (MJ/kg)	Starch Digestibility (%)
1	3.01[a]	10.80	96.51
2	2.11[hg]	8.79	89.24
3	2.01[h]	10.17	85.66
4	1.71[j]	9.88	89.59
5	2.43[d]	9.30	89.31
6	1.82[i]	8.95	94.90
7	2.34[e]	9.53	94.60
8	2.09[hg]	9.94	93.89
9	2.17[fg]	10.72	90.56
10	2.22[f]	9.33	85.87
11	2.08[hg]	10.55	88.71
12	3.00[a]	11.06	92.65
13	1.65[j]	11.05	94.63
14	2.64[c]	10.66	93.26
15	2.04[h]	9.64	95.96
16	2.90[b]	10.92	90.91
Mean	2.23	10.00	91.59
SEM	0.05	1.21	4.77
P value	0.001	0.45	0.16

observed. In this regard, most varieties have lower excreta viscosity amounts than average (1.51 cPs). The highest amount of excreta viscosity (1.77 cPs) was belonging to Shiraz variety and the lowest amount of it (1.36 cPs) was belonging to Dez variety. Regarding metabolizable energy, most varieties have higher amounts than average (12.60 MJ/kg). The highest amount of MEn (13.85 MJ/kg) was belong to Akbari variety and the lowest amount of it (9.83MJ/kg) was belong to Pishtaz variety. Also, most varieties have higher amounts of starch digestibility than average (96.17 %). The highest amount of starch digestibility (98.97 %) was belonging to Chamran variety and the lowest amount of it (85.78 %) was belonging to Shiraz variety. The effect of barley varieties on excreta viscosity, MEn and starch digestibility in adult cockerels were shown in Table 2. Based on these results, excreta viscosity amounts was significantly influenced by the inclusion of barley in feed formulation ($P<0.001$) whereas wheat MEn and starch digestibility were not significantly affected. In this regard, most varieties have lower excreta viscosity amounts than average (2.23 cPs). The highest amount of excreta viscosity (3.01 cPs) was belonging to variety 1 and the lowest amount of it (1.65 cPs) was belonging to variety 13. Regarding MEn, most varieties have lower amounts than average (10.00 MJ/kg). The highest amount of MEn (11.06MJ/kg) was belonging to variety 12 and the lowest amount of it (8.79 MJ/kg) was belonging to variety 2. Also, most varieties have higher amounts of starch digestibility than average (91.59 %). The highest amount of starch digestibility (95.98 %) belonged to variety 15 and the lowest amount of it (85.66 %) belonged to variety 3.

The relationship between the viscosity and MEn of wheat in adult cockerels is shown in Figure 1. In this regard, there was a negative linear relationship between the excreta viscosity and MEn. From the intercept, it can be seen that at zero viscosity excreta, the MEn intake was 2.17. When excreta viscosity was increased, the MEn intake was reduced. Regression analysis gave correlation coefficient of 0.29 for relationship between excreta viscosity and MEn. The equation indicates that at zero viscosity of excreta, the MEn intake is 2.17. The relationship between the viscosity and starch digestibility of wheat in adult cockerels is shown in Figure 2. In this regard, there was a linear relationship between the excreta viscosity and starch digestibility. From the intercept, it can be seen that at zero viscosity excreta, the starch digestibility was 2.8. When excreta viscosity was increased, the starch digestibility was reduced. Regression analysis gave correlation coefficient of 0.19 for relationship between excreta viscosity and starch digestibility. The equation indicates that at zero viscosity of excreta, the starch digestibility is 2.8.

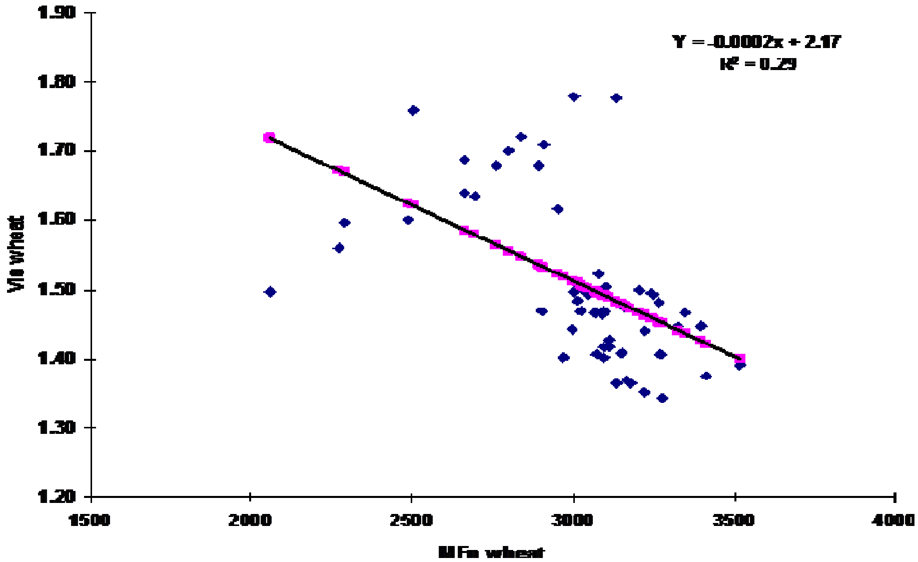

Figure 1. The relationship between metabolizable energy (MEn) and Viscosity of wheat in adult cockerels

