COMPARATIVE STUDY REGARDING THE WORK PERFORMANCES FOR TWO TYPES OF FORAGE DISTRIBUTING MACHINES
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STUDIU COMPARATIV PRIVIND PERFORMANȚELE DE EXPLOATARE A DOUĂ TIPURI DE MAŞINI PENTRU DISTRIBUIT FURAJE

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ABSTRACT

For the study of methods and means to achieve a high performance technology for the distribution of forage, two different machines have been built and investigated, capable to perform several activities within the technology for preparing and distributing forage to cattle. In this article are presented the results of experimental researches carried out at a livestock farm, on a lot of milk cows, in similar working conditions, emphasizing the technical performances, the structure of working times, the working capacity of machines, important indicators for obtaining high production and increasing work productivity.

REZUMAT

Pentru studierea metodelor şi mijloacelor de realizarea a unei tehnologii performante de distribuire a furajelor s-au realizat şi cercetat doua maşini deosebite constructiv, capabile să execute mai multe activităţi din cadrul tehnologiei de pregătire şi distribuire a nutreţurilor la bovine. În cadrul acestui articol sunt prezentate rezultate ale cercetărilor experimentale desfăşurate la o fermă zootehnică, pe un lot de vaci de lapte şi în condiţii asemănătoare de lucru, cu accent pe performanţele tehnice, structura timpilor de lucru, capacitatea de lucru a maşinilor, indicatori importanţi pentru obţinerea de producţii ridicate şi creşterea productivităţii muncii.

INTRODUCTION

Agricultural scientific research, by its research object - soil, plant, animal – aims to offer high quality biological products, raw material, technologies, appropriate knowledge that should contribute to promotion of sustainable agriculture and rural development, increase food security and safety according to general and specific requirements of the market.

For the economy, the agriculture can represent an opportunity, in recent years, being manifest trends of its diversification and consolidation, farming becoming more attractive to investors, (*Ciupercă et al., 2015; Eurostat, 2011; MADR, 2014*). In Romania, almost all the species from animal farms are being breeding, assuring the whole variety of agro-food products of animal origin of natural and cultivated grasslands, as well as the outstanding potential of cereal and fodder vegetable production can help to obtain important animal origin products for exportation, as “organic or ecological product”.

Cattle’s growing is a traditional activity in rural and especially mountain and hill area of Romania. Diversity of productions achieved, reduced energy consumption and type of fodder used make from cattle breeding a sustainable and perspective activity.

In 2011, the value of animal production represented 28% out of agricultural production amount (*Eurostat, 2011*), severely decreasing from 44%, as was registered in 1998. Cattle population (approximately 2 millions of heads in 2012, used especially for milk production) is mainly concentrated in North and North-Eastern of Southern Plain.

Cattle food has a specific structure, being based on producing high quality forage in sufficient quantity able to ensure balanced ratios for animal daily necessity, especially volume forage (hay juicy fodder, green matter) and concentrated fodder. Ensiling represents one of the three methods of current use of fodder plants in animal feeding, the other two being grazing and hay production, (*R. Jarrige et al., 1993; Mocanu and Hermeneanu, 2013; Voicu E. et al. 2007*).

Quality of food designed to animals must have an appropriate quality and be in suitable quantity with a nutritive value appropriate to physiological requirements of each breed, age or weight category, absence

of contaminants, as important values of free access to food and water, depending on feeding, number of daily portions correlated to growing and maintenance system, *(Pintea I., 2015*). The feeding technique is characteristic on categories of animals and ecological areas, depending on variety and quality of fodder produced, specialty and endowment level of respective units and even on area tradition, *(Mănişor P., 1994; Mănişor P., 1991)*.

Fodder UNIC corresponds to method of feeding with balanced ratios made of several types of forages (fibrous, raw, root and concentrated) mixed in a technological trailer. Quality of UNIC fodder depends on components quality and mincing and mixing processes quality, for homogenizing it in machines storage hopper, (*Dărăban S., 2010; Mănişor P., 1991*).

In recent years, the modern technique has highly developed in this field, being manufactured mobile or fixed machines which perform several operations (dosing, mixing and distributing food to stables or paddock), (*Mănişor P., 1994; Mocanu and Hermeneanu., 2013*)

Working systems of foddering machines are known as tillage cutter which breaks and loads into the silage, rotor with blades or spires for mincing and mixing the forage, conveyor that distributes the fodder mixture to animals. For reducing the manpower and especially for obtaining high quality works, scientific studies and researches on this equipment working processes, have been achieved, (*Nedelcu A et al., 2007 Nedelcu A. et al., 2012*).

