Pricing Feed Ingredients on the Basis of Market Values of Nutrients

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Summary

In many instances, nutritionists, feed manufacturers, dairy producers, and their advisors need an estimate of what a feed is worth on a nutritional basis to facilitate the formulation of balanced diets and the purchase of appropriate and price competitive feedstuffs. Up until now, all methods used shared common flaws. We derived a maximum likelihood method that uses composition and prices of all feedstuffs traded in a given market to estimate unit costs of nutrients and break-even prices of feedstuffs. The method was programmed as a Windows® application named ***SESAME.*** The software can be used (1) to rapidly and accurately identify commodity purchasing opportunities, and (2) to benchmark feed costs from nutrient requirements and nutrient unit prices.

Introduction

A variety of methods have been proposed to estimate unit costs of nutrients and, implicitly, the break-even price of feedstuffs. All methods fall into one of two general categories: equation-based (**EBM**) and inequation-based methods (**IBM**). For EBM, a set of equations developed from the nutritional composition of referee feeds is solved using their market prices. The best-known method among this group is the Petersen Method (**PM**), in which the energy and protein compositions of corn grain and soybean meal are equated to their respective prices, setting a set of two equations with two unknowns. The method dates back to 1932 (Petersen, 1932) and is presented and discussed at length by Morrison (1956). Although widely used, the method is fundamentally flawed in that it assumes perfect markets in corn and soybean trading and implies economically incoherent behavioral patterns by buyers and sellers of commodities.

The second series of methods, IBM, are basically constrained optimization models solved using mathematical programming techniques (Beneke and Winterboer, 1973; St-Pierre and Glamocic, 2000). Linear programming (**LP**) is the best-known member of this group and became widely used in animal nutrition with the discovery of an efficient algorithm (Dantzig, 1960) and the advent of high-speed computers. Within an LP model, a cost function is minimized subject to a series of inequations forcing the solution to meet the nutritional requirements of the animal for which the diet is being optimized.

Many have assumed that linear (and nonlinear) optimization models yield accurate and precise estimates of break-even prices of feedstuffs. This thinking is erroneous. Optimization programs suffer from being very case specific, and they deliver little information on the unit costs of nutrients. They assume perfect knowledge of unit prices of feedstuffs, nutrient requirements, and nutrient composition of feedstuffs. In practice, none of these assumptions are met and complex stochastic optimization models must be used to solve correctly in the presence of uncertainty in nutrient composition (St-Pierre and Harvey, 1986). Even when the solution is deemed optimal, nutrients with non-binding constraints have an implicit unit cost of zero. Shadow costs of binding nutrients provide information on unit costs that can only be valid at the margin. Additionally, the information delivered has a very narrow inference range because it provides estimates that are applicable only to one group of animals in a given herd. Consequently, IBM is limited in providing estimates of aggregate unit costs of nutrients within a given market. To circumvent these problems, we developed a new procedure that provides estimates of aggregate unit costs of nutrients and break-even prices of feedstuffs based on the trading of all feed commodities in a given market (St-Pierre and Glamocic, 2000).

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The method is based on maximum likelihood estimation of nutrient costs. The objective of this paper is to describe briefly the method that we developed, the computer software that we wrote to make our procedure available to the industry, and to show examples of how this information can be used by professional nutritionists and dairy producers to identify buying opportunities and to benchmark total feed (nutrient) costs.

Method Development

Understanding the Method

In the PM, prices of ground shelled corn (**GSC**) and soybean meal (**SBM**) are equated to their composition in energy and protein. Using NRC (2001) composition at 3x maintenance and $111.80/ton for GSC and $203.90 for SBM, the resulting equations are:

GSC: $111.80 = 1612 NE$ + 165.6 CP$ [1]

SBM: $203.90 = 1794 NE$ + 963.0 CP$

where,

NE$ = cost per Mcal of NE_L (unknown)
CP$ = cost per lb of CP (unknown)

This system of equations is easily solved, with the result that NE_L is priced at $0.059/Mcal and CP at $0.102/lb. These nutrient costs are then used for calculating break-even prices of other feedstuffs.

