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Martillotti F., Francia U., Terramoccia S.

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Technology to improve by-products

MARTILLOTTI F., FRANCIA U.,
TERRAMOCCIA S.
FORAGE AND FEEDINGSTUFFS SECTION
ISTITUTO SPERIMENTALE PER LA ZOOTECNIA - ROME (ITALY)

SUMMARY - The purpose to improve by-product feeding value is achieved by sodium hyroxide, ammonia treatments and ensiling technique. Performances of some machines, chemical and feeding characteristics of treated by-products are reported with practical examples of use.

RESUME - "Technologie de l'amélioration des sous-produits". Le problème de l'amélioration de la valeur nutritive a été abordé au moyen de traitements avec NaOH et ammoniac; on décrit les prestations de differentes machines et on rapporte des données sur les caractéristiques chimiques et nutritionnelles des sous-produits traités, avec des exemples sur les utilisations possibles dans la pratique.

Introduction

The large availability in our country (table 1) of agricultural and agro-industrial by-products, coming fron main crops, directed the attention of research organizations, MAF, NRC, University, ENI over many years, on the need: to organize, through the new technological progress, the harvesting and conversion of crop-residues into animal feeds; to inform farmers on technological processes and on modality to use them as feeding resources for livestock; to avoid that agro-industrial by-products become environmental pollution causes.

Experimental data

Among numerous crop-residues produced on our farms and industry, serious problems are created sometimes by residues of cereal, beet, tomato crops and of olive, citrus and vine fruit for their harvesting, elimination or right utilization.

Table 2 shows how the main crops, cereal, forages and their residues can be used for humans or animals on the basis of their fibre, starch, sugar and protein content, i.e. of their quality on the basis of rumen degradability. Through the technological progress biodigestion of crop residues can be increased and their utilization can be brought about with major profit for farmers in animal breeding.

In this report we present a review of the most important technological processes and assemblage of particular machines used in our Institute in the framework of national projects in order to increase the biodigestion of crop-residues produced in large quantities in Italy.

Table 1. Cultivated surface (ha x 1000) of crops or trees and estimated production (t x 1000) of correspondent by-products (1986-1989).

	1986		1987		1988		1989	
Crops	ha	Prod.	ha	Prod.	ha	Prod.	ha	Prod.
Wheat (T.ae.)	1271	2335	1192	2452	1093	2014	1143	2173
Wheat (T.d.)	1871	2203	1895	2238	1782	1962	1809	1533
Oat	184	278	177	253	171	267	169	207
Barley	465	771	445	855	450	781	473	827
Rice	192	796	190	745	198	765	206	872
Maize	848	4481	768	4034	842	4402	805	4471
Sorghum	13	25	14	24	20	26	22	411
Tomato (peels)	114	1489	107	1325	110	1255	128	1609
Beets	312		302		276		299	
- exau. beet pulps		8975		9195		8124		10090
- molasses		630		644		569		706
Vine, grape pruning	1093	24920	1082	24669	1073	24464	1065	24282
Citrus, pulp	184	284	183	185	183	265	183	261

Source: Istat data.

Options Méditerranéennes - Série Séminaires - n.° 16 - 1991: 81-88

Table 2. Priorities for use of feed resources.

Resource	Characteristics	Prefferred usage
Cereal and oilseed based concentrates	Low fibre, high starch/ sugar protein	Humans Pigs Poultry As supplements for ruminants*
Forages, crop residues and low protein by-products:		
Good quality	Readily degradable (T1/2<12 hr)** Medium protein	Hervivores (Rabbits, horses, mules)
Medium quality	Readily degradable carbohydrate (T1/2< 12 hr) Low protein	Ruminants (milk/beef)
Low quality	Slowly degradable carbohydrate (T1/2> 12 < 48 hr)	Ruminants (Draught/manure)
Very low quality	(T1/2> 48 hr)	Fuel/fertilizer

* See Leng (1982) for discussion of this aspect.
** T1/2 is time (hr) to degrade half the dry matter when suspended in a nylon bag in the rumen.

Table 3. Machines and plants used to treat the cereal straw with naoh (CNR project for agricoltural, mechanization, 1976 - 1981).

