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Research Article

Valorization of Tomato Pulp in Animal Feed: Brakes and Levers for the Development of Innovative Sector

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Faced with the challenge of food security in developing countries, the valorization of agricultural by-products in animal feed is an effective strategy if several conditions are met by the various actors in the agro-industrial sectors. This article, based on qualitative surveys of agri-food and livestock industry stakeholders in Algeria, provides an analysis of the brakes and levers for the creation of incentives for the adoption and dissemination of the use of tomato pulp in animal feed. Beyond the technical knowledge on the nutritional values of this by-product and its potential use in animal feed, this work shows that the main strategies currently implemented by food manufacturers for the recovery of tomato pulp remain sporadic and do not offer the possibility of expanding the market for the recovery of tomato pulp. The coordination of the actors in the sector remains the key to creating incentives for the adoption and dissemination of this new animal feed technique.

Keywords: Tomato byproducts, Valorization Strategies, Innovation, Brakes, Levers.

INTRODUCTION

A major challenge in developing countries is food security. In Algeria, fodder resources remain insufficient and often offset by the import of soya meal, barley, and corn, which generates significant expenditure for the State. In 2014, the purchase of corn cost him $977.13 million, barley $196.6 million and soybean meal $540 million. Over the past 20 years, and to meet the growing demand for animal products, imports of corn have increased by more than 10,000 and soybean meal by nearly 7,000 (ONS, 2017). Recent economic and demographic developments in Algeria have led to a growing demand for agri-food products. The country classified as semi-arid with arid dominance, where the desert covers more than 80% of its surface area, faces a major risk of food shortage that can lead to political instability. The local agri-food market is currently highly dependent on the international market for most food (72% of foodstuffs are imported) and more particularly cereals and milk. Animal sectors have not stopped developing but remain handicapped, among other things, by the lack of natural resources on which they rely. To this end, agro-industrial by-products can represent an alternative to importing the raw materials necessary for the manufacture of animal feed or at least lighten them, given their availability and nutritional value. Several experiments have been carried out around the world to promote by-products in animal feed (Famuyiwa and Ough, 1982; Arosemena et al, 1995; Joshi and Sandhu, 1996; Howie et al, 1996; DePeters et al, 1997; Batajoo and Shaver, 1998; Fadel, 1999; Aregheore, 2000; Westendorf, 2000; Westendorf and Wohlt, 2002; Tripodo et al, 2004; Abbas et al, 2009; Kumar et al, 2016; San Martin et al, 2016....). Among these, tomato by-products appear to be a promising raw material for animal feed (Fondevila et al, 1994; Weiss et al, 1997; Knoblich et al, 2005; Del Valle et al, 2006; Denek and Can, 2006; Ventura et al, 2009; Aghajanzadeh-Golshani et al, 2010; Kalogeropoulos et al, 2012; Cassinerio et al, 2015; Heguy et al, 2015; Arco-Pérez et al, 2017; Valenti et al, 2018). In contrast to this

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research, which often focuses on the nutritional value of tomato by-products and the form of their incorporation as an ingredient in animal feed, this article proposes a broader analytical approach to address the levers and barriers to the development of value chains for tomato by-products. This work tries to answer a central question: what are the brakes and levers to the development of this innovative sector relating to the valorization of tomato by-products in animal feed? The aim of this paper is to analyzing current action strategies and proposing improvements to encourage the emergence of this sector. We propose to explain here how the tomato pulp value chain - a by-product of the industrial tomato processing industry - can be structured. In the manner of (Martini and Pellegrini, 2005; Rijkens-Klomp, 2012; Karlsson-Vinkhuyzen et al, 2018; Meijer et al, 2019) and beyond the technical knowledge on the nutritional values of this by-product and its potential use in animal feed, this article is based on qualitative surveys of stakeholders in the agri-food and livestock industries to provide an analysis of the brakes and levers for creating incentives for the adoption and dissemination of the use of tomato pulp in animal feed. The article is structured around four sections. In the first section, we describe the evolution of the livestock feed market, its chronic dependence on imported raw materials and its functioning which marginalizes the place of agro-industrial by-products. In the second part, we make an inventory of the availability of the tomato by-product and its zootechnical interest as a potential input in animal feed. The third part presents the main strategies currently implemented by food manufacturers for the recovery of tomato pulp and their limitations. Finally, the fourth section proposes ways forward to structure a value chain for tomato pulp in the livestock feed manufacturing industry.

1. The livestock food market in Algeria: strong dependence on imports

Evolution of the livestock feed market and opening up to private competition

Algeria is one of the world's largest importers of cereals. This is why the Algerian government favors the cultivation of cereals, which covers 3.5 million hectares of wheat and barley for the 2017 season. Algeria remains in deficit, especially in soft wheat, which represents 49% of food imports in quantity and 46% in value for 2016, followed by corn and finally the least imported barley. Algeria's enthusiasm to reduce its food dependence, particularly on cereals, has slowed the development of other crops such as fodder crops. The supply of inputs for the manufacture of food by the industrial subsidiaries of the ONAB (national office of animal feed) is around 90% dependent on imports. Corn and soybean meal alone account for 85% of the budget for the import of raw materials for animal feed. Their purchase price is set by the Chicago Stock Exchange and the volume of transactions.