The PM contains fundamental flaws that cannot be ignored. First, the referee feeds (GSC and SBM) are never either well or poorly priced. That is, the method implicitly assumes that referee feeds are always priced at their breakeven prices. Invariably, one finds other commodities that are priced under their own breakeven prices. Hence, one would conclude that corn and soybean meal should never be purchased based on a PM evaluation. This is an odd conclusion because the method implicitly assumes that referee feeds are market movers and set the prices of other commodities in the marketplace. The second flaw is that PM assumes perfectly competitive markets. This implies that those trading corn and SBM have perfect market information, with trading occurring at a perfect equilibrium point between supply and demand. Third, the application of PM over a long period of time (years) results implicitly in an incoherent economic behavior by buyers and sellers. That is, buyers keep purchasing some commodities well above their breakeven prices, while sellers keep selling other commodities at prices considerably less than their breakeven prices. Fourth, it is difficult to augment PM to accommodate additional nutrients, not because of the algebra involved, but because of the difficulty in identifying proper referee feeds. That is, one must assume near-perfect knowledge of the composition of referee feeds. This assumption may be reasonable for CP, a poor indicator of biological value in ruminants, but is greatly challenged when nutrients with more uncertain characteristics, such as RUP and NE_L, are being considered.

Some of the problems associated with the PM can be alleviated by considering more than two feedstuffs for the estimation of the unit costs of two nutrients. For example, we could evaluate the unit costs of NE_L and CP using GSC, SBM, corn hominy (**HOM**), and canola meal (**CAM**) using the standard nutritional composition reported by NRC (2001). If we use HOM and CAM, and $110.00/ton and $144.00/ton as their respective prices, we get:

HOM: $110.00 = 1510 NE$ + 210.6 CP$ [2]

CAM: $144.00 = 1442 NE$ + 682.7 CP$

which results in estimates of $0.062/Mcal and $0.081/lb of NE_L and CP, respectively. It is easy to see that we could pair any two feeds to produce a set of equations as in [1] and [2] to get estimates of NE_L and CP. We can also introduce the concept of price-error, which is the difference between the market price of a feedstuffs and the value of its nutrients. Using SBM, for example, we can set the following equation:

SBM: $203.90 = 1794 NE$ + 963.0 CP$ + ε_1 [3]

Using this approach, we can set four equations for the four feedstuffs:

GSC: $111.80 = 1612 NE$ + 165.6 CP$ + ε_1 [4]
SBM: $203.90 = 1794 NE$ + 963.0 CP$ + ε_2
HOM: $110.00 = 1510 NE$ + 210.6 CP$ + ε_3
CAM: $144.00 = 1442 NE$ + 682.7 CP$ + ε_4

The set of four equations in [4] has six unknowns and, thus, has an infinite number of solutions. However, only one solution among this infinite set of solutions minimizes the sum of ε_i squared. This solution produces the least-squares estimates of nutrient unit costs. Under certain conditions, the least-square estimates are also maximum-likelihood estimates. With this approach, it is easy to expand the equations in [4] to accommodate any number of m feedstuffs for the evaluation of n nutrients (for m > n).

Assumptions

Maximum likelihood properties are obtained under the following conditions:

- Buyers and sellers of commodities act rationally; that is, a buyer would not keep buying an overpriced commodity and a seller would not keep selling commodities at discount prices over time.

- The value of a feedstuff is equal to the sum of the values of its nutrients. Feedstuffs are used exclusively as sources of nutrients. Feedstuffs with valuable characteristics other than nutrient content (e.g., mold inhibitors) are not evaluated properly.

- The errors are independently and normally distributed. In the software, we insure that this assumption is met by eliminating any outlier feedstuffs.

SESAMEÔ Release 2.04

SESAME is a Windows® based program. In its development, we tried as much as possible to keep the software user friendly to non-economists and non-statisticians.

Nutrient Composition: The Feedstuffs Menu

By default, *SESAME* contains the full NRC (2001) feed library, a few commercial feedstuffs whose nutritional composition are reasonably known, and a few additional by-product commodities primarily from California. All of these feedstuffs are *protected* in that they can be used by users to set-up a problem, but their composition cannot be directly edited. The user can customize the nutritional composition of a feedstuff by first copying it to his library where it can be edited. A set of feedstuffs forms a *group.* In *SESAME*, we have defined various groups of feedstuffs primarily on a regional basis. Likely, a frequent user would set-up a personal group of feedstuffs to regroup the protected feedstuffs of interest with user-defined feedstuffs.