MATERIAL AND METHOD

For studying the methods of achieving a state-of-the art technology for fodder distribution, within INMA, two variants of machines designed to prepare and distribute food to farm animals, were designed, manufactured and tested, namely: *Technological trailer for chopping, mixing and distributing the forage, RTF* (fig.1), *Fodder machine, MF8* (fig.2), having specific technical and functional characteristics each, determined by the constructive requirements of main technical equipment designed to loading, , chopping, mixing and distributing the fodder.

The technological sequences within the technology of distribution of fodder, which were analyzed, are the following:

- movement of tractor-machine aggregate to feeding points;
- dislodging from the store and loading into the body of fibrous forages;
- automated weighing or special platform of fodder weighed;
- chopping and homogenizing the fodder mixing;
- aggregate movement to distribution points;
- distribution of fodder to animals.

Fig.1 – Technological trailer for chopping, transporting and distributing the forage, RTF

Fig.2 – Fodder machine, MF8

With *Technological trailer for chopping, mixing and distributing the forage, RTF*, that is simpler as construction, the technological processes of chopping and mixing the fodder loaded into the body, transport and distribution of fodder to animals, were performed; with *Fodder machine* F8, a real domestic kitchen, the technological processes of silage forage dislodging and loading, chopping and mixing of fodder ensilaged, straw or hay bales chopping, automated weighing of recipe fodder, homogenization and distribution of resulted fodder mixture, were performed.

The two machines were tested at a livestock farm for cattle growing from S.C. AGROINDUSTRIALA Pantelimon S.A./Ilfov/Romania.

In figure 3, are shown the technological variants achieved by the two types of technical equipment, emphasizing the working processes and methods of achieving them.