		EXP. TRIALS
Stationary farming machines	1) Taarup 805 2) Scherz natromat	- *In vivo* OMD, feed. trial - Cheminal analyses - Feed. of heifers - Cheminal analyses
	3) Tub grinder FB 975 with cutter loader fereaboli 940	"
Mobile machines and plants	1) Self-propelled cuber John Deer 425	"
	2) Windrowns with a towed field-Cuber (lundell wafer-king)	"
Pilot industrial plant	1) Chopping-treating mixing-pelleting plant	- *In vivo* OMD - Fatt. of lambs - (2 trials) fatt. of young bulls - Feed, of dairy cows

NaOH treatment of cereal straw

a) *Stationary and mobile machines.* All machines and plants (reported in table 3) were acquired and organized into the framework of a national project supported by NRC over 5 years, in which researchers, belonging to different organizations,participated.

The operational figures of different machines used for NaOH treatment of straw are reported in table 4. The data relative to working capacity (t/h), specific working capacity (kg/kwh) and requested labour (h/t) are very important to know. The TAARUP seems to give the best results: to treat 5.9 t of straw, 61.5 of kW and 0.30 man unit/t are needed. During the testing trial on TAARUP 805 machine, a stack of 60 t was prepared.

The distribution homogeneity of NaOH was controlled in different points of mass after 15 days: "in vitro" OMD was determined (table 5) on the straw. It was also object of a feeding trial on heifers. The animals were fed a ration of 14.9 kg of DM, constituted by 6 kg of treated straw (TS), 8 kg of maize silage and 0.9 kg of supplement. They had no problems and grew normally. As they were fed daily 300 g of natrium hydroxide, they needed over 30% water (MALOSSINI *et al.*, 1982).

b) *Pilot industrial plant.* Numerous experimental trials were carried out using the pelleted treated straw (PTS), prepared by the pilot industrial plant (Fig. 1).

The most significant experiments, carried out in our Institute are reported. Table 6 shows the composition and feeding value of the 5 diets, including the control diet, containing two levels of TS, 20 and 35%; each level with urea and without urea.

The treated and pelleted straw obtained through the pilot plant was used, after loosening, to prepare 5 mixtures corresponding to 5 diets, by means of a common feed mill. Their utilization in a feeding trial on lambs is reported on table 7. The best results were obtained in the group fed a low quantity of Ts diet and supplemented with SBM.

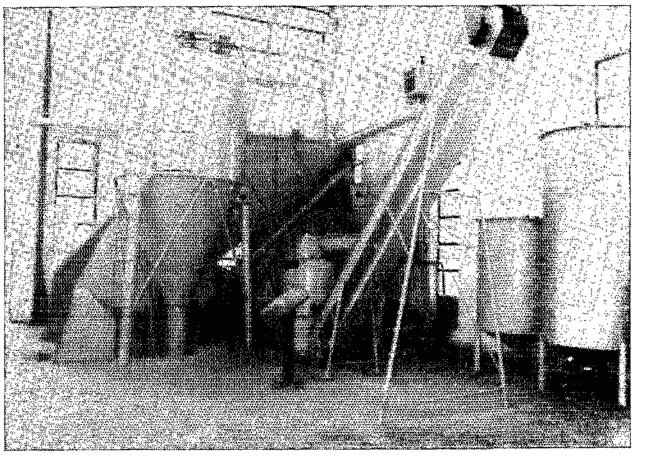

Figura 1

Table 4. Operational figures about different machines for Naoh treatment of straw.

Speed. of tape advancing (m/min)	Grate holes 0 (mm)	Length of chopping (cm)	Pump delivery capacity (1/h)	Working capacity (t/h)	Max. couple at p.d.p. (Nm)	Average requested power (kw)	Specific working capacity (kg/kWh)	Required labour (h/t)
			Taarup 805					
5.0	–	2.1	330	2.99	539	27.1	11.0	0.65
9.5	–	3.2	650	5.90	1030	61.5	9.6	0.30
			Natromat Scherz					
2.0	–	3.0	200	1.80	343	17.6	10.2	1.11
5.0	–	3.0	468	4.20	392	26.0	16.2	0.48
			Mill, FB 975 Falda					
–	10	2.3	85	0.77	736	50.2	15.0	1.63
–	40	4.8	134	1.22	1177	81.3	15.0	1.63
–	no grill	6.7	329	2.99	785	39.1	76.4	0.66
			RTC 940 Feraboli					
–	–	4.0	183	1.65	450	9.0	18.3	1.21

CNR, 1981.

