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Nutritive Value of Pastures in Kars District II. Degradation Kinetics in the Rumen with Respect to Stages of Maturity*

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Abstract: This study was conducted to determine the ruminal degradation characteristics of nutrients with respect to pasture stage of maturity in Kars district. The nutritional parameters were dry matter (DM), organic matter (OM), crude protein (CP) and crude fiber (CF). Samples were collected from pastures of 9 vicinities of Kars district over a 28-day interval. Three adult Morkaraman rams were fitted with a rumen cannula and samples were incubated in the rumen for 4, 8, 16, 24 and 48 h. Parameters for degradation kinetics included readily degraded fraction, slowly degraded fraction, lag phase and fractional rate of passage. The cumulative disappearance rate of DM, OM, CP and CF was linearly and quadratically decreased with advancing maturity. For DM, OM, CP and CF, readily degradable fraction, slowly degradable fraction, sum of totally degradable fraction, rate constant of passage and effective degradability linearly decreased, whereas lag phases linearly increased with advancing maturity.

In conclusion, stage of maturity had a great impact on the degradation characteristics of nutrients. The adverse effect of advancing maturity on the degradation of nutrients could be related to its direct effect on lignification. The data presented in this article provide important information on the rate of digestion by the ruminants of the pasture throughout the grazing season in Kars district.

Key Words: Pasture, ruminal degradation, vegetation, stage of maturity.

Kars Yöresi Çayır-Meralarının Besinsel Değeri II. Olgunlaşma Dönemlerine Göre Rumende Yıkımlanma Özellikleri

Özet: Bu çalışma, Kars yöresi çayır-meralarının besin madde içeriklerinin olgunlaşma dönemine göre ruminal yıkımlanma özelliklerini belirlemek amacıyla yapıldı. Besinsel parametreler kuru madde (KM), organik madde (OM), ham protein (HP) ve ham selüloz (HS)'u içermektedir. Örnekler 28 gün arayla Kars yöresinin dokuz değişik bölgesinden toplandı. Üç baş Morkaraman koça rumen fistülü açtırıldı ve örnekler 4, 8, 16, 24 ve 48 saat süreyle rumende inkubasyona bırakıldı. Yıkımlanma parametreleri hızla yıkımlanan, yavaş yıkımlanan, lag faz ve yıkımlanma hız oranını içermektedir. Toplam KM, OM, HP ve HS'un kaybolma miktarı olgunlaşmanın ilerlemesiyle linear ve quadratik olarak azaldı. KM, OM, HP ve HS'un hızlı yıkımlanan, yavaş yıkımlanan, toplam yıkımlanan fraksiyon, etkin yıkılabilirlik ve yıkımlanma hız oranı olgunlaşmanın ilerlemesiyle linear olarak azaldı, lag faz ise linear olarak arttı.

Sonuç olarak olgunlaşmanın ilerlemesinin besin maddelerinin yıkılabilirlik özellikleri üzerine büyük bir etkisi bulunmuş olup bu etki lignifikasyonun etkisiyle ilişkilidir. Bu çalışmada elde edilen veriler, Kars yöresindeki çayır-meraların otlatma sezonu boyunca ruminantlar tarafından hangi oranlarda sindirilebildikleri hakkında önemli bilgi verecektir.

Anahtar Sözcükler: Çayır-Mera, rumen yıkılabilirliği, vejetasyon, olgunlaşma dönemi.

Introduction

Pastures are the major constituents of the diets of livestock animals. The determination of pasture digestibility characteristics after the elucidation of botanical and nutrient composition is essential to develop feeding strategies. The analytical procedures for feedstuffs so as to characterize nutrient composition have been standardized (1). Recent improvements clarified

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specific constituents of macronutrients. For instance, the use of degradable and undegradable rumen fractions in place of crude protein is done to improve the utilization of feedstuffs (2,3). The nylon bag technique offers an easy, fast, economical, and effective method to determine crude protein (CP) fractions (4,5)

Stage of maturity affects the nutrient composition of forage and the utilization of nutrients by animals (6). Sarwar et al. (7) reported that the dry matter (DM) degradability of grasses is higher at early vegetation than at late vegetation. Similarly, organic matter (OM) digestibility decreases with plant maturation (8). The degradation kinetics of forages vary (6,9); Balde et al. (6) investigated degradation kinetics of alfalfa at early bud, early bloom and full bloom stages and orchardgrass at early vegetation, early head and anthesis stages and showed that the digestibility of DM and CP for both plants linearly decreased with advancing stage of maturity.