Nutrient Definition: The Configuration Menu

Over 140 nutrients are defined in *SESAME* to cover applications in a multitude of species. Nutrients can be defined as direct entries (e.g. crude protein), or as calculated nutrients (e.g. NFC). Calculated nutrients are defined using equations inserted in the **Formula** section of the program. Most users will never have to use this section of the program because all nutrients commonly used in dairy nutrition are already defined.

Market Prices of Feedstuffs: The Price List Menu

Various price lists can be set to reflect different prices across space (markets) or time. Feedstuffs can be added to a price list using a convenient drag-and-drop feature. There are no limits to the number of price lists.

Setting up a Problem and Finding Break-Even Prices: The Solver Menu

The core engine resides within the **Solver** section of the program (Figure 1). To create a problem, the user must indicate which feedstuffs, nutrients, and prices are part of a problem. The calibration set contains all feedstuffs traded in a given market. Feedstuffs are added or deleted from this set through a simple drag-and-drop function. Alternatively, the user can identify in the appraisal set those feedstuffs for which he has no current price, but for which estimated break-even prices are desired.

The **nutrient composition** tab allows the selection of the specific nutrients whose values are to be estimated. Active prices of feedstuffs are selected using the price list button.

Applications

Table 1 reports the nutritional composition of 24 commodity feedstuffs actively traded in the Mid-South market. Prices reported are for the week of February 10, 2003 and include a modest handling charge. Feed composition values are from NRC (2001).

