Strategy of Utilization of Locally Available Crop Residues and By-Products for Livestock Feeding in Tunisia

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Summary

Important quantities of crops residues and by-products are yearly available in North African countries. This paper presents the screening of the most important by-products in Tunisia, their nutritional characteristics and the appropriate strategies to use most of them in order to improve ruminants feeding systems.
One or several by-products are specific of each region of the country, but most of them are localised in the northern region. Some of the agricultural wastes are available in important quantities but are of nutritionally poor or moderate qualities (straw, olive wastes, poultry litter, etc), while others are produced in limited amounts but are of very interesting feeding values (sugar beet pulp, brewers grain, date residue, etc).
The main applied strategies to valorise Tunisian agricultural by-products consist in ammoniation of cereal straws along with supplementation with multinutriment blocks and formulation of balanced diets based totally or partially on them. These alternatives are crucial in the improvement of feeding values of studied diets and animal performances essentially by improving microbial activity in the rumen. In Tunisia such solution could be applied both in extensive and moderate animal production systems.

Résumé

Stratégie d'utilisation des résidus de récolte et des sous-produits locaux pour l'alimentation des ruminants en Tunisie.

Des quantités importantes de résidus de récolte et de sous-produits sont chaque année disponibles dans les pays d'Afrique du Nord. Dans cet article, nous présentons des résultats originaux concernant l'inventaire des plus importants de ces résidus en Tunisie et leurs caractéristiques nutritionnelles. D'autre part nous discutons certains travaux réalisés dans notre laboratoire portant sur les stratégies appropriées pour l'utilisation de certains résidus afin d'améliorer les systèmes d'alimentation des ruminants.
Généralement, chaque région du pays est caractérisée par la production de l'un ou de plusieurs de ces sous-produits, mais les plus importantes quantités sont disponibles en grandes quantités, mais présentent une valeur alimentaire moyenne voire faible (pailles, sous-produits de l'olivier, fientes de volai!lles ...). Cependant, d'autres résidus sont produits en quantités limitées, mais présentent une bonne valeur alimentaire (pulpes de betterave, drêches de brasserie, déchets de dattes ...).
Les principales stratégies envisagées pour la valorisation des sous-produits agricoles en Tunisie, sont l'ammonification des pailles et leur complémentation par les blocs multinutritionnels, ainsi que la mise au point de rations équilibrées basées totalement ou partiellement sur ces ressources.
Ces alternatives ont permis d'améliorer la valeur alimentaire des régimes, ainsi que les performances animales, essentiellement par l'amélioration de l'activité microbienne dans le rumen. En Tunisie, ces stratégies pourraient être envisagées aussi bien dans les systèmes extensifs de production que dans les systèmes modérés.

The inventory of locally available by-products

In order to estimate the quantities of the most important Tunisian by-products, a large enquiry was carried out about their origin, the produced quantities, their availability and their current use. Data were collected from various branches of the Tunisian Department of Agriculture, and mostly, directly from the producers (farms, industries). For controlled production residues, estimation of produced quantities was based on the amount of transformed raw material and their specific transformation rate. Table 1 summarizes the characteristics of the main by-products and crop residues in Tunisia.

Cereal straw: In Tunisia, there is about 1.5 million tons of straw yearly produced from wheat, barley, oat and

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tritical. This amount is related to grain production and therefore, varies largely from one year to another. Straw is available all over the country and especially in the North (about 75%). These residues constitute a traditional feedstuff for sheep and cattle (about 50%), the remaining quantities are used as litter.

Olive residues and wastes: The production of olive oil is of importance in the Tunisian economy. Olive trees cover about 1.5 million ha (about 57 millions of trees) especially in the northern and the central parts of the country. Olive oil production yields large amount of residue and by-products each year, such as olive cakes and olive leaves and twigs.
More then 200 000 tons of residue (olive cakes) are produced yearly from oil extraction out of 1 400 oil-plants. Since the use of olive by-product in ruminant nutrition is limited, it is used generally as fuel.
The pruning of olive trees gives about 750 000 tons or residues which are used as traditional feed-stuff in olive producing zones. It should also be noted, that important quantities are used as fuel by rural population.

Raisin kernels: In Tunisia, the vineyards cover about 27 000 ha. There are 40 factories (60% in the north eastern part of the country) which produce yearly 10 000 tons of grape wine residues made of fruit pulp and kernels. The by-product of wine is generally used as fuel and only about 10% is directed to feed ruminants by some farmers.

