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Deviations of feedstuffs loading in TMR preparation

Selim SIRAKAYA[1,*], **Osman KÜÇÜK**[2]

[1]Technical Sciences Vocatinal School, Aksaray University, Aksaray, Turkey

[2]Faculty of Veterinary Medicine, Department of Animal Nutriton and Nutritional Diseases, Erciyes University, Kayseri, Turkey

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Abstract: Loading of feedstuffs in planned amounts in total mixed ration (TMR) recipes are very important in terms of profitability, productivity, animal health, and performance. In the scope of this study, the planned and loaded feedstuffs amounts were determined in the mixer wagons. The study was conducted on a dairy cattle farm with ~1500 milking cow capacity. In this study, 13,276 feedstuffs loading data were examined and the mean and standard deviation of the deviation from the planned amount was 8.95 ± 18.38%. Deviation values of feedstuffs loading were found to be different; according to 1- TMR preparing operators, 2- type of loader, 3- physical property of feedstuffs, 4- feedstuffs loading methods, 5- measure of the amount of feedstuffs in TMR, 6- type of ration, 7- type of feedstuffs. In this context, five different TMR preparation operators, three different loaders, the physical properties divided into four categories, two different loading methods, feedstuffs quantities in TMR mixture, eight different ration type, and fourteen different feedstuffs were evaluated. The difference between the deviations ratios of each case was found to be significant ($P < 0.0001$). According to the data evaluated, the deviation percentage values in the feedstuffs loadings varied for the aforementioned factors in TMR preparation.

Key words: Total mixed ration, mixer feeder wagons, feedstuffs deviation, operators, feedstuffs loaders

1. Introduction

One of the important activities in dairy and beef cattle farms is the total mixed ration preparation process. Feed costs are estimated to be 60%–70% of the total cost [1–3]. TMR is a feeding system used to provide consistent feed to animals and to stabilize rumen conditions as desired [4]. Feeding activities also have an important place in terms of animal health, performance, yield, and operating profitability. Therefore, TMR mixtures should be regular and stable. Each mouthful of TMR consumed by animals must be homogeneous and balanced; otherwise, animals can be adversely affected. TMR, which is properly prepared for the feeding of dairy cows, is extremely important for animal health and productivity. Despite all the efforts made to prepare the correct TMR, it is clear that there are differences between the ration prepared and the ration consumed by the cow [5].

Although animal nutritionists have been preparing more accurate rations thanks to developing technologies and programs in recent years, there may be deviations in the amount of feedstuffs loading due to different reasons during TMR preparation [6,7]. Due to the variations in feedstuffs loading, milk and beef cattle farms are affected at significant levels. Therefore, monitoring and managing feedstuffs loadings are an important issue for an economical and efficient production activity.

Within the scope of this study, the deviation rates of the feedstuffs loading quantities were analyzed by using the software program reports integrated to the scales on the TMR mixer wagons.

It was attempted to determine the deviation values according to TMR preparation operator, type of loader, physical property of feedstuffs, feedstuffs loading method, range of the amount of feedstuffs in TMR, type of ration, and type of feedstuffs.

2. Materials and methods

2.1. Profile of farm

The study was carried out in Turkey's Kayseri Province. The farm where the study is conducted has approximately 1500 milking cows. The study data were obtained from two TMR preparation mixer wagons on the farm. These mixer wagons have 17 m^3 volume, are horizontal helical, and can be driven by a tractor (Seko Samurai 5, Italy). The wagons are equipped with a weighing scale (SekoTronic 150) and a weigher-integrated software program (Farm Manager4). On the farm, TMR distribution is ~95,000 kg per day, and ~40,000 L of raw milk is produced daily.

* Correspondence: selimsirakaya@hotmail.com

2.2. Parameters

The amounts of feedstuffs planned and loaded were obtained from the software program (Farm Manager4). For each feedstuffs loading amount (planned and loaded) from the software program; TMR preparation operator, loader, physical properties of feed, loading method, feed amount, ration and feed type data were matched. In the case of over- or underloading of the planned amount is calculated as the percentage value according to the planned amount. This calculation is used as deviation percentage data. In order to evaluate the process correctly, data collection was done without the aware of TMR preparation operators.