Pasture nutrients may be utilized differently in vivo. The aim of this study was to determine the degradation kinetics of pastures with the nylon bag technique in the rumen with respect to stage of maturity.

Materials and Methods

Sample Collection

Representative pasture samples were collected bi-weekly from 9 different locations (Susuz, Burcalı-Arpaçay, Arpaçay, Akyaka, Dolaylı-Digor, Dağpınar-Digor, Selim, Söğütlü-Kars, Kars) during the vegetation period in Kars district. To determine degradation kinetics, samples harvested on 21 May, 1999 (1st cut), 18 June, 1999 (3rd cut), and 16 July, 1999 (5th cut), were dried in an air-forced oven at 60 °C for 48 h and then ground to pass through a 4 mm sieve.

In Situ Technique and Calculations

For degradation kinetics in the rumen, 3 Morkaraman rams (1.5-2 years old) weighing an average of 48 kg were fitted with a rumen cannula. The animals were fed a diet consisting of 82.2% medium quality hay and 17.8% concentrate on a DM basis (Table 1). The mixture of concentrate contained barley (50%), cottonseed meal (25%), wheat bran (22%), salt (1%), limestone (1%) and vitamin-mineral premix (1%). The animals were housed in individual pens and fed once daily (900 g of hay and 200 g of concentrate) with free access to water.

Table 1. Ingredient and nutrient composition of the basal diet.

	Ingredients		
Nutrients[1]	Grass hay	Concentrate	Ration[2]
DM	92.82	90.94	92.49
		% of DM	
OM	91.70	91.08	91.59
CP	9.07	16.68	10.43
CF	28.54	6.97	24.69
EE	2.71	3.22	2.80
NFE	51.38	64.21	53.67
Ash	8.29	8.91	8.40

[1]Nutrients: DM = dry matter, OM = organic matter, CP = crude protein, CF = crude fiber, EE = ether extract, and NFE = nitrogen free extract. [2]Calculated values. Ration consisted of 82.17 and 17.83% of grass hay and concentrate on a DM basis.

Pasture samples harvested at different stages of maturity (2.5-3.0 g) were put in nylon bags provided by E. R. Ørskov (Rowett Research Institute, Aberdeen, UK) and then placed, in triplicate, in the rumen for 4, 8, 16, 24 and 48 h to determine the extent of degradation. Following incubation, the samples were removed and placed into cold water to suppress post-incubation microbial activity. In order to determine washing loss prior to determination of nutrients with respect to the extent of degradation, the nylon bags with the samples were put into lukewarm water (37-40 °C), washed and then dried at 60 °C for 48 h in an air-forced oven. The samples were analyzed for DM, OM, CP and crude fiber (CF) as outlined by the AOAC (10).

Rumen degradation kinetics for DM, OM, CP and CF were calculated using the nonlinear model proposed by Ørskov and McDonald (11):

$$P = a + b^{*}(1 - e^{c^{*}t}).$$

where P = percentage of degradability for response variables at t_i, t = time relative to incubation (h), a = highly soluble and readily degradable fraction, b = insoluble and slowly degradable fraction and c = rate constant for degradation. Following the determination of these parameters, the effective degradability of nutrients in the leaves was calculated using an equation described by Ørskov and McDonald (11):

$$Pe = a + (b*c)/(c + k).$$

where Pe = effective degradability for response variables (%), a = highly soluble and readily degradable fraction, b = insoluble and slowly degradable fraction, c = rate constant for degradation and k = rate constant of

passage. When calculating effective degradability, rate constant of passage was assumed to be 0.02, 0.05 and 0.08% per hour (4) so that the results could be extrapolated to other ruminants that differ in rumen capacity.