Table 5. Chemical composition and feeding value of wheat straw untreated and treated by taarup 805 with 5% naoh % DM.

	Untreated	Digestibility coeff.	Treated	Digestibility coeff.
DM %	81.30	(39.2)	80.70	(55.8)
OM %	90.48	(41.9)	85.52	(58.4)
CP %	2.92	(-38.4)	2.80	(-88.3)
CF %	40.84	(47.40)	38.72	(68.50)
Ash %	9.52		14.48	
NDF* %	78.72	(48.10)	70.92	(63.90)
ADF %	54.16	(41.20)	51.24	(52.60)
ADL %	7.78	(-9.50)	7.35	(-0.03)
Milk FU/kg DM	0.36		0.56	
Meat FU/kg DM	0.25		0.49	

NDF corrected
N. 6 heifers (CH x Frisona), Initial LW= 364.2 kg, Trial lenght 183 days, ADI= 14.9 kg DM= 6 kg of TS + 8 kg Maize silage + 0.9 kg supplement.
MARTILLOTTI et al., 1980
SETTENERI and VERNA, 1983

Table 6. Formulation of pelletted mixtures.

Components	Control	Mixture 1	Mixture 2	Mixture 3	Mixture 4
Maize meal	38	43	33	27	17
Barley meal	27	12.5	12	13	10.5
Fine bran	12	10	10	10	10
Soybean meal	8	–	12	–	14.5
Alfalfa meal	8	5	5	5	5
Treated straw (4% NaOH)	–	20	20	35	35
Beet prot. conc.	2	4	4	4	4
Urea	–	1.5	–	1.8	–
Meat FU/kg DM	0.77	0.67	0.73	0.63	0.68

Table 7. Live weight ADG, ADI, feed conversion rate relative to male lambs.

	Mix. Control	Mix. 1	Mix. 2	Mix. 3	Mix. 4
Animals	7	7	7	7	7
Trial length, days	42	42	42	42	42
Initial LW, kg	13.24	13.26	13.24	13.26	13.24
Final LW, kg	24.30	22.17	22.51	21.10	21.53
ADG, g	263.26	212.24	220.74	186.74	197.29
ADI, g DM	873.00	830.00	799.00	852.00	899.00
ADI, g Meat FU	672.21	556.10	583.27	536.76	611.32
Feed conv. rate:					
ADI, DM/kg gain	3.31	3.91	3.61	4.56	4.55
ADI, Meat FU/kg gain	2.55	2.62	2.64	2.87	3.09

CIRUZZI et al., 1984

The pilot industrial plant was used also to prepare a complete diet containing 60% TS, 28% maize meal, 12% supplement. Numerous tests were carried out to control the homogeneity of mixture. We chose the Mn, as oligo-element present, according to the CLINE method (1978).

The production of the pilot plant was 0.785 t/h = 0.525 t of treated straw (50%), 0.245 t maize meal (28%), 0.105 t proteic-vitaminic-mineral supplement (12%). The specific performance of the plant, expressed as kg products x kWh absorbed = 8.9 for straw alone, = 21.6 for straw with meals.

Table 8 reports the data relative to feeding trial on 14 heifers (7 CH x MA + 7 LI x MA). As the control group received the farming diet, it was impossible to control the individual ADI. The ADG of the experimental group was 0.874 kg. *datum* very close to the gain of the farming heifers.

Table 8. ADG, ADI, relative to growth of heifers (7 *charolatse x maremmana* and *limousine x maremmana*). Pellet by pilot industrial plant.