2.2.1. TMR preparing operators

Five different TMR preparation operators working on the farm were coded as A, B, C, D, E and deviation percentage data were evaluated for feedstuffs loading for TMR mix with the same content for each operator.

2.2.2. Type of loaders

Three different loaders are used in the loading of feedstuffs to mixer wagons on the farm. These loaders are coded as 140, 821, 928. The deviation percentage values in feedstuffs loading were matched with loader models and the data were evaluated. The loader brands are not specified for commercial reasons.

2.2.3. Physical property of feedstuffs

Feedstuffs are divided into four different groups according to their physical characteristics: rough, concentrated, pulp, and silage. Particulate size long, untreated grass and bale forage (alfalfa, alfalfa silage, wheat hay etc.) are described as rough. The concentrated group feeds are feedstuffs with high viscosity and low particle size (barley, wheat, corn, soybean meal, cottonseed meal etc.). Pulp group feeds are moist feedstuffs such as orange pulp, brewer grain, and beet pulp. Corn silage was evaluated in silage group feeds. Examples of loading method according to physical properties of feedstuffs are shown in Figure 1.

2.2.4. Feedstuffs loading methods

Two different loading methods are used on the farm for concentrated feedstuffs only. These loading methods are two parts; 1- loading with loader, 2- spiral loading. The deviation percentage rates of these two loading patterns were compared. These two loading methods are shown in Figure 2.

2.2.5. Measure of the amount of feedstuffs in TMR

The amount of feedstuffs in TMR recipe was divided into eight different categories. This distinction is 0–100 kg, 101–200 kg, 201–500 kg, 501–750 kg, 751–100 kg, 1001–1500 kg, 1501–2000 kg, 2001–3000 kg was made and coded as

Figure 1. Examples of loading method according to physical properties of feedstuffs:
(a) silage loading, (b) pulp loading, (c) rough loading, (d) concenrated loading.

I, II, III, IV, V, VI, VII, VIII, respectively. Deviation rates of feedstuffs corresponding to these values are evaluated in TMR.

2.2.6. Type of ration

Eight different TMR mixture recipes (close up, calf, heifer, early lactation, dry period, milk 1, milk 2, fattening) are used on the farm. Deviation rates in these mixtures were examined. Animal group descriptions are expressed in Table 1.

2.2.7. Type of feedstuffs

In terms of raw material, deviation rates in 14 different feedstuffs (sunflower seed meal, wheat stalk, meadow, whole cotton seed, concentrated feed, vetch cereals hay, vetch cereals hay silage, brewer grain, corn silage, orange pulp, cotton seed meal, soybean seed meal, alfalfa silage, alfalfa) loading processes were examined.

2.3. Data collection plan

In this study, 13,276 feedstuffs loading data were examined in mixer wagon. The above-mentioned parameters were recorded and evaluated for each loading data.

The TMR recipe information was transmitted via the software program (Farm Manager4) to the scale (SekoTronic 150) in the mixer wagon by means of a data transfer apparatus. After the TMR distribution process was completed, the information received from the scale with the same data transfer apparatus was transferred to the software program. TMR distribution time, planned and loaded feedstuffs quantity, and ration type data were obtained from the software program report. With the data taken from the program, the TMR preparation operator, loader type, feedstuffs feature, feedstuffs quantity range in TMR data are matched.

2.4. Calculations and statistical analysis

Percentage of deviation rates in loading on mixer wagons; the amount of feedstuffs loaded was calculated by proportioning to the quantity of feedstuffs planned. For example, if a 100 kg feedstuffs to be loaded are 110 kg, the deviation is calculated as 10%. Example calculation; Deviation % = (100 × loaded amount) / (planned amount) Differences between groups; with analysis of variance (ANOVA) and analysis of Tukey's, family error rate were determined. Minitab16.1 statistical program was used for these analysis.

3. Results and discussion

3.1. Deviation rates of TMR preparation operators

The deviation percentage rates of five TMR preparation operators working in the farm were compared. The deviation percentage values of operators coded as A, B, C, D, E are shown in Table 2.

Figure 2. Two loading methods: (a) loading with loader, (b) spiral loading.

Table 1. Ration type and animal group.