Statistics

The cumulative disappearance for DM, OM, CP and CF was analyzed using the general linear model procedure of Minitab (12). Data were computed as repeated measures in a split-plot arrangement with time of incubation being a sub-plot. The structure of the model was as follows:

$$Y_{ijk} = \mu + S_i + t_j + (S*t)_{ij} + e_{ijk}$$

where Y_{ijk} = response variable (DM, OM, CP and CF), μ = population mean, S_i = stage of maturity (I = 1st, 3rd and 5th cut), t_j = time of incubation (j = 4, 8, 16, 24 and 48 h), $(S*t)_{ij}$ = interaction between i^{th} stage of maturity and j^{th} time of incubation, and e_{ijk} = residual error.

The final model included the effect of stage of maturity and time of incubation because there was no stage of maturity by time of incubation interaction. Moreover, polynomial contrast coefficients were employed to describe the nature of the degradation pattern and quadratic regression lines were developed to project the extent of degradation. The final model was also computed to evaluate parameters for degradation kinetics (a, b, c, lag, etc.). Statistical significance for the effect of stage of maturity and time of incubation on response variables was reported at $P < 0.05$.

Results

Time of incubation linearly and quadratically increased the cumulative disappearance for DM (upper panel) and OM (lower panel) (Figure 1; $P < 0.05$ for both). The second derivative of quadratic regression lines indicated that the average extent of both DM ($y = -0.02t^2 + 2.13t$

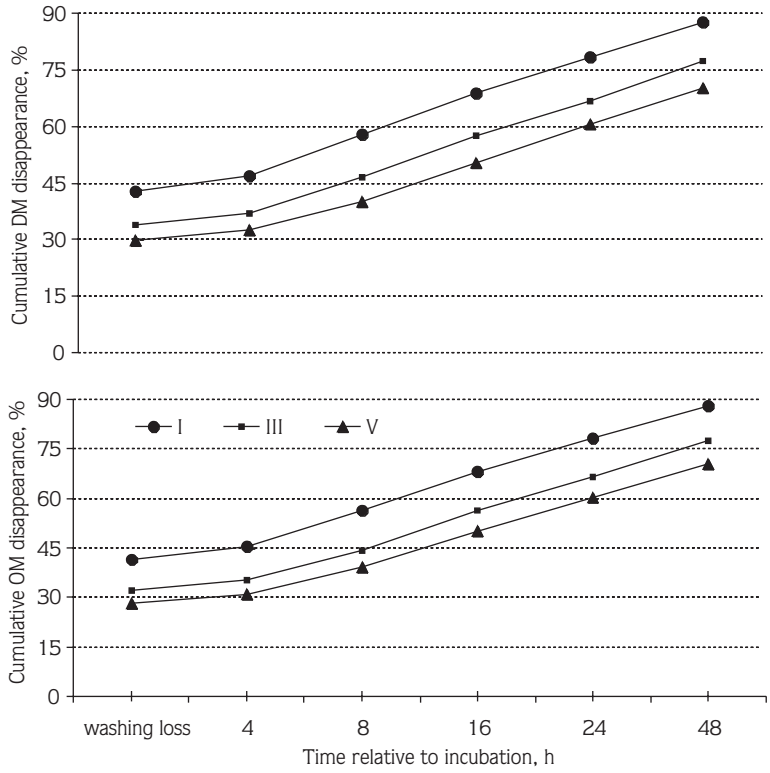

Figure 1. Disappearance rate for dry matter (upper panel) and organic matter (lower panel) of pastures harvested on 21 May 1999 (●); 16 June 1999 (■); and 16 July, 1999 (▲). There were significant harvest time and incubation period effects on the cumulative disappearance of DM and OM ($P < 0.05$ for both). There was no harvest time by incubation period interaction in both response variables. Pooled SEM was 0.85 and 0.92 for DM and OM, respectively.

+ 31.39 with R^2 = 0.99) and OM (y = -0.02t^2 + 2.22t + 29.37 with R^2 = 0.99) was highest at 44.5 h after incubation. There were linear decreases in the cumulative disappearance of DM and OM with advancing maturity (Figure 1; P < 0.05 for both). Average cumulative disappearance at the first, third and fifth cut was 87.7, 77.4 and 70.1% for DM and 87.9, 77.7 and 70.1% for OM, respectively.