	Treated Straw	
Animals	14	
Trial length, days	188	
Initial LW, kg	200.7 ± 6.2	
Final LW, kg	365.1 ± 10.6	
ADG, kg	0.874 ± 0.138	
ADI, kg	7.24	Pellet
	2.14	Hay (alfalfa)
Feed conv. rat.		
DM/kg gain	9.39	

CONTE et al., 1982.

The same pilot plant was used to prepare a pellet having 2 different by-products: NaOH treated straw and condensed demineralized beet stillage (CBDS). They were mixed with maize meal and $CaHPO_4$.

Table 9 shows chemical analyses and feeding value of feeds used in an experimental trial on dairy cows (4 *Frisian* and 4 *Pezzate Rosse Friulane*) by ROBERTIELLO *et al.*, (1985). the replacement of alfalfa hay with the experimental pellet in the ration gave the same results (13 kg of milk/d) in both groups.

The same pellet in comparison to a commercial pellet was used in a feeding trial on two groups of 8 Polish Frisian young bulls (ROBERTIELLO *et al.*, 1984). These experiments, and many others which followed, had as their main purpose the utilization of CDBS, a by-product coming fron distillary effluent of beet molasses process.

Table 9. Chemical composition of diets used in the trial (% DM). Pilot industrial plant.

Items	Experimental feed	Maize Silage	Concentrate	Alfalfa hay
N.° of samples	6	3	3	3
DM %	88.59 ± 0.30	33.45	89.34	78.07
CP	12.52 ± 0.64	8.37	18.79	19.26
EE	1.04 ± 0.04	3.22	2.92	1.10
CF	23.56 ± 0.20	21.46	8.11	33.50
NDF	47.30 ± 0.12	N.D.	N.D.	55.36
ADF	33.59 ± 0.15	N.D.	N.D.	40.61
ADL	4.43 ± 0.05	N.D.	N.D.	8.05
Ash	13.74 ± 0.23	4.25	7.18	9.27
NFE	49.14 ± 0.45	62.70	63.00	36.87
Calcium	0.28 ± 0.11	0.23	N.D.	1.58
Phosphorus	0.19 ± 0.01	0.29	N.D.	0.37
Milk FU/kg Dm	62.50	N.D.	N.D.	58.40

(1) Composition: wheat straw treated with 4% NaOH, 60%; condensed depotassified beet molasse stillage, 30%; maize meal, 9%; dicalcium phosphate, 1%.
(2) Mean ± standard error.
(3) Feed Unit for milk production/100 kg DM.
N.D. = Not determined.
ROBERTIELLO et al., 1985.

ROBERTIELLO and DEGEN (1978) improved such effluent through insolubilization of kalium (whose effluents are very rich) by means of treatment with sulfuric acid, ethyl alcohol and through the following concentration. It is necessary to remark that the initial by-products belong to environmental polluting materials.

NH3 treatment of cereal straw

Systems and plants, used to treat by-products with anhydrous ammonia are reported in the table 10. The treatment with anhydrous NH_3 can be easily organized in the farm with a little expense for the ammonia cylinders and PVC sheets.

A major cost is necessary for the purchase of the gas-chamber (Fig. 2) but it is possible to harmonize treatment times with requirements of breeding. Table 11 compares the nutrients and the relative apparent digestibility coefficients of NH_3 treated straw with untreated straw: the treatnent affected positively the CP content (+134%), the CPD (+38%), OMD (+28%) and CFD (+34%) (MARTILLOTTI *et al.*, 1980).

Table 10. Systems and plants used to treat straw with anydrous ammonia by ist. Sper. Zootecnia, Rome (Italy).

		Exp. Trials
1) Sundstol method	Stacks with Rectangular bales of 5 tons	- Fatt. of heifers - Suckler ewes
2) FMA tunnel	1) Rectangular small bales 2) Big square bales L= 135 cm. 3) Big round bales O= 189	- Suckler cows

Table 11. Chemical composition and feeding value of straw untreated and treated with NH_3 by sundstol system.