TMR code	Close-up	Calf	Heifer	Fresh	Dry	Milk1	Milk2	Beef
Description	Last 15 days of dry period (Close-up)	Female-male mixed calves between 0 and 6 months	Heifers; from 6 months to pregnancy	Cows in the first 100 days of lactation	Pregnant and dry animals	High milk-yield, after 100th day of lactation	Low milk-yield, after 100th day of lactation	Male; up to slaughter after 6 months

Table 2. Feedstuffs loading deviation rates of TMR preparation operators.

	TMR preparation operators					
	A	B	C	D	E	P <
Loading number	2416	3242	2341	2721	2555	
Deviation mean%	12.23[a]	10.32[b]	8.76[c]	7.86[c]	5.48[d]	0.0001
±standard deviation%	25.11	17.70	17.63	17.36	11.44	

There is a significant difference between the different letters (a, b, c, d) in the same line.

The deviation percentage rates of TMR preparation operators differ from each other in the feedstuffs loading process (P < 0.0001). According to TMR preparation operators, in the feedstuffs loading process the deviation rates are different. A, B, C, D, E operators' deviation mean and standard deviation values in feedstuffs loading; 12.23 ± 25.11%, 10.32 ± 17.70%, 8.76 ± 17.63%, 7.86 ± 17.36%, 5.48 ± 11.44% in the given order.

Within the scope of this study, it is considered that one of the most important factors causing unplanned loading in the feedstuffs loading processes is personnel skills. As can be seen in the study results, although TMR preparation operators operate under the same conditions and with the same equipment, there are significant differences in the unplanned loading rates (P < 0.0001). The maximum deviation mean is 12.23% for Operator A and the least deviation mean is 5.48% for Operator E. Under normal circumstances, there should be no difference between the operators. The same TMR recipe is served with different content rates to each operator change. Considering the importance of stable feeding in ruminant feed, these errors in feedstuffs loading should be reduced to minimum levels. It is thought that this difference between operators of TMR preparation can be reduced by operator training or can be improved with highly skilled operators. In order to reduce these deviation rates, it is necessary to train the operators, to follow the operators, and to create positive competition among the operators. Daily control cards to be prepared for each operator are considered to be important in terms of follow-up.

3.2. Deviation rates of loader type

The loaders used in the loading of raw feedstuffs to the mixer wagons are coded as 140, 821, 928. The deviation percentage values for loaders are shown in Table 3. The difference for the deviation percentage between loaders was significant (P < 0.0001).

As shown in Table 3, for the loader models coded as 140, 821, 928, the mean deviation and standard deviation values are 9.04 ± 22.64%, 7,43 ± 17.35%, 10.44 ± 17.72%, respectively. The maximum deviation rate was found to be 928 with 10.44% and the least deviation rate was observed 821 as 7.43%. The ergonomics, capacity, and characteristics of the loaders used in feedstuffs loading are extremely important in terms of unplanned feedstuffs loading rates. Therefore, the loaders used in the TMR preparation process must be suitable for the feedstuffs loading process.

Table 3. Feedstuffs loading deviation rates of loader type.

	Loader type			
	140	821	928	P <
Loading number	3316	1511	7146	
Deviation mean%	9.04[a]	7.43[b]	10.44[c]	0.0001
±standard deviation%	22.64	17.35	17.72	

There is a significant difference between the different letters (a, b, c) in the same line.

3.3. Deviation of feedstuffs physical property

Feedstuffs are divided into four different groups according to their physical characteristics: rough, concentrated, pulp, and silage. Deviation rates were evaluated according to these properties. These loads are shown in Figure 1. The difference between the deviation values between groups is significant (P < 0.0001).

As shown in Table 4, mean and standard deviation values for rough, concentrated, pulp, and silage are 12.66 ± 23.90%, 7.71 ± 14.64%, 8.17 ± 16.19%, 2.77 ± 4.92 % repectively. The maximum deviation was observed in the roughage group with an average of 12.66% and the lowest deviation was observed in the silage group feedings with 2.77%. Physical properties of feedstuffs were grouped. Feedstuffs which are unbroken and long-particle are expressed as rough. Further deviation has occurred in the loading of unbroken and long-particle feedstuffs. Because of their physical properties, these feeds are difficult to be loaded into the mixer wagon. For feedstuffs expressed as rough due to their low flow rates, long particles and bales, there are difficulties in loading them in the

Table 4. Feedstuffs loading deviation rates of feedstuffs physical property.