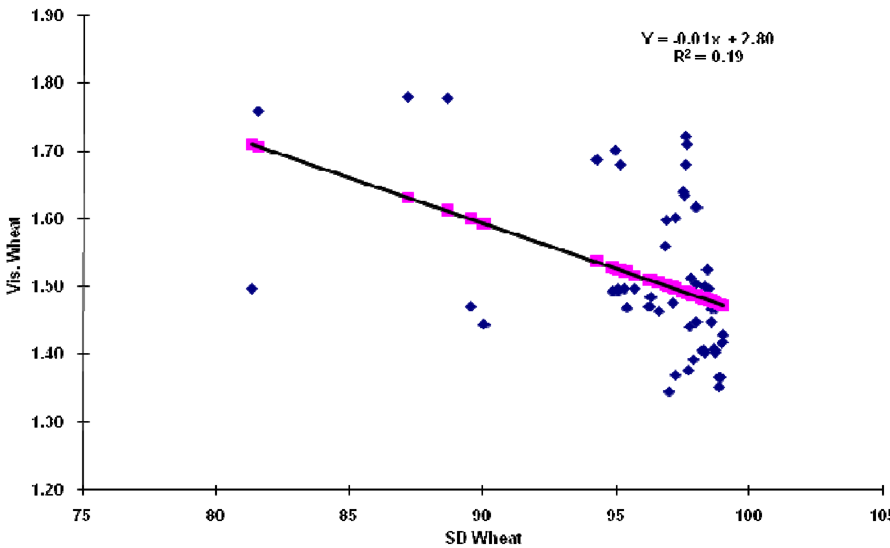

Figure 2. The relationship between starch digestibility and viscosity of wheat in adult cockerels.

The relationship between the viscosity and MEn of barley in adult cockerels is shown in Figure 3. In this regard, there was a weak negative linear relationship between the excreta viscosity and MEn. From the intercept, it can be seen that at zero viscosity excreta, the MEn intake was 1.74. When excreta viscosity was increased, the MEn intake was reduced. Regression analysis gave correlation coefficient of 0.02 for relationship between excreta viscosity and MEn. The equation indicates that at zero viscosity of excreta, the MEn intake is 1.74. The relationship between the viscosity and starch digestibility of barley in adult cockerels is shown in Figure 4. In this regard, there was a linear relationship between the excreta viscosity and starch digestibility. From the

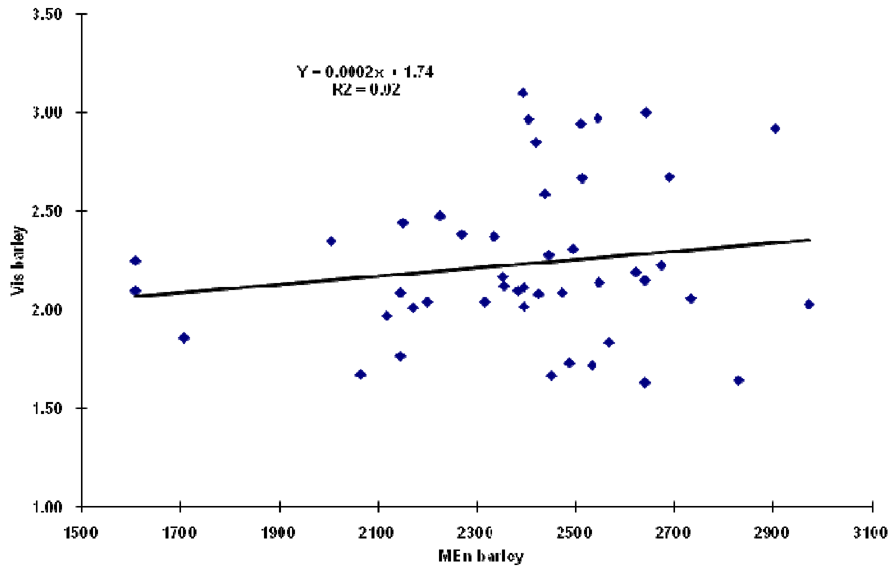

Figure 3. The relationship between metabolizable energy (MEn) and Viscosity of barley in adult cockerels.