	Untreated	(Digest coeff.)	Treated	(Digest coeff.)
DM	90.70	(39.20)	88.10	(50.60)
OM	89.50	(41.90)	90.70	(53.70)
CP	4.1	(38.40)	9.60	(53.10)
CF	42.5	(47.40)	45.30	(63.70)
Milk FU/kg DM	0.39	–	0.55	–
Meat FU/kg DM	0.29	–	0.45	–

MARTILLOTTI et al., 1980.

The NH3 TS was object of a fattening trial on 38 young bulls (CH x Ma) subdivided in two groups of 19 animals: the control group received 5.25 kg hay + 3.93 kg of concentrate, and the experimental group received 4.9 NH3 TS + 3.91 kg of cDncentrate. The analyses of feeds and the data on animals are reported on table 12; the ADG and the FCR were equal to the two groups (BARTOCCI *et al.,* 1985).

The NH3 TS, treated by stack system, was used on a flock of sheep in comparison with untreated straw and pasture. Table 13 shows the ADI of feeds by ewes that lambed and suckled their lambs, during the trial period.

The same table shows the LW, ADI, ADG of ewes and their lambs also. The *data* represent two cycles of breeding.

While the fecundity in the first cycle was low, because the ewes were not yet ready to be fecunded, in the second cycle no negative effect was recorded on fecundity, fertility, growth of ewes and lambs, that received NH3 TS in comparison with animals fed on UTS or herbage.

The last trial with NH3 TS, that we present, is that relative to breeding of suckling cows; the suckling cows

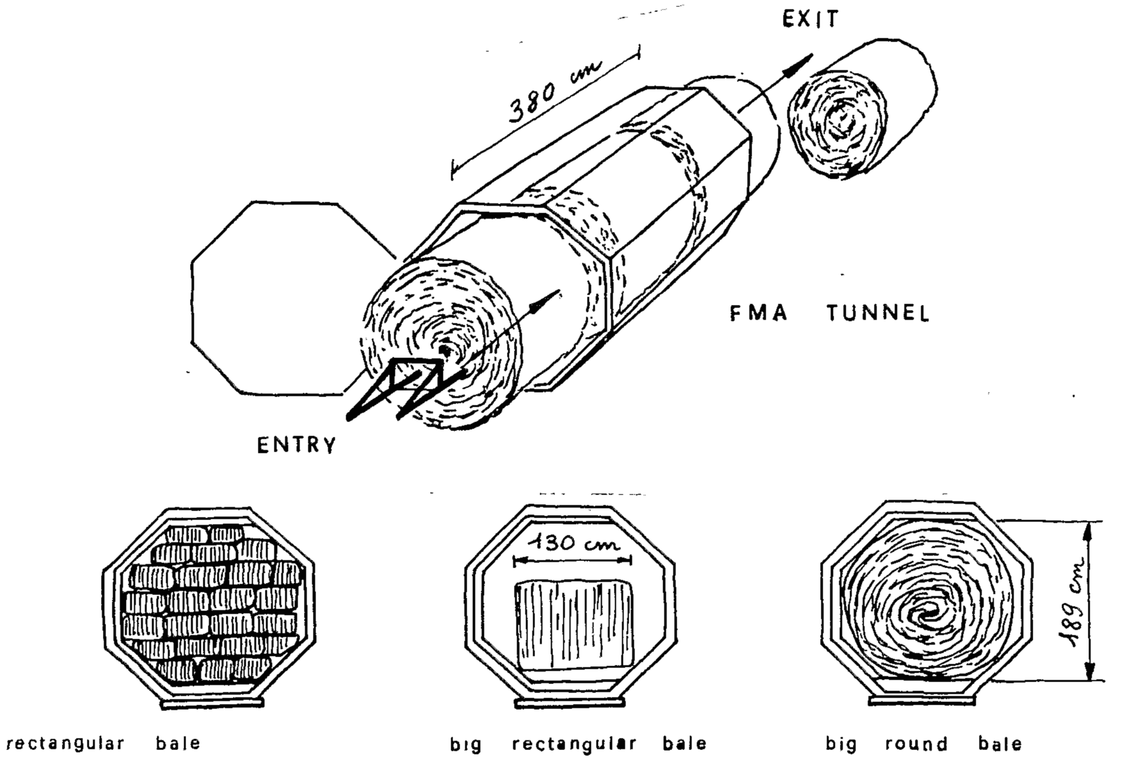

Figura 2

Table 12. Chemical composition (% dry matter) feeding value of feeds (mean ± S.E.) and live weight, ADG, ADI, feed conversion rate relative to young bulls (Charolais x maremmana).