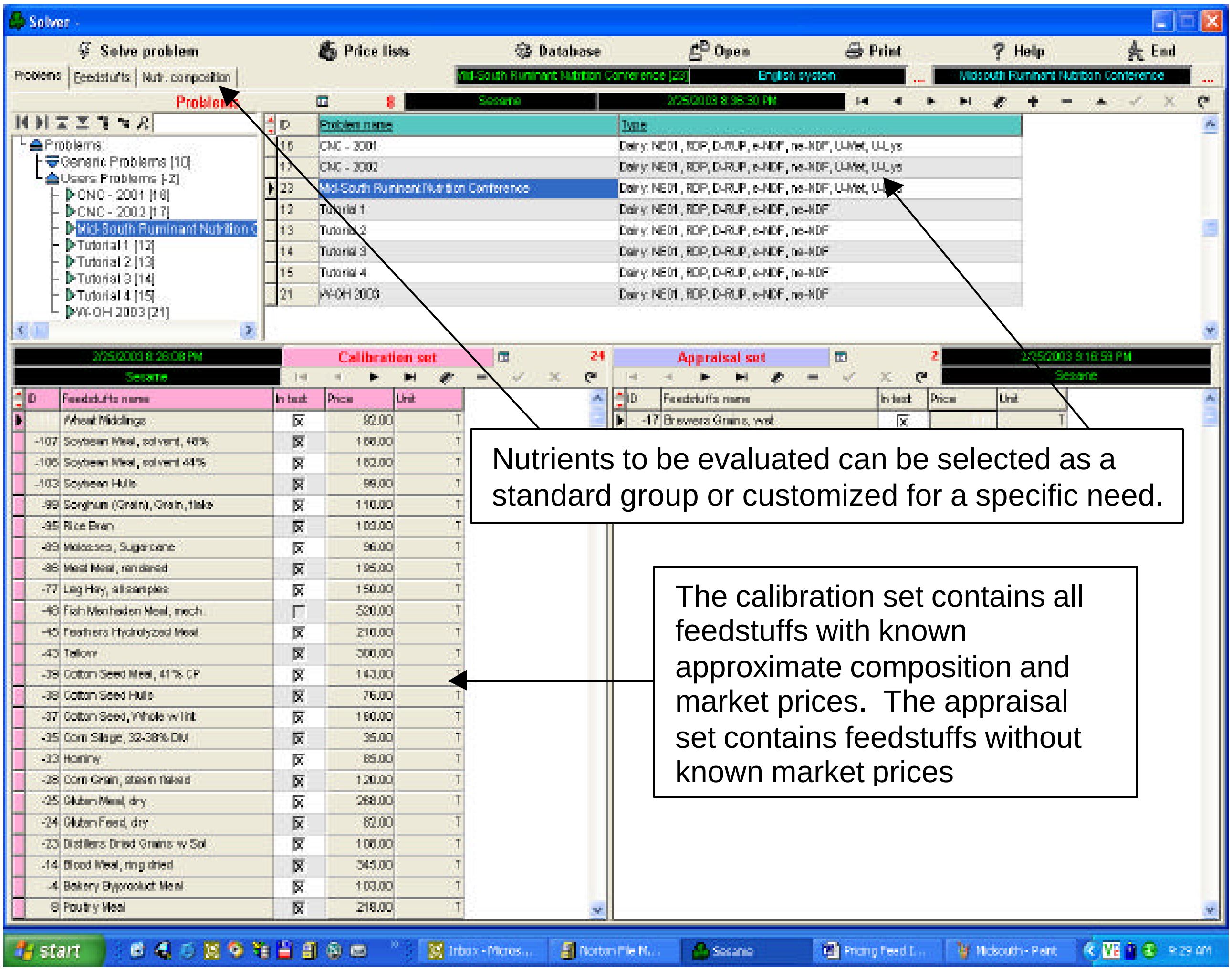

Figure 1. Solver section showing the selected problem, calibration, and appraisal sets of feedstuffs. Tabs and buttons allow users to select feedstuffs, nutrients, and prices to build a problem. A solution is found by pressing the "Solve problem" button.

Table 1. Nutrient composition and market prices of 24 feedstuffs, FOB Fort Worth, TX; Memphis, TN; or Lubbock, TX for the week of February 10, 2003. Composition values are on an as-fed basis.[a,b]

	NE_l – 3X (2001)	RDP (%)	Digestible RUP (%)	ne-NDF (%)	e-NDF (%)	Price ($/ton)
Bakery Byproduct Meal	0.849	8.078	2.258	11.772	0.001	102.50
Blood Meal, ring dried	0.953	19.382	53.407	0.000	0.000	365.00
Distillers Dried Grains	0.806	13.180	10.887	33.598	1.400	108.00
Gluten Feed, dry	0.702	14.894	5.426	20.312	11.425	81.50
Gluten Meal, dry	0.933	14.265	38.544	6.138	3.453	267.00
Corn Grain, steam flaked	0.803	4.364	3.525	4.352	4.017	120.00
Corn Hominy	0.755	7.246	2.957	16.993	1.681	85.00
Cotton Seed, Whole, w lint	0.793	16.325	3.879	0.000	45.320	150.00
Cotton Seed Meal, 41% CP	0.702	21.171	17.907	17.839	10.035	143.00
Cottonseed Hulls	0.194	2.444	1.537	37.825	37.825	76.00
Fat, Tallow	2.051	0.000	0.000	0.000	0.000	300.00
Feathers Hydrolyzed Meal	0.910	29.699	36.489	0.000	0.000	210.00
Fish Menhaden Meal, mech.	0.964	21.365	36.996	0.000	0.000	520.00
Meat and Bone Meal	0.941	28.558	20.423	0.000	0.000	195.00
Milo	0.820	3.977	5.355	6.374	3.284	105.00
Molasses, Sugarcane	0.593	3.529	0.780	0.297	0.000	96.00
Poultry Meal	0.941	23.287	27.945	0.000	0.000	218.00
Soybean Hulls	0.602	7.000	3.945	53.716	1.096	99.00
Soybean Meal, expellers	0.967	12.860	26.621	14.971	4.472	224.70
Soybean Meal, solvent 44%	0.861	29.077	14.307	10.222	3.053	182.00
Soybean Meal, solvent 48%	0.897	27.639	19.076	6.754	2.017	188.00
Rice Bran	0.842	7.344	4.354	23.528	0.118	103.00
Wheat Middlings	0.678	12.633	3.532	32.190	0.657	92.00

[a]*SESAME*: Nutritional Composition of feedstuffs.
[b]DRUP = Post-ruminally digestible rumen undegradable protein, RDP = rumen degradable protein, NE_l – 3X = Net energy lactation at 3X maintenance, ne-NDF = non-effective NDF, and e-NDF = effective NDF.