The effect of time of incubation and stage of maturity on cumulative disappearance for CP and CF was similar to that for DM and OM. Cumulative disappearance for CP (upper panel) and CF (lower panel) increased both linearly and quadratically with increasing incubation time (Figure 2; P < 0.05 for both). Moreover, the second derivative of quadratic regression lines for CP (y = -0.02t^2 + 1.76t + 45.77 with R^2 = 0.99) and CF (y = -0.03t^2 + 2.90t + 7.26 with R^2 = 0.99) indicated that they were highest at 44.3 and 45.4 h post-incubation, respectively. Cumulative disappearance for CP and CF also linearly decreased by advancing maturity (P < 0.05 for both). Average cumulative disappearance at the first, third and fifth cut was 90.8, 84.9 and 78.3% for CP and 81.0, 72.3 and 64.7% for CF, respectively.

Except for fraction b and lag phase, all parameters for DM degradation kinetics in the rumen decreased linearly with advancing maturity (Table 2). All parameters for OM degradation kinetics also decreased linearly with advancing maturity (Table 2). The effect of stage of maturity on DM and OM degradation kinetics was similar to that on CP and CF degradation kinetics (Table 3).

Discussion

This is the first study establishing the rumen degradation characteristics of pasture grown in and around Kars district during the grazing period. Although

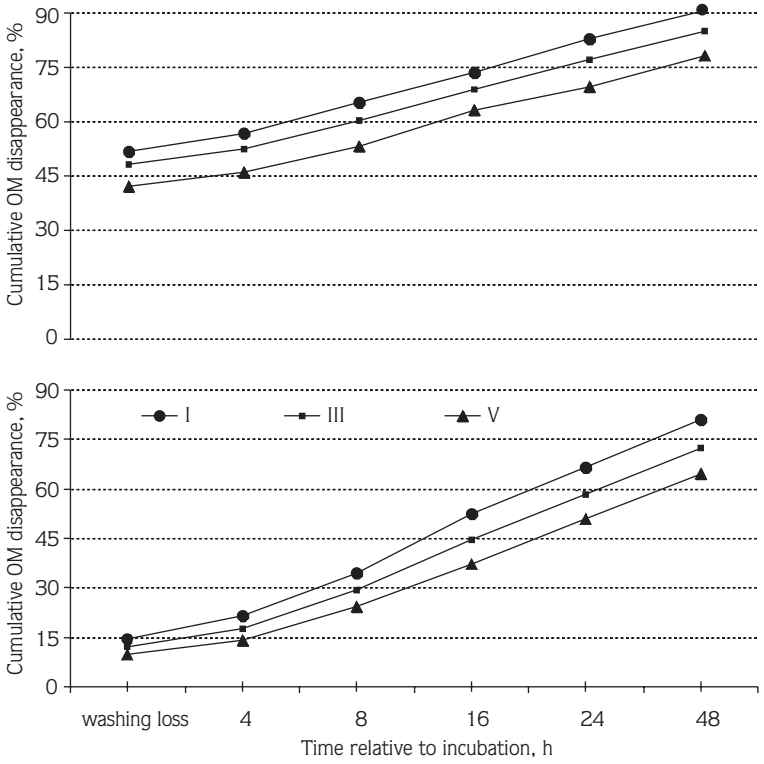

Figure 2. Disappearance rate for crude protein (upper panel) and crude fiber (lower panel) of pastures harvested on 21 May 1999 (●); 16 June 1999 (■); and 16 July 1999 (▲). There were significant harvest time and incubation period effects on the cumulative disappearance of CP and CF (P < 0.05 for both). There was no harvest time by incubation period interaction in both response variables. Pooled SEM was 0.77 and 0.87 for CP and CF, respectively.

Table 2. Degradation kinetics for dry matter and organic matter in the rumen[1].

	Dry Matter				Organic Matter			
	Harvest No.[2]				Harvest No.[2]			
Kinetic Parameters[3]	I	III	V	SEM	I	III	V	SEM
Fraction a,%	35.13[a]	26.71[b]	22.66[c]	1.11	33.36[a]	24.07[b]	20.76[c]	1.19
Fraction b,%	55.59	55.13	52.53	0.97	57.92[a]	58.90[a]	54.94[b]	1.14
Fraction a+b,%	90.72[a]	81.84[b]	75.19[c]	1.02	91.27[a]	83.27[b]	75.70[c]	1.08
c fraction, h	0.061[a]	0.054[b]	0.050[b]	0.002	0.065[a]	0.053[b]	0.051[b]	0.005
Pe, 0.02%/h	77.16[a]	66.89[b]	60.36[c]	0.78	77.00[a]	66.66[b]	60.25[c]	0.73
Pe, 0.05%/h	66.15[a]	55.54[b]	49.42[c]	0.75	65.46[a]	54.48[b]	48.85[c]	0.80
Pe, 0.08%/h	59.93[a]	49.41[b]	43.62[c]	0.77	58.99[a]	47.98[b]	42.84[c]	0.87
Lag, h	2.41	2.59	2.91	0.67	2.51[a]	2.73[b]	2.92[b]	0.12