	Treated Straw	Hay	Concentrate (1)
Analysis n	8	5	3
DM %	88.2 ± 0.93	88.8 ± 0.47	91.0 ± 0.61
CP	8.2 ± 0.43	7.7 ± 0.15	16.4 ± 0.19
CF	36.6 ± 0.88	30.9 ± 0.81	8.6 ± 0.54
EE	1.8 ± 0.11	2.4 ± 0.15	3.5 ± 0.20
NFE	44.2 ± 0.96	51.2 ± 0.68	64.1 ± 0.59
Ash	9.2 ± 0.22	7.8 ± 0.23	7.4 ± 0.27
Meat FU/kg DM	0.49	0.48	1.01
Animals	19	19	
Trial length, days	302	302	
Initial LW, kg	242.6 ± 9.1	243.9 ± 8.9	
Final LW, kg	532.1 ± 12.9	548.2 ± 11.9	
ADG, kg	0.953 ± 0.02	0.951 ± 0.03	
ADI, kg DM	4.9 (Straw)	5.21 (Hay)	
ADI, kg DM of Conc.	3.91	3.93	
ADI, Meat FU	6.34	6.46	
Feed. conv. rate.			
ADI, DM/kg gain	9.24	9.66	
ADI, Meat FU/kg gain	6.65	6.83	

BARTOCCI et al., 1985.

Table 13. Average daily intake and live weight, ADG, ADI, feed conversion rate relative to ewes and lambs during the first two parturitions (1st and 2nd cycles).

	A (NH_3 TS)*	B (UTS)**	C Pasture
Animals	34	33	permanent meadow
Straw, kg	1.154	1.133	or 1 kg of
Alfalfa meal, kg	0.639	0.638	permanent meadow
Soybean meal, kg	–	0.060	hay during winter
Molasses, kg	0.100	0.100	
Urea, g	–	10	
Total DM, kg	1.646	1.703	
Animals (ewes)	34	33	34
Trial length, days	98	93	93
Initial LW, kg	43.7 ± 1.24	43.7 ± 1.29	45.0 ± 1.27
Final LW (at lambing), kg	45.7 ± 1.51	45.8 ± 1.58	49.8 ± 1.53
LW (at 60 days), kg	45.6 ± 1.44	45.6 ± 1.49	48.4 ± 1.46
Animals (lambs)	34	33	35
Trial length, days	60	60	60
Birth weight, kg	3.7 ± 0.76	3.9 ± 0.75	3.8 ± 0.77
LW (at 60 days), kg	15.0 ± 2.51	15.0 ± 2.58	15.8 ± 2.60
ADG (g/d)	188.7 ± 37.08	186.8 ± 37.45	199.2 ± 37.98

No difference was significant.

* ATS = NH_3 Treated Straw
** UTS = untreated Straw
BARTOCCI et al., 1987.

Table 14. Live weight at the birth and at the weaning of young bulls.

	n.	at birth kg	at weaning kg	ADG kg
Father genetic type				
CN	92	46.24	196.4	0.838
PD	85	45.06	195.2	0.835
Mather genetic type				
CN x ITF	30	47.14	192.2	0.800
CH x ITF	29	44.95	196.8	0.852
LM x ITF	30	44.89	195.3	0.839
MG x ITF	20	45.93	198.6	0.852
PD x ITF	34	45.22	192.0	0.815
RM x ITF	34	45.76	199.9	0.860
Sex				
Males	78	46.93 a	203.4 a	0.866 a
Females	99	46.37 b	188.2 b	0.806 b
Mean	177	45.65	195.8	0.836
Variance		35.547	1079.08	0.0290

Different letters mean significant differences for P = 0,05
BORGHESE et al., 1989.

received straw treated with NH3 in a gas chamber, FMA TUNNEL, has shown before.221 animals received 7 kg of NH3 TS, 1.5 kg glucoprotil, 14 kg maize silage and 1 kg protein concentrate in a ration distributed by unifeed. Tables 14 shows the figures on animals.