Figure 2 shows the results using February, 2003 prices. Because the method is statistically based, nutrient costs are reported as estimates (standard errors of nutrient costs are provided in the long report format). Although much has been written about the recent rise in corn market, steam flaked corn is still relatively well priced among all commodities. The same results are presented graphically in Figure 3. This figure partitions feedstuffs into three groups: over-priced (e.g., soybean hulls), neutrally-priced (e.g., meat meal), and under-priced (e.g., gluten feed).

Break-even Price of Wet Brewers Grains and Almond Hulls

Feedstuffs without known prices can automatically be appraised using the best estimates of nutrients unit costs. As an example, we added wet brewers grains and almond hulls to the appraisal dataset. The break-even price of wet brewers grains is estimated at $27.19/ton, FOB Ft. Worth. Likewise, the break-even price of almond hulls is approximately $96/ton.

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Price Prediction Reliability	20.594

The Price Prediction Reliability is a measure of error in the model.

Estimate of Nutrient Unit Costs		
Nutrient name	Estimate	
NEI - 3X (2001)	0.067989	**
UIP-Methionine	5.805844	**
UIP-Lysine	1.076679	**
RDP	-0.001668	
ne-NDF	-0.026919	~
e-NDF	0.064290	**

- A blank means that the nutrient unit cost is likely equal to zero
- ~ means that the nutrient unit cost may be close to zero
- * means that the nutrient unit cost is unlikely to be equal to zero
- ** means that the nutrient unit cost is most likely not equal to zero

This section reports the estimated unit price of the nutrients selected for evaluation.

Calibration set				
Name	Actual [/T]	Predicted [/T]	Lower limit	Upper limit
Bakery Byproduct Meal	103.000	115.462	108.903	122.020
Blood Meal, ring dried	345.000	348.771	324.474	373.069
Corn Grain, steam flaked	120.000	123.749	117.453	130.046
Corn Silage, 32-38% DM	35.000	45.805	41.617	49.992
Cotton Seed Hulls	76.000	64.154	47.197	81.111
Cotton Seed Meal, 41% CP	143.000	151.288	143.516	159.060
Cotton Seed, Whole w lint	160.000	179.708	162.489	196.927
Distillers Dried Grains w Sol	108.000	128.196	118.383	138.009
Feathers Hydrolyzed Meal	210.000	202.688	191.129	214.248
Gluten Feed, dry	82.000	114.351	107.508	121.194
Gluten Meal, dry	268.000	258.031	234.273	281.790
Hominy	85.000	104.679	98.622	110.737
Leg Hay, all samples	150.000	118.343	106.295	130.392
Meat Meal, rendered	195.000	199.007	187.878	210.137
Molasses, Sugarcane	96.000	80.745	75.450	86.041
Rice Bran	103.000	124.448	116.866	132.030
Sorghum (Grain), Grain, flak	110.000	128.608	122.154	135.063
Soybean Hulls	99.000	69.311	53.488	85.135
Soybean Meal, solvent 44%	182.000	161.212	149.543	172.881
Soybean Meal, solvent, 48	188.000	182.114	171.774	192.454
Tallow	300.000	278.846	258.123	299.568
Wheat Middlings	92.000	85.639	75.955	95.323

This portion of the output reports actual market prices and predicted prices (i.e., breakeven prices) of traded feedstuffs. The lower and upper limits identify the 75% confidence range. A feedstuffs whose actual price is within these two limits is considered neutrally-priced. If the actual price is less than the lower bound, it is under-priced; above the upper bound, it is over-priced.

Appraisal set		
Name	Actual [/T]	Predicted [/T]
Almond Hulls	0.000	95.615
Brewers Grains, wet	0.000	27.219
Poultry Meal	218.000	95.615

Poultry meal was deemed an outlier and was removed from the calibration set during the solution process. Almond hulls and wet brewers grains did not have known, actual market prices.