The objective of filling the gap in forage resources through the manufacture of compound feeds was the impetus of the feed industry provided by the ONAB until the sector was privatized. The latter experienced a considerable increase in its production, which increased fivefold between 1982 and 1999. Since then, a regressive trend in production has been observed. This is due to the privatization of ONAB's units, which fell by more than 666,000 t/year between 1999 and 2014, or the equivalent of 66% of its production capacity (Houmani, 1999). The gap created about market needs has gradually been filled by private sector operators, whose number is estimated at more than 2,900 units. The entry of private importers reduces the influence of the ONAB in its negotiating power as a monopoly: outsiders have reduced the place of the ONAB as the main trader with no driving effect. Competition from private manufacturers has led ONAB subsidiaries to seek cost optimization to offer more attractive prices. However, livestock feed manufacturers, both public and private, are unable to break the impasse over the import of the corn-soybean pair, mainly because of the frequent unavailability of local raw materials due to climatic hazards (increasingly frequent and prolonged drought). The use of mill by-products (wheat bran) and barley has become an internal necessity (Houmani, 1999; Kaci, 2015). The infinite substitution variants between these various raw materials used for animal husbandry relativize the standard established for compound feed mainly derived from the soya-corn meal pair.

Feed formulation and price-quality relationship

The strategy of the livestock feed units is based on the question of feed costs, which account for 70% of the cost price of certain animal productions (off-land livestock farming). Overall, the cost price of livestock production is dominated by the value of food consumption. The dependence of the Algerian livestock feed industry on imports means that prices are dependent on fluctuations in international market prices.

On the local market, the price fluctuation at the factory exit is linked to the seasons (availability of green fodder). Private industrialists adopt controversial strategies by playing on the price/quality ratio of products. During the summer season, private manufacturers lower prices and improve the quality of their products (compliance with nutritional quality standards) by trying to attract their customers who are less interested in the compound feed because of the availability of green food. During the winter, private manufacturers increase prices already affected by the increase in raw material prices on the international market while lowering the quality of the food produced (non-compliance with nutritional quality standards). The use of substituting soya cornmeal for other local raw materials (barley, barley from mills, various agro-industrial by-products) is made possible not only by technological progress to determine their nutritional intake but above all by the lack of a regulatory framework capable of rigorously controlling the quality of the food produced.

The ONAB subsidiaries, for their part, are satisfied with the limited incorporation of barley and barley from flour mills in addition to the traditional pair (soy meal-corn). Their products remain a reference in terms of quality in the livestock feed sector but with exorbitant prices. Private manufacturers use quality as a variable for adjusting their selling prices. Indeed, the products from the ONAB units are considered better for their quality/price ratio. As farmers have less visibility on feed quality, they prefer products from private units sold at lower prices. Here, for the same product, for example, young cattle feed, the price difference is 500 to 1000 DA/q (7.5 €/q). It seems that this phenomenon is due to the lack of knowledge of farmers in terms of the quality and nutritional balance necessary for a good production yield. This context provides a better understanding of the difficulties of developing livestock feed based on agro-industrial by-products.

2. Industrial tomato pulp: a field to be exploited

Available deposit

The domestic production of industrial tomatoes has increased steadily over the last twenty years. Between 2000 and 2016, production increased from 4.7 to 12.5 million quintals (Figure 1). Production has benefited from technical modernization but also supervision and public subsidy.

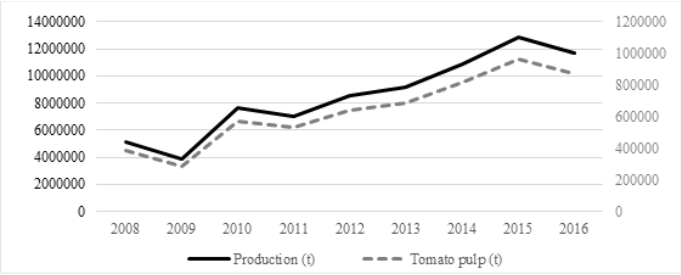

Figure 1: Quantitative evolution of industrial tomato production and pulp

Production is particularly concentrated in the eastern region of the country (Skikda, Annaba, Guelma, El-Tarf), which alone accounts for more than 30% of national production. However, the transformation is much more dispersed with a total of 27 units spread over the entire national territory. This industrial activity releases waste commonly known as tomato pulp, which represents between 5 and 10% of the quantities processed. It is the harvesting season of the tomatoes and their level of maturity that varies this percentage. Assuming an average of 7.5% tomato pulp, the annual available quantity would be about 87,500 tons. Its conservation and valorization are particularly easy, as processing is concentrated in the summer season when pulp can be preserved by simply drying in the sun or by silage in a suitable region. These advantages should normally promote its value in animal feed.