NH3 and NaOH treatments of maize stalks

The residues as corn crop represent a potential source of energy for ruminants because in Italy about 660 millions SFU per year can be obtained. This energy is sufficient to keep in production 60.000 cows if we suppose that half of corn grain crop area is harvested. This should be possible if various problems related to the harvesting system, conservation techniques and their use in cattle nutrition can be solved.

The experiments conducted over a five year period within the framework of Agricultural Mechanization Project of NRC have been made possible to select the most suitable solutions for the problem under examination. The best results have been obtained with self propelled forage harvesting, being adapted for areas of over 1OO had for areas between 35 and 60 ha (C.N.R., 1981). The ensiling was revealed as a possible solution especially when the stalks are harvested with 30% moisture content.

Table 15. Effect of energy supplement and NH_3 treatment of stovers on heifer performances.

	Heads	Initial LW	Final LW	DM intake ADG	Whole rat.	Stovers	Ener. sup.	Roughage/ ration DM
	n.	kg	kg	g	kg	kg	kg	%
Energy supplement:								
- maize	14	336.6	395.8	465	6.640	4.261	2.065	64.2
- dried beet pulp	14	334.2	405.7	558	6.832	3.960	2.558	58.0
Maize stovers:								
- untreated	14	339.0	392.0	419	6.533	3.875	2.312	59.3
- treated with NH_3	14	331.8	409.6	604	6.939	4.346	2.312	62.6
Error mean square		634.71	440.93	6.708	0.130	0.109	–	4.789

LANARI and PINOSA, 1989.

It is recommendable to improve the voluntary intake to add 1) water when stovers have a moisture content higher than 35% of whole plant of maize (50% of the product molasse 10% on the product), 2) fresh beet pulp (40% on the product and chemical agents like natrium hydroxide, NH3 or calcium hydroxide.

Among several experimental trials carried out on animals, we chose some of the most significant results (table 15) obtained on heifer performances.

Citrus pulp

13.2% only of citrus pulp national production is transformed by industry. Before 1968-69 the citrus pulp was utilized with 81.9% of moisture on farms near industry.

MAYMONE and DATTILO (1962) carried out trials to determine the apparent digestibility coefficients on citrus pulp with a high level of moisture. They found this residue had a very high digestibility coefficient of NFE and it could be used by replacing cereal grains in feeding of ruminants. In order to lower losses of dry matter, D'URSO *et al.*, (1984) experimented that no leachate was released ensiling fresh orange pulp with 10% of straw.

After 1969 a new technological process produces juice, dried pulp with 8% moisture as press cake (peels, seeds, pulp), essential oil distilled from natural liquid and citrus molasses (20%).

According to studies conducted by LANZA and MESSINA (1985) on digestibility trials, dried citrus pulp resulted characterized by high energy content with 95-98 of SFU. By analyses carried out in our laboratory, dried citrus pulp had OMD = 90-95%, DT = 62.74%, NDF = 32%, ADF = 21%; ADL = 1.5%.

Tomato skins and seeds

The TSS (Tomato skins and seeds), residue of manufactures of tomato such as concentrate, has about 26% dry matter and can be used as feed in animal breeding near the industry.

Often its production is much larger than the requirements of breeding and it is necessary to store TSS by ensiling.

As silage, although it has low nutritional quality characteristics, good results were obtained on the feeding of heifers when it replaced 50% of maize silage or about 1/4 of the ration of dry matter.

Conclusions

The use of specialized equipment can improve the nutritional value of by-products, increasing organic matter digestibility and voluntary intake.

The investment cost is often justified only for areas of over 100 ha. For smaller areas, cooperative societies could be created.

The chemical agents, added to crop-residues, have to be used in a strictly necessary ratio.

As effect of nutrient complementarity, from the association of two or more by-products a nutritionally complete feed could arise.

Finally, it cannot be over emphasized that we now need to promote the use of the experimentally acquired data into possible applicative framework.

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