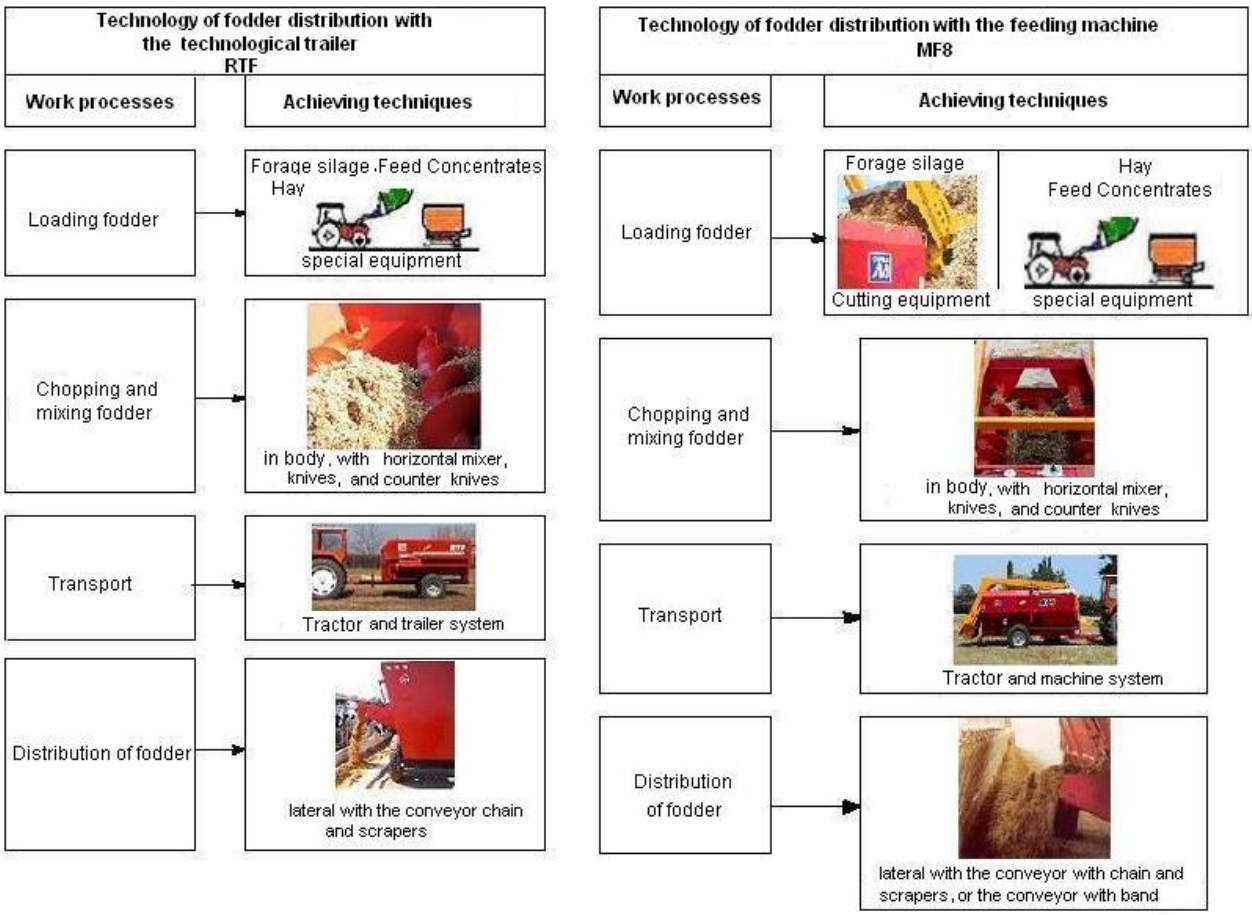

Fig.3 – Scheme of foraging technology with achieving variants according to equipment used

Within the technology of preparing and distributing the fodder to cattle, measurements for determining the working parameters of equipment loaded, were achieved, namely: moments, distribution height, time and qualitative working and exploitation indexes *(Nedelcu A., 2012)*.

The tests were made with wheeled tractor U 650, suitably equipped with lower traction coupler and system of taking over the vertical loads, independent PTO with rotating speed of n=540 rot/min; storage battery 12 V; 12/150 Ah, tensiometer plug with moment transducer HBMT4Wa-S3, centrifugal tachometer 40 - 48000 rot/min, mechanical chronometer, weighing lever 250 - 10000 kg and other specific measuring instruments.

In the machine body were loaded especially the ensiled material and different proportions of hay and straw bales, according to recipe established by the specialist.

Corn silage loading was made in a silage cell where the material density per worked surface has varied from upper to lower part ranging between: 520…756 kg/m^3 .

Material ensilaged was dislodged and loaded with fodder machine cutter MF8, and in technological trailer RTF with special equipment of IFRON type.

Power, *P*, necessary for driving each working equipment was calculated with relation (1) *(Şandru A. et al. 1983, Tecuşan N. et al., 1982*):

$$P = \frac{M \cdot n}{9550} \quad [kW] \qquad (1)$$

where:

M – moment measured [Nm];

n – rotating speed [rot/min];

Aggregate moving to loading or distribution points has been done with constant speed in a horizontal road and that is why the traction force and traction power are calculated with relations (2).

$$F_t = f \cdot Q \quad [N] \tag{2}$$

$$P = \frac{F_t \cdot v_l}{1000} \quad [kW]$$

where:

F_t - traction force in towing point, [N];

f – coefficient of resistance to running;

f = 0.018 - 0.020, on worn asphalt or concrete road, (*Tecuşan N. et al., 1982*).

Q – machine's weight including the load, [N].

V_l – rate of travel, [m/s];

Performing the operations with mechanized methods greatly contributes to increasing work productivity, due to the quality of work.

Working capacity of aggregate, W, represents the average volume of suitable quality operations, U, achieved in time unit T_i, according to relation (3).

Structure of working time represents the group of elements belonging to a shift time, being calculated with relation (4) *(Şandru A. et al., 1983*).

$$W = \frac{60 \cdot U}{T_i} \quad [UM/h] \tag{3}$$

$$\begin{aligned} T_{02} &= T_1 + T_2 \\ T_{03} &= T_{02} + T_3 \\ T_{04} &= T_{03} + T_4 \quad [min] \\ T_{07} &= T_{04} + T_5 + T_6 + T_7 \\ T_{08} &= T_{07} + T_8 \end{aligned} \tag{4}$$

where:

T_1 – working time; T_2 – additional time, T_3 – time designed to technical service of the machine; T_4 – time for remediation of technological failures, T_5 – time for personal rest; T_6 – time for changing the workplaces; T_7 – time for technical maintenance, T_8 – total working time.