Calculation log	
Action	Reason
Nutrient "Digestible RUP" removed	VIF over the limit
Feedstuffs "Poultry Meal" removed	Outlier

Sesame 2.04: Regression results ()

Figure 2. Solution output for the example. Prices are wholesale prices plus mixing charge, FOB Ft Worth, TX; Lubbock, TX; or Memphis, TN; for the week of February 10, 2003.

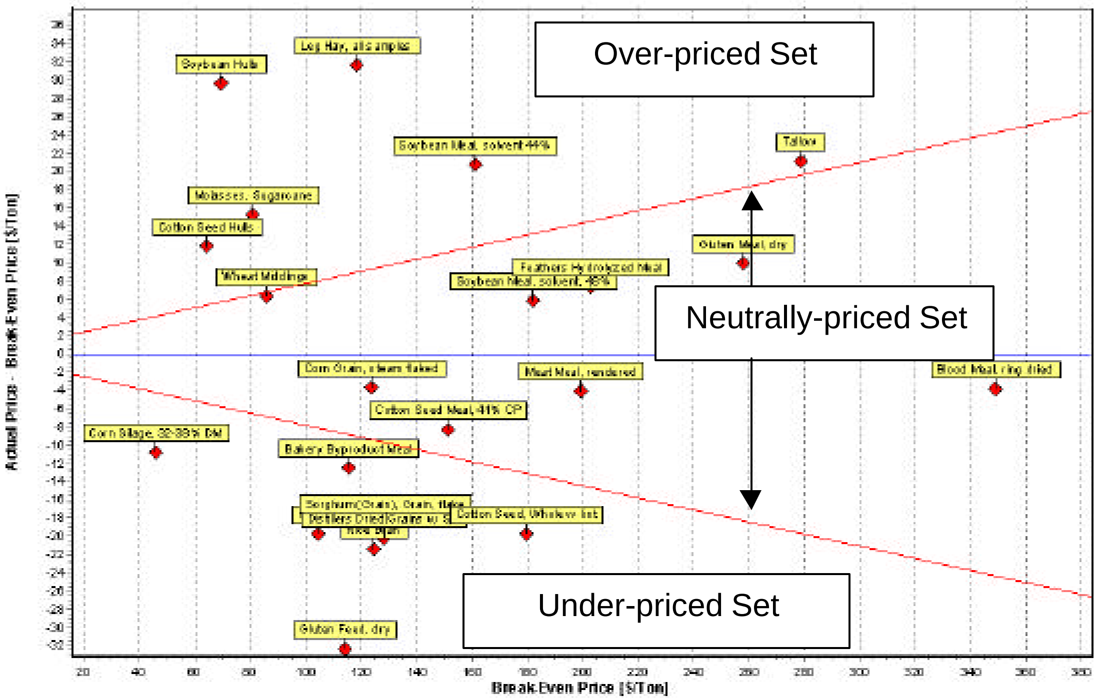

Figure 3. Partitioning of feedstuffs into over-priced, neutral and under-priced sets. Prices are wholesale prices, FOB Ft. Worth, TX; Lubbock, TX; or Memphis, TN for the week of February 10, 2003.

Discounting Feedstuffs for Phosphorus

Under current environmental regulations, phosphorus is often the nutrient that drives the area of land required for balanced manure application. In the past, phosphorus had a positive economic cost in dairy diets. That is, the unit value of phosphorus was positive and markets were factoring the value of phosphorus in feed and mineral commodities. This is no longer true. When phosphorus is added to the list of nutrients that are factored in the price of commodities, its economic value is estimated at -0.44/lb. In essence, current markets are discounting feedstuffs by $0.44 per ton for each pound of phosphorus that they contain.

Conclusions

Our maximum likelihood method uses the prices of all feedstuffs traded in a given market to estimate the implicit costs of nutrients. Because it is a statistically based method, it provides measures of dispersion of estimated nutrient costs and break-even prices. Also, because it does not use referee feeds (e.g., corn and soybean meal), each feedstuff used in the estimation can potentially have a break-even price above or below its market price. The method can be used to identify purchasing opportunities and/or to estimate unit costs of nutrients.

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