	Physical property of feedstuffs				
	Rough	Concentrated	Pulp	Silage	P <
Loading number	4833	4723	2030	1689	
Deviation mean	12.66[a]	7.71[b]	8.17[b]	2.77[c]	0.0001
±standard deviation	23.90	14.64	16.19	4.92	

There is a significant difference between the different letters (a, b, c) in the same line.

planned amounts. Concentrated feeds are feeds with high flowability. Examples of these feedstuffs are feeds produced in feed plants, grain property feeds, and defatted meal seed. Pulp group feedstuffs are determined in moist form such as orange pulp and brewer grain. Silage group feeds (such as corn silage) are small size particles. The loading of mentioned feedstuffs groups into the mixer wagon is shown in Figure 1. Considering all these, the loading processes should be made more precisely in feedstuffs which are difficult to load due to their physical properties.

3.4. Deviation of feedstuffs loading methods

On the farm where the study was conducted, the concentrate feedstuffs group can be loaded into the mixer wagons in two different ways: loader or spiral. These loading methods are shown in Figure 2. The deviation rates in terms of these two loading patterns are evaluated and shown in Table 5.

The deviation percentage and standard deviation values of these methods were found as 2.35 ± 2.83%, 5.70 ± 8.67%, respectively. In two different loading methods, the difference of deviation percentage was significant (P < 0.0001). There was less deviation in the loading with the spiral. The process of loading the spiral with a button caused less deviation. Stopping the loading process with the button immediately after the loading of the planned amount to the mixer wagon causes the deviation rate to be less.

Table 5. Feedstuffs loading deviation rates of feedstuffs loading methods.

	Loading methods		
	Spiral	Loader	P <
Loading number	1301	388	
Deviation mean	2.35[a]	5.70[b]	0.0001
±standard deviation	2.83	8.67	

There is a significant difference between the different letters (a, b) in the same line.

3.5. Deviation of measure of the amount of feedstuffs in TMR

The feedstuffs amounts used in TMR formulations were divided into eight different groups and the deviation rates were evaluated. The feedstuffs quantity range groups evaluated are shown in Table 6.

Percentage deviation rates of TMR mixtures according to feedstuffs quantities have varied (P < 0.0001). Deviation rates and standard deviations are shown in Table 7.

The amount of feedstuffs in TMR is extremely important in terms of deviation. When the deviation ratios for the quantity ranges were evaluated, it was found to be different from each other. The rate of deviation in TMR with less feedstuffs quantity range is higher. As the amount of raw material used in ration recipes increases, the deviation rate decreases (P < 0.0001). As the results show, the maximum deviation is between 0–100 kg and 101–200 kg; the deviations in this range were 15.74% and 10.50 % in the given order. TMR should be evaluated together in terms of operating and animal feeding conditions and they should be prepared as much as possible with maximum capacity or should be worked with more precise loading methods.

3.6. Deviation of ration type

Deviation values for TMR mixtures prepared in different ratios according to the needs of the animals were examined. Eight different types of TMR mixtures are used on the farm. The TMR group codes and animal group description are shown in Table 1.

The deviation rates of the feedstuffs loading process were different in terms of ration type (P < 0.0001). In terms of ration types, mean and standard deviation values of deviation rates are shown in Table 8. Percentage deviation mean and standard deviation values in terms of ration types are shown in Table 8.

TMRs are prepared in different ratios according to the needs and physiological conditions of animals. As a result of statistical evaluations, it was determined that the deviation percentage values in ration types differ

Table 6. Range of measure of feedstuffs amounts in TMR.

Feedstuffs amount range kg	0–100	101–200	201–500	501–750	751–1000	1001–1500	1501–2000	2001–3000
Code	I	II	III	IV	V	VI	VII	VIII

Table 7. Deviation of measure of the amount of feedstuffs in TMR.

	Range of measure of feedstuffs amounts								
	I	II	III	IV	V	VI	VII	VIII	P <
Loading number	4497	1541	3867	818	810	904	782	56	
Deviation mean	15.74[a]	10.50[b]	6.00[c]	3.42[d]	2.68[d]	2.78[d]	1.48[d]	1.67[c,d]	0.0001
±standard deviation	27.35	16.53	8.35	4.67	4.32	3.84	1.67	1.37	

There is a significant difference between the different letters (a, b, c, d) in the same line.