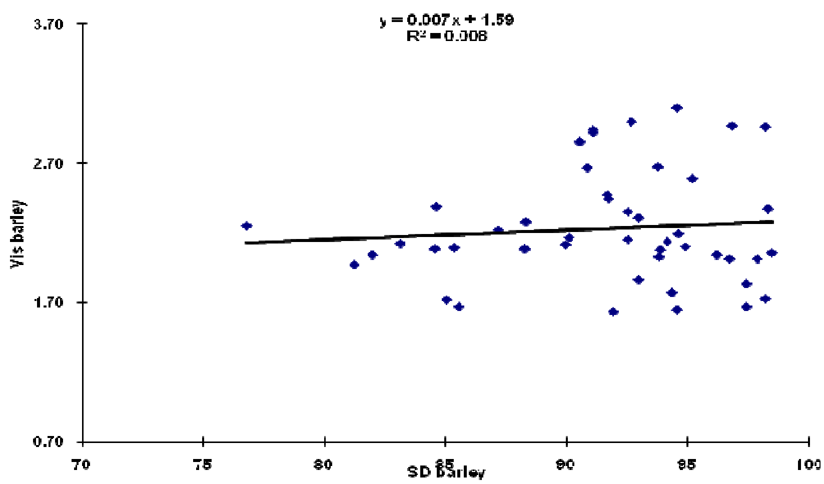

Figure 4. The relationship between starch digestibility and viscosity of barley in adult cockerels

intercept, it can be seen that at zero viscosity excreta, the starch digestibility was 1.59 cPs. When excreta viscosity was increased, the starch digestibility was reduced. Regression analysis gave correlation coefficient of 0.008 for relationship between excreta viscosity and starch digestibility. The equation indicates that at zero viscosity of excreta, the starch digestibility is 1.59.

It is now well-established that the nutritive value of cereal grains for poultry is inversely related to the level of viscosity resulting from non-starch polysaccharides (NSP) (Annison 1991). The results of the present study are in good accordance with those of chesson (2001) who reported the negative correlation between viscosity and AMEn of cereals such as wheat and barley. The consequence of this is the widespread use of feed enzyme supplements to enhance nutrient digestibilities in monogastrics. Our results also agree with those obtained by Annison (1990) who reported that increasing of viscosity due to soluble arabinoxylans content resulted in decreasing of AMEn and also these NSP prevent digestion and absorption of nutrients. However, Carre et al. (2002) showed that reason of different wheat variety not only can be viscosity variations, but also can be other factors such as starch digestibility and hardness of wheat variety because they didn't find strong correlation between starch digestibility and intestinal content viscosity. Negative correlation between soluble NSP and starch digestibility is reported by Classen et al. (1995), (2005) and Choct and Hogus (2000). It has been shown that variable AMEn value of wheat is related to anti-nutritive effects of soluble fiber (Choct et al., 1995; Choct et al., 1999), since addition of fiber-degrading enzymes increases the nutritional value of the low-AMEn wheat. Viscosity, which again is related to soluble fiber in wheat, has also been shown to be related to AMEn value of wheat (Dusel et al., 1997). The starch digestibility, but not its content, is highly correlated (R^2=0.886) with the AMEn (Mollah et al. 1983; Rogel et al. 1987). Apart from starch, cereal grains contain various amounts of NSP, which are composed predominantly of arabinoxylans (pentosans), beta-glucans and cellulose. Only small amounts of pectin polysaccharides are found in the stems and leaves of cereals. The low-MEn wheat in broilers, first described by Mollah et al. (1983) and Rogel et al. (1987), is caused by soluble NSP (mainly arabinoxylan and some beta-glucan) in cell walls (Annison 1993). Some studies (Choct et al. 1995; Choct et al. 1996; Hughes and Choct 1997) provided further evidence of the occurrence of low-MEn wheats. The reduction in AMEn is directly attributable to NSP. However, some dissenting views have been expressed by Nicol et al. (1993) who found no correlation between soluble NSP and AMEn. In addition, Wootton et al. (1995) observed a positive correlation (r = 0.63; n = 19) between pentosan content of wheat and AMEn. This suggests that the higher the fiber content in diets, the better their nutritive value for poultry, a view which contrasts with the conventional understanding of monogastric nutrition. The anti-nutritive effect of soluble NSP on AMEn is manifested through inhibition of digestion of starch, lipid and protein in the foregut (Choct and Annison 1992). The possibilities that gut microflora have a role in depression of starch digestion and AMEn (Annison 1993) was confirmed by Choct et al. (1996) and Smits et al. (1997). The mechanism of action of soluble NSP is thought to involve increased viscosity of digesta which limits contact between digestive enzymes and substrates, and for contact between nutrients and absorption sites on the intestinal mucosa (Annison 1993; Bedford and Morgan 1996; Smits et al. 1997). The experiment confirms that viscosity content of different wheat variety effect to reduce amount of MEn and starch digestibility values.

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