Knowing the structure of time the coefficients of time utilization are calculated, as well as the exploitation indexes characterizing the working time and contribute to estimation of technological and technical deficiencies.

RESULTS

Within the tests, measurements were made for determining the dimensional characteristics shown in table 1.

During the basis operations of the technology one or several main assemblies will be put in function, depending on variant of machine used; when measuring the moments and analyze the power consumption one will take into account all these.

Table1

Main technical characteristics of equipment tested

Technical characteristics	MU	Technical equipment	
		Technological trailer for chopping, transporting and distributing fodder RTF	Fodder machine MF 8
Category	-	Machine for works	Machine for works
Type	-	uniaxial	uniaxial
Overall dimensions:			
- length	mm	4280	6250
- width	mm	2860-2550	2350
- height	mm	2275	2445
Distribution height	mm	600 -1340	400-630

Technical characteristics	MU	Technical equipment	
		Technological trailer for chopping, transporting and distributing fodder RTF	Fodder machine MF 8
		(depending on conveyor type)	(adjustable working position)
Wheel track	mm	1600	1800
Useful volume	m^3	3.5	8
Own mass	kg	2000	3650
Loading equipment	-	-	Cutter type
Type of distributing conveyor	-	With chain and blades	With chain and blades
Working speed	km/h	2-4	2-4

In table 2 were comparatively identified the assemblies which participate in performing the working processes appropriate to technology of foraging.

During forage loading into the machine body, the mixing worms are permanently operating, being driven from tractor's PTO through the mechanical transmission; at the same time, if the body is loaded with fodder and moves to the distribution points, the worms will be driven for chopping and mixing in order to homogenize the matter.

In table 3 are given the average values of rotating speed and moments measured at the main axle driving the working parts for loading, mincing, mixing and distributing the fodder.

Table 2

Table of consumers of power developed by tractor from the PTO

Working process	Operating assemblies				
	Technological trailer, RTF		Fodder machine, MF8		
	Mixing worms	Conveyor	Mixing worms	Cutter	Conveyor
Motion of unloaded machine	-	-	-	-	-
Loading of fibrous ensilaged fodder	X	-	X	X	-
Loading of concentrated or other types of forage	X	-	X	-	-
Movement to points of fodder feeding	X	-	X	-	-
Chopping, mixing and travel to distribution points	X	-	X	-	-
Distribution of forage mixture	X	X	X	-	X

PTO's rotating speed when the machine is unloaded has had values ranging within 500-540 rot/min

Table 3

Determinations per different working stages

Working process	Technological trailer - RTF			Fodder machine - MF 8		
	Operating assemblies	Moment [N m]	Power necessary [kW]	Operating assemblies	Moment [N m]	Power necessary [kW]
Silage fodder loading	Mixing worms	200-230	11.31-13.1	Worms and cutter	330-400	18.7-22.6
Other fodder loading according to recipe	Mixing worms	200-250	11.31-14.2	Mixing worms	300-350	17-19.8
Blending and grinding	Mixing worms	220-280	12.5-15.8	Mixing worms	320-390	18-21.5
Fodder distribution	Mixing worms and conveyor	260-290	14.70-16.4	Mixing worms and conveyor	340-400	19.2-22.6

Power necessary to drive the working systems for the main working processes within the technology studied, were calculated with relation (1), where the rotating speed n=540 rot/min (according to Tractor technical book), results being synthesized in table 4.

In order to test the machine operation and determine their functional characteristics, different types of silage fodder were loaded in machines body: silage corn, hay and straw bales, fodder combined in different proportions according to recipe.

Fodder matter loaded in machine body during works:

- technological trailer, RTF, *m* = 1000 kg
- fodder machine, MF 8, *m* = 2000 kg

During the experiments, it has been found that for machines good operation, the humidity of fodder used should not surpass 70%. Using appropriate humidity forage, the processes of mixing, homogenization and distribution are continuously run and the material adhesion and settlement phenomena on the bottom of the body, as well as an excessive shredding or a pasty mixture, are avoided.

Measurements for finding out the characteristics of ensiled fodder used were made on 500 g samples of silage maize with husk, taken during two different stages of technology:

1. from the silage cell, before dislodging and charging into the machine body;
2. from the layer of chopped material in the machine body and distributed to animals.