Sugar beet pulp: The area for the production of sugar beet is nearly 5 700 ha. The sugar beet is treated in two factories located in the North-west. The processing gives annually about 65 000 tons of sugar beet pulp, which is ensiled by farmers and used for intensive livestock systems, especially for dairy cattle feeding.

Tomato pulp: In recent years, tomato canning is widely developed in Tunisia. About 25 000 ha are annually cultivated and 42 tomato canneries, principally localised near Tunis or in the North eastern regions, produce annually 20 000 tons of tomato pulp. This by-product is more and more stored as silage, and used for cattle feeding.

Brewers grain: The annual production of brewery grain is relatively limited to 5 000 tons from the sole brewery factory near Tunis. It is totally collected by farmers for dairy cows feeding.

Wheat bran: Tunisia is traditionally a large consumer of wheat bread. Wheat is treaded in 21 mills that produce almost 3.5 millions tons of wheat bran each year. Most of mills are localised in the region of Tunis, and all the bran is used directly by farmers in animal feeding or by factories to make compound feed.

Date residues: Date palm trees are widely developed in Tunisia's southern oases, and occupy about 22 000 ha. The annual production of date is about 80 000 tons of fruit wastes which are frequently used to feed goats, dromedaries and to a less extend for sheep.

Poultry litter: In Tunisia, the intensive poultry industry has known a considerable leap during the two last decades. Consequently, a large amount of excreta and litter is produced, which raises a serious pollution threat in some areas. Enormous quantities of these wastes are available during the year (about 700 000 tons) mainly in the North-eastern region of the country. Poultry litter is currently used as a soil fertiliser or accumulated in dumping grounds. The utilisation of poultry litter in animal feeding is worldwide practice (9); but in Tunisia, this alternative is not very frequent in spite of several research trials carried out since 1988. The results are successfully applied by some farmers.

Determination of nutritive value of by-products and crop residues

Locally available crop residues and by-products are largely variable and their chemical composition is often insufficient to characterise their nutritional value. Therefore, for a better understanding of the digestion processes, we established simple nutritional evaluation techniques based on chemical composition, fermentation characteristics and on degradation measured by the *in sacco* and *in vitro* methods.

Table 1
Principal Tunisian by-products and crop residues

By-products	Production (tons)	Principal production regions	Period of production
Cereal straws	1.5 million	North	June - August
Pressed olive cakes	200 000	North and center	November – February
Olive leaves and twigs	750 000	North and center	January - March
Raisin kernels	10 000	North-east	September - November
Sugar beet pulp	65 000	North-west	June - July
Tomato pulp	19 000	North-east	July - August
Brewers grain	4 600	Tunis	All the year
Wheat bran	3.5 million	Southern oasis	All the year
Date fruit residues	10 000	North-east	November - January
Poultry litter	700 000	North and centre	All the year

Used methodology

In vitro *determination*

In vitro determinations were made on 10 substrates (Table 2) and carried out using Batch system (6).

Rumen contents were collected before the morning feeding out of 2 fistulated sheep deprived of water 12 h earlier and fed 500 g of oat hay and 500 g of concentrate in 2 equal meals per day. The inoculum was introduced into each fermenter made of a one liter flask. The inoculum was composed of 100 ml of filtered rumen fluid, 100 g of solid rumen content and 200 ml of artificial saliva saturated with CO_2 at 40°C (pH = 6.8). In addition, 187 mg of soluble nitrogen provided by a $(NH_4)_2SO_4$ solution were added to the fermenter. Each substrate was studied as following:

- two fermenters with inoculum + $(NH_4)_2SO_4$ (187 mg N) + x g of OM of substrate providing 125 mg of N,

- two fermenters with inoculum + $(NH_4)_2SO_4$ (187 mg N) for control.

Liquid samples (9 ml) were taken from the fermenters at the beginning of incubation (t0) and after 24 h. They were mixed with 1 ml of conserving solution [1% (w/v) H_3Cl_2) and 5% (v/v) H_3PO_4] and conserved at -20°C for volatile fatty acids (VFA) analysis. Gas production was recorded at 1, 2, 3, 4, 5, 6 and 24 h in 2 liters graduated cylinder which is inverted and filled with a $CaCl_2$-$2H_2O$ solution [30% (w/v)]. Kinetic of gas production was fitted according to the following model:

$$\mathbf{Y = a(1-e^{-ct})}$$, in which:

y: gas production at time t, (ml);
a: potentially gas production, (ml);
c: rate of gas production, (h^{-1}).