[1]Data are the least square means. Different superscripts within rows differ ($P < 0.05$).
[2]Samples were harvested monthly from 21 May to 16 July, 1999.
[3]Parameters were calculated using the formula proposed by Ørskov and McDonald (1979). Pe = a + (bc)/(k+c), where Pe = effective degradability, a = soluble fraction, b = degraded fraction, c = fractional rate of degradation, and k = rate constant of passage.

Table 3. Degradation kinetics for crude protein and crude fiber in the rumen[1].

	Crude Protein				Crude Fiber			
	Harvest No.[2]				Harvest No.[2]			
Kinetic Parameters[3]	I	III	V	SEM	I	III	V	SEM
Fraction a,%	48.24[a]	43.97[b]	36.94[c]	0.92	4.95[a]	3.47[b]	2.28[c]	0.48
Fraction b,%	46.35	44.62	44.48	1.36	82.18[a]	75.70[b]	70.77[c]	0.76
Fraction a+b,%	94.59[a]	88.59[b]	81.42[c]	1.14	87.13[a]	79.18[b]	73.05[c]	0.82
c fraction, h	0.055	0.055	0.057	0.003	0.056[a]	0.052[a]	0.046[b]	0.002
Pe, 0.02%/h	81.99[a]	76.58[b]	69.86[c]	0.74	65.53[a]	58.14[b]	51.57[c]	0.79
Pe, 0.05%/h	72.33[a]	67.40[b]	60.81[c]	0.61	48.69[a]	42.36[b]	36.40[c]	0.82
Pe, 0.08%/h	67.06[a]	62.36[b]	55.84[c]	0.62	39.43[a]	33.91[b]	28.59[c]	0.80
Lag, h	1.46[a]	1.81[b]	2.18[b]	0.24	2.25	2.34	2.43	0.10

[1]Data are the least square means. Different superscripts within rows differ ($P < 0.05$).
[2]Samples were harvested monthly from 21 May to 16 July, 1999.
[3]Parameters were calculated using the formula proposed by Ørskov and McDonald (1979). Pe = a + (bc)/(k+c), where Pe = effective degradability, a = soluble fraction, b = degraded fraction, c = fractional rate of degradation, and k = rate constant of passage.

there are some studies investigating the chemical composition of the hay or pasture in the region (13-15), in none of these studies were the vegetation period and the interaction of nutrients in the rumen taken into account. However, studies have shown that vegetation, soil type and climate might dramatically affect the utilization of nutrients by animals. The results of this study might therefore contribute to our current knowledge and allow us to find strategies to improve animal nutrition in the region.

The disappearence of DM, OM, CP and CF increased with time of incubation in the rumen (4-48 h), but decreased with the progress of vegetation. These values were in line with those of Keyserlingk et al. (9) and Komprda et al. (16). Komprda et al. (16) incubated lucerne (*Medicago sativa*), harvested at different stages of maturity, for 48 h and showed that the disappearance of OM decreased linearly by up to 46% with advancing maturity (from 9 to 109 days, relative to vegetation). They also observed a 22% reduction in CP disappearance

with advancing stage of maturity (13). Decreases in degradation could be attributed to an increased lignification process in the cell wall (9), because lignified tissues limit feed intake and occupy space in the rumen, which may in turn reduce the attachment of bacteria to substrates. Overall, the cumulative disappearance pattern for nutrients appears to decrease linearly with advancing maturity, but slight differences in cumulative disappearance reported in the present study compared with those reported in the literature could be due to differences in forage sources, stage of maturity and environmental conditions.