Time of mixing and shredding was of 20 min.

Table 4 comparatively shows the characteristics of silage fodder before and after processing it in the body of fodder distribution machines RTF and MF 8. Values indicated represent the average of two material samples taken for each machine and are valid for both machines, because of the mixing worms identical constructive solutions and their endowment with notched knives.

Table 4

Silage material characteristics before and after the processing in distribution machines

Fragments length [mm]	Characteristics of material loaded in machines body			Characteristics of material after the processes of shredding and mixing		
	Humidity [%]	Quantity [g]	Shredding level [%]	Humidity [%]	Quantity [g]	Percentage in fodder mass [%]
l<50	31.82	241.6	48.34	37.54	433.5	86.7
l=50-100		70.8	14.16		66.5	13.3
l=101-150		54.1	10.82		-	-
l=151-250		133.4	26.61		-	-

For *f*=0.02, the working speed *v*=2…4 km/h and fodder mass loaded, the following values for traction force and power necessary to traction, were registered:

- technological trailer RTF, F_t = 600 N; P_t =0.36…0.66 kW
- fodder machine, MF 8 , F_t = 1130 N, P_t =0.63-1.25 kW

Wheeled tractor U 650 with which tests were performed, is an average power tractor, equipped with Diesel engine of 47.8 kW (65 HP) at 1800 rot/min.

In table 5 are shown the values for power stock in different stages of technology, calculated for the working speed v = 4km/h.

Within the technology for preparing and distributing fodder to cattle, performed with the machine studied, besides the functional characteristics were determined also the working time, working capacity and the results obtained were analyzed and a series of exploitation indexes shown in testing reports according, were established.

Table 5

Power consumption during different working stages [kW]

Operation	Technological trailer - RTF		Forage machine - MF 8	
	Max. power consumed	Power stock	Power necessary	Power stock
Silage forage loading (stationary)	13.1	34.7	22.6	25.2
Other fodder loading according to recipe (stationary)	14.2	33.6	19.8	28
Mixing and grinding (stationary)	15.8	32	21.5	26.3
Mixing, grinding and travel to distribution point	16.46	31.34	22.75	25.05
Forage distribution	17.1	30.7	23.85	23.95

Structure of working time was estimated when the forage was distributed to 100 milk cows, and the feeding portion was of 35-40 kg/day *(Şandru A et al, 1983*).

Table 5

Structure of working time

Parameter	Symbol	Technological trailer, RTF	Fodder machine, MF 8
		Values measured	Values measured
Working hours for one charge [min	T1	36	28.5
Number of charges per day [min]	N_S	4	4
Additional time (unloaded machine movement) [min]	T2	5	3
Time for machine technical service (preparation of working machine) [min]	T3	5	5
Time for remedying the deficiencies {min]	T4	6	4
Operating time [min]	T_{02}	41	31.5
Total operating time, [min]	T_{03}	46	36.5
Time of production [min]	T_{04}	52	40.5
Working hours per day [min]	$T_{zi} = N_S \times T1$	144	57
Total working time (one day) [min]	$T_{08}=N_S \times T_{04}$	208	114
Hourly working capacity appropriate to one charge production time [kg/h]	W_{04}	1154	2963
Coefficient of utilization of operating time for one charge	K_{04}	0.69	0.70
Coefficient of safety operation	$k_4 = \frac{T_1}{T_1 + T_4}$	0.86	0.88

CONCLUSIONS

The both machines differ from constructive point of view, which resulted in specific characteristics for each of them, according to table 1, as well as different involvement in achieving technological sequences within the technology;

After the analysis of moments measured and power driving the working parts, the following have been found:

- for technological trailer RTF, loaded with 1000kg forage, the max. necessary power is of 16.46kW suitable to transport and distribution processes (the mixing worms operate simultaneously with chain and rake conveyor);
- for fodder machine MF8, loaded with 2000kg of forage, the maximum necessary power is of 23.85kW corresponding to forage transport and distribution the (mixing worms operate simultaneously with chain and rake conveyor);
- for both variants of machines, a power stock has remained during operations performing;

Endowment of fodder machine, MF 8 with own dislodging and loading equipment and weighing installation has led to obtaining smaller time of loading and movement, thus, resulting smaller working hours: T1=28.5min for the machine MF8, instead of T1=36min for trailer RTF, influencing also the other components of time structure and hourly working capacity.