In sacco *organic matter digestibility*

Two Holstein cows fitted with rumen fistula were used for *in sacco* measurements. Both received 2 equal meals at 8 h 30 am and 4 h pm. The diet (75 g/$kg^{0.75}$) consisted of 70% of ray-grass hay and 30% of concentrate. The samples were ground with a 1 mm screen, and 5 g of each substrate was introduced in nylon bags (42.5 µm, 15 mg/cm^2) and then dried at 60°C for 48 h. Organic matter was analyzed to determine 48 h OM digestibility. For every substrate, 4 replications (2 bags for each animal) were used.

Chemical analysis

Substrate were analyzed according to the AOAC (1) methods. VFA were analyzed following the method described by Jouany (5). Energy value is determined according to the French System (UFL) but based on stoichiometric equations (2).

Results

Results are presented in table 2.

Cereal straw: Straw is a poor quality forage: low nitrogen and high cellulose contents with low *in sacco* digestibility. Fermentations expressed by gas and VFA production are, therefore, low. This low nutritive value is essentially due to high content of lignin.

Pressed olive cakes: Olive cakes contain a large amount of kernel fragments responsible for their high content of lignocellulosic materials representing half of dry matter content; nitrogen content and digestibility are also very low. Production of gas and VFA are very limited, indicating that olive cakes are very poor feedstuff and therefore they could not be recommended as sole ingredient food.

Fresh olive leaves and twigs: Olive leaves and twigs are relatively high in nitrogen with a moderate content of cell wall. *In sacco* digestibility is relatively high com-

Table 2.
Chemical composition, *in sacco* digestibility, gas and VFA production and energy value of studied crop residues and by-products

By-products	Dry matter (%)	Ash (% DM)	N x 6.25 (% DM)	ADF (% DM)	OMD (%)	Gas ml/g OM	VFA mmol / g OM	UFL
Wheat Straw	89.0	7.4	3.7	40.7	40.1	70.7	3.6	0.38
Olive cakes	45.5	11.5	4.0	46.5	36.3	45.4	1.6	0.34
Olive leaves	56.8	3.6	10.5	29.9	60.3	54.5	3.2	0.65
Raisin kernels	37.1	9.2	13.8	45.7	52.2	73.7	6.6	0.35
Sugar beet pulp	17.2	6.2	9.1	31.6	86.2	140.5	9.6	0.85
Tomato pulp	25.5	4.5	21.5	35.0	59.9	100.3	5.3	0.61
Brewery grains	24.3	4.0	28.5	22.1	75.4	208.6	8.9	0.80
Wheat bran	89.1	7.0	16.0	13.7	71.9	166.7	8.5	0.73
Dates residues	87.6	2.5	3.2	7.8	93.8	178.6	10.1	1.11
Poultry litter	70.6	15.4	23.5	24.9	65.9	120.5	6.5	0.68

OM: Organic matter
OMD: *In sacco* digestibility (48 hours) of OM
VFA: volatile fatty acids.
UFL/kg DM: unité fourragère lait; results are obtained from the knowledge of the *in sacco* digestiblity and the Metabolisable Energy of VFA (acetic, propionic and butyric acids) according to stoechiometric equations of Demeyer (2).
N: nitrogen

Table 3
Nitrogen content, *in sacco* digestibility, feed intake and liveweight variation of ewes fed untreated, treated wheat straw and multinutritient blocks (30 animals per treatment; 120 days trial) (10)

	N x 6.25 (% DM)	72 h *in sacco* digestibility	Intake (g DM / kg $P^{0.75}$)	Liveweight variation (kg)
Untreated wheat straw	5.0 a	45.0 a	43.0 a	-2.8 a
Urea treated straw (5%)	11.0 b	55.0 b	56.0 b	+4.0 b
Anhydrous ammonia treated straw (3.5%)	12.0 b	57.0 b	58.0 b	+5.7 c
Untreated straw supplemented with feedblocks	-	-	60.0 c	+6.4 c

a, b, c: averages in the same column with different letters are significantly different ($P < 0.05$).
Multinutrient blocks are composed of (%): molasses (10), urea (8), poultry litter (20), wheat bran (20), olive cakes (15), cement (15), salt (6), minerals (6)

pared to current values; this is probably due to young age of the tree. Gas and VFA production are moderate. These residues are nutritionally better than olive cakes and straw. Nevertheless, their nutritive value is fickle, mainly because of lignocellulosic content, depending on the pruned wooden parts production and the trees age.