Table 8. Deviation of ration type.

	Ration type								
	Close-up	Calf	Heifer	Fresh	Dry	Milk1	Milk2	Beef	P <
Loading number	525	240	2305	1126	964	7078	627	410	
Deviation mean	18.68[a]	5.72[c,d]	6.47[d]	11.79[b]	13.88[b]	7.80[c]	14.39[b]	4.59[d]	0.0001
±standard deviation	30.73	12.13	10.76	25.88	24.42	16.18	23.77	6.83	

There is a significant difference between the different letters (a, b, c, d) in the same line.

significantly from each other (P < 0.0001). Since the contents, amounts, and roughage ratios of TMR types are different from each other, the deviation percentage rates are different from each other. The maximum deviation average was 18.68% for close-up and the lowest deviation was 4.59% for beef group. It is considered that there is little error in the beef group due to the high proportion of concentrate in the TMR. In the close-up group TMR, more roughage proportion is thought to cause more deviation.

3.7. Deviation of feedstuffs

In the study, deviation percentage values of feedstuffs were also examined. Fourteen different feedstuffs are used in TMR preparation process on the farm. We can list these raw materials. Sunflower seed meal (ATK), wheat stalk (BUGSAP), meadow (CAYIR), whole cotton seed (CIGIT), concentrated feed (FABYEM), vetch cereals hay (FIGHUB), vetch cereals hay silage (FIGSLG), brewer grain (MALT), corn silage (MSRSLG), orange pulp (PORTK), cotton seed meal (PTK), soybean seed meal (STK), alfalfa silage (YNCSLG), alfalfa (YONCA). The deviation rates of loading these raw materials into the mixer wagon are shown in Table 9. The difference deviation percentage value of the feedstuffs loading process into mixer wagon was significant (P < 0.0001). Deviation and standard deviation values of feedstuffs loading are shown in Table 9. This evaluation is in part similar to the analysis we made in the title of feedstuffs property type. The most deviation in feedstuffs loading is done in vetch cereals hay (FIGHUB), meadow (CAYIR), vetch cereal hay silage (FIGSLG). The mean deviation of these feedstuffs was 20.55%, 18.35%, and 14.51%, respectively. The least deviation occurred in the feeds called as the concentrated feed (FABYEM) with 3.12%. The difference of these deviations is due to the difficulty of loading due to the physical properties of the raw materials.

Depending on all factors causing deviation; the time series graph of the deviations in feedstuffs loading (13,276 loading) during the study is indicated in Figure 3. As the graph shows, the process was quite unstable. The mean and standard deviation for the all process was 8.95 ± 18.38%.

Because of all these reasons, TMR rations for animal health and productivity should be stable, balanced, and

Table 9. Deviation of feedstuffs.

	Feedstuffs												
	Atk	Bugsap	Cayir	Cigit	Fabyem	Fighub	Figslg	Malt	Msrlg	Portk	Ptk	Stk	Yncslg	Yonca	P <
Loading number	1273	776	301	418	1689	498	1174	1685	1689	345	893	450	1068	1016	
Deviation mean	12.72^{c,d}	8.75^{f,g}	18.35^{a,b}	6.91^{g,h}	3.12^{i}	20.55^{a}	14.51^{b,c}	7.59^{g}	2.77^{i}	11.03^{c,d,e,f,g}	11.92^{c,d,e}	3.14^{h,i}	11.05^{d,e,f}	9.65^{e,f,g}	0.0001
±standard deviation	21.05	15.76	22.15	9.72	5.04	25.19	32.76	12.95	4.92	26.75	16.84	6.71	19.82	18.80	

There is a significant difference between the different letters (a, b, c, d, e, f, g, h, i) in the same line.