Operation safety coefficient, K_4, calculated for the two variants of machines are very close.

Utilization of fodder machine, MF8, has been more advantageous than the technological trailer, RTF, because it performs with its own equipment the silage forage dislodging and loading in its own body.

REFERENCES

[1] Ciupercă R., Lazăr G., Popa L., Nedelcu A., Ştefan V., Zaica A, Petcu A., (2015), Organic plant and animal waste management system (Sistem ecologic de gestionare a deşeurilor vegetale şi animale), *INMATEH-Agricultural Engineering Journal,* Vol.46, No.2, pp.69-76, ISSN: 2068–2239, Bucharest/Romania;

[2] Dărăban S., (2010), Sheep feeding during the stable feeding, (Hrănirea ovinelor în perioada de stabulaţie), *The Village World* Journal Publishing, No.1, 1-15 January;

[3] Jarrige R. et al, (1993), *Cattle, sheep and goats feeding*, INRA, ISBN 2-7380-0563-2, Paris/France;

[4] Mănişor P., (1994), *Mechanization and automation of livestock works (Mecanizarea şi automatizarea lucrărilor în zootehnie)*, CERES Publishing, ISBN 973-40-0304-6, Bucharest/Romania;

[5] Manişor P., (1991), *Technologies and equipment for valorisation of volume forage in industrial flow (Tehnologii şi utilaje pentru producerea şi valorificarea furajelor)*, CERES Publishing, ISBN 973-40-0156-6, Bucharest/Romania;

[6] Mocanu V, Hermeneanu I., (2013), *Mechanization of agricultural works on lawns. Technologies, machines and equipment (Mecanizarea lucrărilor agricole pe pajişti. Tehnologii, maşini şi echipamente),* Ed. Universitatea Transilvania Braşov Publishing, ISBN 978-606-19-0237-8, Braşov / Romania;

[7] Nedelcu A., Popa L., Cojocaru I., Ciupercă R., (2007), Modern technologies for forage distributing in cattle farms (Tehnologii moderne pentru distribuirea furajelor in fermele de bovine), *INMATEH Scientific Works (INMATEH -Lucrări ştiinţifice)*, vol. 20, no. 2/2007, ISSN 1583–1019, pp.61-66;

[8] Nedelcu A. Ciuperca R., Popa L., Bodea C., (2012), Researches Regarding the Shredding, Mixing and Distribution Processes within Foddering Technology of the Cattle (Cercetări asupra proceselor de mărunţire, amestecare, distribuţie din cadrul tehnologiei de furajare a bovinelor), *The 4th International Conference "Advanced Composite Materials Engineering" COMAT 2012,* ISBN 978-973-131-162-3, pp. 838-842, Brasov/Romania;

[9] Pintea I., (2015) Recommendations regarding the production, storage and foraging to animals (Recomandari privind producerea depozitarea si distribuirea furajelor pentru animale), *Gazeta Agricolă*, http://www.gazetadeagricultura.info;

[10] Şandru A., Popescu S., Cristea I., Neculaiasă V., (1983), *Exploitation of agricultural equipment (Exploatarea utilajelor agricole)*, Ed. Didactica şi Pedagogică Publishing House, Bucharest / Romania;

[11] Tecuşan N., Ionescu E., (1982), *Tractors and motor cars (Tractoare şi automobile),* Ed. Didactică şi Pedagogică Publishing House, Bucharest/Romania;

[12] Voicu E., Gângu V., Ciure G., Tican N., (2007) Machine for green fodder ensiling in polyethylene bags, (Maşina pentru însilozat furaje verzi în sac de polietilena), *INMATEH Scientific Works (INMATEH - Lucrări ştiinţifice)*, vol.23, no.5/2007, ISSN 1583–1019, pp.33-38, Bucharest/Romania;

[13] *** EUROSTAT - http://ec.europa.eu/eurostat/data/browse-statistics-by-theme;

[14] *** MADR - (2014) *Strategy for long and average term development of agro-food sector-Horizon 2020-2030, (Strategia pentru dezvoltarea sectorului agroalimentar pe termen mediu şi lung orizont 2020-2030),* Romania, http://www.madr.ro/proiecte-de-acte-normative/1291-proiect-1-25-06-2014.html.