Raisin kernels: The chemical composition of grape wine residues is similar to straw, but they are higher in nitrogen, more digestible and produce more gas and VFA.

Sugar beet pulp: Sugar beet pulp is deficient in nitrogen and relatively high in fiber, while *in sacco* digestibility is very high. This is probably due to high digestibility of the fiber fraction which is poor in lignin. Sugar beet pulp is highly fermented, as indicated by high production of gas and VFA. These nutritional characteristics are close to those for a concentrate.

Tomato pulp: Tomato pulp is an interesting feedstuff. It is high in nitrogen which is lowly degraded in the rumen (4). We noted also suitable gas and VFA productions and then nutritional value.

Brewers' grain: This substrate is characterised by high nitrogen content. Brewery grain is also highly fermented and digested, with an important production of gas and VFA. The proportion of acetate is high and could be related to the high content of digestible fiber (13). It presents therefore a high nutritive value.

Wheat bran: Wheat bran has a relatively important nitrogen content and is highly digestible. Gas and VFA productions are also important with a relatively high proportion of butyrate and propionate. Similar observations were shown *in vitro* (3). Wheat bran presents a substantial nutritive value.

Dates residues fruits: Nitrogen and mineral contents are very low while they are very high in cytoplasm carbohydrates. These wastes are well fermented and almost completely digested because of high sugar content.

Poultry litter: Poultry litter has a important nitrogen content; gas and VFA production are also high.

The *in vitro* techniques and stoichiometric equations based on the processes of digestion could be considered as promising methods to evaluate and to classify the nutritive value of locally available crop residues and by-products. A highly positive correlation was found between *in sacco* organic matter digestibility and VFA production ($r = 0.83$). Furthermore, the energy value (French system UFL) was calculated with a suitable accuracy according to stoichiometric equations based on the digestibility and the molar proportion of VFA.

Different applied strategies to improve local ressources

Ammoniation of cereal straws

Straw is frequently the main feed-stuff for cattle and sheep during the winter season in the North of Tunisia. However, straw is a poor quality forage with a low nitrogen content and digestibility, leading to low intake. Straw ammoniation is a well known and proved technology to increase the nutritive value. Straw treatment with 3% anhydrous ammoniac is widely used in the North of the country where 10 000 tons are treated yearly. Ammoniation of straw by urea-ensiling (5% of urea) has been applied also during the past years. This process is expected to extend because of the recent increase of anhydrous ammonia price and also because of the simplicity of the urea treatment. Recently, we compared wheat straw treated with ammonia or urea and fed to sheep during 4 dry season months (10). Results in table 3 show that ammoniation with 3.5% anhydrous ammonia or with 5% urea (water added: 45%) increased significantly nitrogen content and *in sacco* digestibility. Moreover, treated straw intake was increased by 30%. Ewes lost weight when fed untreated straw while they maintained their weight and even they gained weight when offered treated straw. The weight gain reached 4 and 5.7 kg after 120 days trial period respectively for urea and ammonia treated straw (Table 3). Such effect of ammoniated treated straw has been observed elsewhere (12).

Some other aspects are to be considered for the treatment of straw. Unpublished experiments carried out in our laboratory showed differences between various species of cereal straw in terms of chemical composition and *in sacco* digestibility. When treated with urea, the increase of nitrogen content and *in sacco* digestibility is more important for the initially poor and less digestible straws before treatment. The same experiments showed that the feeding values of vetch-oat hay, the most important forage cultivated in Tunisia, are low and close to that of the untreated straw; this hay could be replaced totally or partially by the treated straw in feeding ruminant.