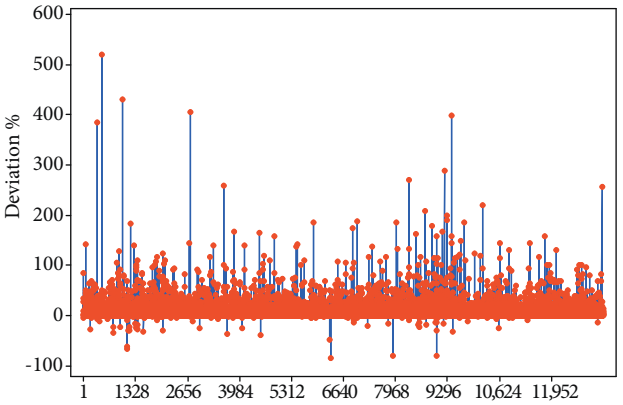

Figure 3. Time series plot of deviation in all process.

proper [4, 5]. There is an acceptance in the literature that the standard deviation for TMR mixtures should not be more than ±5% [8]. In a doctoral thesis study in the United States [9], it was found that in dairy cattle farms, feed operators load more than 0.05% to 10% of the planned amount in TMR wagons. A study conducted in California revealed results that are in accordance with our results [10]; the deviation rates of eight different feedstuffs used in 26 different farms were evaluated and it was determined that the deviation rates of the raw materials in the farms are significant. In another study conducted under the present study [11], it was determined that TMR nutrient values and particle size changes were significantly affected.

4. Conclusions

Feeding activities are of great importance in terms of operating profitability, animal health, and productivity. TMR preparation has a critical position in this sense. According to the results of this study and the literature, there may be errors in feedstuffs loading. Ways to eliminate or reduce these errors should be sought. As a result of the evaluations, in preparation of TMR; operator accuracy and skill, loaders, physical conditions of feedstuffs, method of feedstuffs loading, amount of feedstuffs in TMR, nutrient variability of feedstuffs, accuracy of feedstuffs chemical analysis, mixer wagon type, weighing accuracy, mixing times of feed, and environmental factors (bird population, climate) factors are important.

There were significant differences between the operators. Deviations vary between 5.48% and 12.23%. This difference is mainly due to the work discipline and operator capability. We believe that the reduction of these errors will be possible with the provision of personnel training, follow-up, and working discipline.

There were significant differences between the feedstuff loaders for deviation. In this study, mean deviations of three different loaders of 140, 821, and 928 were

determined as 9.04%, 7.43%, and 10.44%, respectively. It was evaluated that the difference between the loaders was due to the ergonomics of the use of the loaders and the ability of the personnel using the loaders. Load buckets on loaders should be able to make their up-down, up-down movements easier and more functional when loading feedstuffs. For these reasons, it is very important for feeding operators to get used to the vehicles so that hand mastery and reflexes can develop. In addition, the bucket capacity of the loaders was considered important for the deviation. Therefore, the amount of feedstuffs loaded and the capacity of the bucket should be matched.

According to the feedstuffs and the physical properties of the feedstuffs, deviation rates in each feedstuff differed. Feedstuffs were grouped as rough, pulp, concentrate, and silage, and the maximum and minimum deviation means were 12.66%, 2.77% in the roughage and silage groups, respectively. When the deviation of feedstuffs was evaluated; more deviations occurred for vetch cereal hay (20.55%) meadow (18.35%) and vetch cereal hay silage (14.51%) with long particle size. The minimum deviation of feedstuffs was determined in the concentrate feed mixtures prepared at the feed mill with 3.12%.

Some feedstuffs were loaded with a loader or spiral. Deviation for loading spiral and loader were determined as 2.35%, 5.70%, respectively. As the loading process with the spiral is done with a single button, the personnel skill is insignificant. Loading and stopping is done with a button. Loading of feedstuffs with loader is not easy. For this reason, as long as the conditions are suitable, spiral, conveyor loading, and similar loading methods should be preferred.

In this study, it was determined that the deviation rates increased with the decrease of feedstuffs quantities in TMR mixture. Therefore, it should be more sensitive in the loading of feedstuffs with little quantity. The deviation in the loading of these feedstuffs may cause nutrient change and increase in ration costs in the final TMR rations due to the high nutritional content and the high cost of these feedstuffs.

This study could be enriched by obtaining data from different farms. At the point of obtaining data from different farms; the vast majority of farms do not have a software program and they also did not want to give the data of farms which are software programs.

As a result, TMR preparation is extremely important in terms of feed loading, balanced feeding of animals, performance, and operational profitability. Therefore, the amount of feedstuffs loaded outside of planning should be minimized when preparing the TMR.

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