In the current study, rapidly degradable fractions (a) of DM decreased with progress of vegetation and, although not as high as rapidly degradable fractions, there were decreases in slowly (b) degradable fractions with maturation process (Table 2). This might be a result of the increase in lignification with the progress of vegetation. The decrease in rapidly and slowly degradable fractions with the progress of vegetation in the current study was also evident in the study of Coblentz et al. (17). They studied gamagrass at different stages of maturity and found that approximately 30 and 10% decreases occur in (a) and (b) fractions respectively from boot stage to physiological maturity. The results obtained in the current study are also in line with those obtained by Balde et al. (6) and Keyserlingk et al. (9). Moreover, the potential degradability (a + b) of DM decreased with grass maturation. The mean value obtained for DM potential degradability in the current study (83%) is similar to that obtained by Balde et al. (6) for alfalfa (77.2%) and orchardgrass (81.6%) and with the results of Keyserlingk et al. (9) for alfalfa (81.92%) and hay (87.03%). However, Coblentz et al. (17) obtained lower potential degradability for gamagrass (mean 72.87%). The differences between the studies might be due to time of harvesting and type of flora.

Rapidly (a) and slowly (b) degradable fractions of CP decreased with maturation of the pasture. Balde et al. (6) found that mean (a) and (b) values for CP were 45.5 and 45.4% for alfalfa and 42.8 and 47.8% for orchandgrass when they were studied at different stages of maturity. The values obtained in the current study (43.1% for (a); 45.1% for (b)) were also in line with those of Balde et al. (6). Similarly, Verbic et al. (18) found that (a) and (b) values for CP were 31.6% and 57.3%, respectively, for hay. The slight differences between the current study and those of Balde et al. (6) and Verbic et al. (18) might be due in part to the different plant species used. Coblentz et al. (17) obtained similar results to those obtained in the current study for alfalfa and red clover, but they obtained different results for gamagrass. Mean potential degradability (a + b) of CP for the entire vegetation period was 88.2% in the current study, and this was also similar to the value obtained by Verbic et al. (18) (88.9%).

Rapidly and slowly degradable fractions and potential degradabilities of CF decreased with the progress of vegetation. The decrease for (a), (b), and (a + b) was 54, 14 and 16%, respectively. We were not able to find any literature concerning the degradability characteristics of CF, so we compared our results with NDF content obtained by Coblentz et al. (17). They also detected a 14% decrease for (a + b) in gamagrass with progress of vegetation.

Lag phase for the degradation of DM, OM, CP and CF was linearly prolonged with advancing maturity, which is in agreement with other reports (6,9). These ascertained that increased lignification with advancing maturity slows the degradation of forages possibly by prolonging the initial step of the degradation process. Moreover, prolonged lag phase is correlated with effective degradability (9). Thus, decreased effective degradability by advancing maturity in this study could be related to the lower percentage of fraction (a) and prolonged lag phase.

The fractional rate of degradation of DM (c) decreased with the progress of vegetation and was determined to be 0.055/h for the entire vegetation period. The effective degradabilities of DM, in respect to the different fractional rate of passage (k), decreased with the progress of vegetation and it was determined to be 57.03% for k = 0.05/h. These results are comparable to those reported by Balde et al. (6). They found that the fractional rate of degradation and effective degradability were 0.096/h and 56.1% for alfalfa and 0.050/h and 68.6% for orchardgrass, respectively.

The mean fractional rate of degradation and effective degradability of CP were 0.056/h and 66.85% in the current study. Similarly, in the study of Coblentz et al. (17), (c) was determined to be 0.05/h. Keyserlingk et al. (9) found that the effective degradability for k = 0.06/h was 62.04% for hay and 76.29% for alfalfa. The differences between these studies might be due to

variations in fractional rate of passage, plant type and time of harvesting.

In conclusion, advancing maturity had a great impact on degradation characteristics for DM, OM, CP and CF. Cumulative disappearance and effective degradability for DM, OM, CP and CF linearly decreased with advancing maturity. The adverse effects of advancing maturity on degradation kinetics for nutrients could be related to their direct effect on lignification. This study contributes preliminary information regarding the nature of pastures in Kars district with respect to stage of maturity. Further studies should specify the degradation characteristics of true protein, neutral detergent fiber and nonstructural fiber as well as calculate energetic efficiency responses to advancing stages of maturity.

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