Multinutrient blocks as supplement of poor quality forage

The feeding system of extensive livestock is based mainly on poor grazing straw stubble and grassland areas during the long dry season (from June to November). Furthermore, the supplementation of animals with concentrate is not a widespread practice because of its high price. So, animals are often characterized by a marked liveweight loss and depraved appetite. The least cost system to improve the nutritional status of animals during dry season is the supplementation with multinutritient blocks. They constitute a strategic catalytic supplement for better valorization of poor quality forage, so, microbial activity is enhanced and finally, digestion and intake are increased (11). The feedblocks are made from local by-products containing urea and minerals. Our experiments carries out in Tunisia (10) show that feedblocks are a promising technique to supplement sheep during dry season. In the trials with treated and untreated straws (Table 3), we added a forth group of ewes supplemented with multinutrient blocks. The blocks are composed on a dry matter basis of molasses (10%), urea (8%), poultry litter (20%), wheat bran (20%), olive cakes (15%), cement (15%), salt (6%) and minerals (6%). An average feedblock intake of 180 g per day significantly increased straw intake (40%) with, as result, a positive liveweight variation of 6 kg. Non supplemented ewes lost 2.8 kg liveweight during the same experimental period of 120 days. This supplementation is currently applied with success by some nomadic farmers who reported good health and positive liveweight variation with sheep grazing straw stubble.

Formulation of rations based on local by-products

Crop residues and by-products present a large variation in their chemical composition, digestibility and fermentation pattern. Several among them can not constitute the basal animal ration. The strategy of the nutritionally acceptable rations at the lowest cost is to combine different by-products. Our objective, when formulating such combination, was to create favourable conditions to rumen microbes in order to induce an optimal lignocellulose digestion and microbial synthesis.

In this respect, some by-products, mainly those with high nitrogen content, could be considered as a suitable strategic supplement allowing a better valorization of crop residues and other feedstuffs deficient in nitrogen and/or with high cellulose content. So olive cakes, wheat straw, raisin kernels and olive leaves and twigs could be reasonably associated to tomato pulp, brewery grain and poultry litter. Sugar beet pulp and dates fruit are also interesting energetic resources and could form well balanced feed rations when associated to the nitrogenous by-products. Some rations were studied and largely used by several farmers in Tunisia.

Poultry litter has been successfully ensiled with olive cakes and wheat bran (45:45:10% w/w/w, dry matter basis). Results indicated that six weeks later, the ensiling technique was efficient for conservation of poultry litter at a low cost and eliminated health hazards. The litter silage was substituted for commercial concentrate and soybean meal and fed to lambs in a growing trial during 66 days (8). Results in table 4 show that daily gain and feed intake obtained with experimental diet were higher than with concentrate diet; furthermore feed cost was lowered by 50% in poultry litter silage group.

Table 4
Feed intake and performance of growing lambs fed an ensiled poultry diet or concentrate diet (12 animals per treatment; 66 days trial) (8)

	Ensiled poultry litter diet[1]	Concentrate diet
In vivo OM digestibility (%)	61.4	74.9
Retained nitrogen (g/day)	33.0	37.2
Feed intake (g DM/day)	1520.0	1098.0
Daily gain (g/day)	252.8	221.2
Feed conversion ratio (kg DM/kg of gain)	6.1	5.4
Carcass yield (%)	47.5	45.1
Feed cost (U.S. $/kg gain)	0.4	0.8

([1]): Poultry litter was ensiled with olive cakes and wheat bran in the following proportion on a dry matter basis 45:45:10 w/w/w. Water was added to obtain 50% DM in the silage.

In an other trial on beef fattening (7), an experimental diet containing sugar beet pulp and poultry litter was compared to a control diet (sugar beet pulp and concentrate with high proportion of soybean meal) fed to fattening beef during a 150 days period. Animal performance (growth rate, feed conversion ratio and carcass quality) were similar, while the ration cost was reduced by 20% within experimental diet (Table 5).

Table 5
Performance of growing beef (salers breed) fed sugar beet pulp supplemented or not with different levels of poultry litter substituting soyabean in concentrate

	Diet 1	Diet 2	Diet 3
Daily gain (g/day)	1194	1163	1103
Feed conversion (kg DM/kg gain)	7.25	8.5	9.5
Meat yield (%)	63.8	64.8	64.1
Feed cost (US$/kg of gain)	1.556	1.228	1.283
Profits (US$/head)	48	109	100

Conclusions

It is concluded that the large potential of by products and crops residues in Tunisia as well as in the other countries of North Africa could be used more efficiently when they are associated to constitute a low cost and balanced supplement or basal ration. Nowadays, this strategy has acquired increasing relevance and importance to several Tunisian farmers because of the lack of good quality forage and also because of the high price of concentrate due to the lack of subsidised imported feed ingredients.

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