Zootechnical interest

Various studies have shown the usefulness of this by-product in animal feed (Dotas et al, 1999; Abdelmadjid et al, 2008; Mirzaei-Aghsaghali and Maheri-Sis, 2008; Salem and Znaidi, 2008; Ventura, et al, 2009; Chapoutot et al, 2010. Due to its chemical composition and nutritional value, tomato pulp, unfairly called "dregs", is positively used in the diet of domestic animals. Various studies have shown the usefulness of this by-product in the ruminant feed (Morel d'Arleux et al, 1991, Arbouche et al, 2018) (Table 1).

Table 1. Chemical composition of tomato pulp in processing units in eastern Algeria

Dry matter (%)	25,8
Crude protein (%)	19,90
Crude fiber (%)	35,3
Crude fat (%)	16,1
Crude ash (%)	4,9
NDF (%)	55,6
ADF (%)	20,3
ADL (%)	25,2
Calcium (%)	0,2
Phosphorus (%)	0,3
Gross energy (kcal/kg)	4063

Source: *Arbouche et al, (2018)*

Its chemical composition depends on the variety and the transformation processes used. In its fresh state, it can be distributed as it is or ensiled. Its nutritional value in the dry matter remains average for gross energy and protein value. Its use is mainly recommended for ruminants with an incorporation rate of between 15 and 20% of raw product.

MATERIALS AND METHODS

Choice of the study area

The choice of the eight wilayas (administrative divisions) in eastern Algeria is justified both by the fact that most of the industrial tomato production produced there (over 9.5 million quintals), and by the high proportion of cattle (657,000 head) and sheep (2.9 million head) production, the main potential feed demand for tomato pulp, in the region (Figure 2).

Survey and analysis method

The objective of this study is to identify and analyze the main brakes and levers in the value chain for the use of tomato pulp as animal feed. The aim is to apply existing theories on the obstacles and levers to the valorization of tomato by-products by using case studies analyzed with the existing documentary literature (Chetty, 1996; Yin, 2017). The study is based on qualitative surveys carried

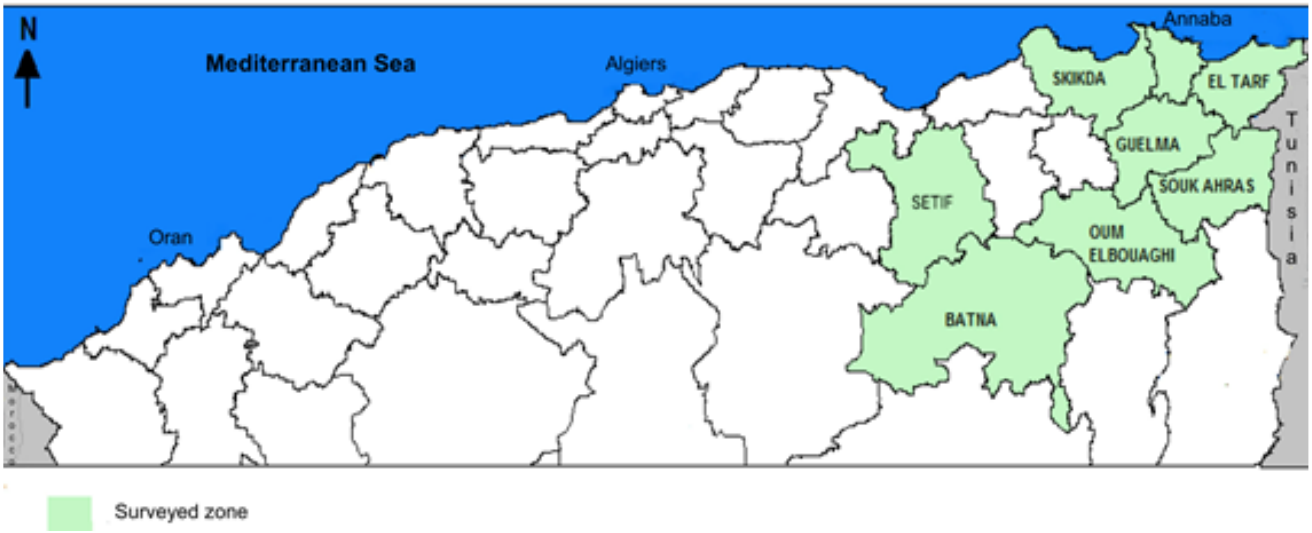

Figure 2. Location of the studied territories

out in 2017 among stakeholders in the agri-food and livestock industry. Data were collected from 27 stakeholders through semi-directive interviews in seven case organizations (Table 2).

Table 2. Overview of our data sources

Function in the sector	Stakeholders	Number of surveys
Economic operators	Tomato canneries	5
	Livestock feed manufacturers	6
	Agricultural cooperatives	3
Technical support	Technical institutes	3
	Chambers of Agriculture	2
	Public research institutions	3
Public regulation	Public agricultural administrations	5

The interviews began with an explanation of the purpose of the survey, and then their socio-economic characteristics as respondents were asked. Next, we asked the interviewees to describe their role in the sector. They were then asked to identify operations related to the use of tomato by-products in their intern organization and to describe the processes for developing, selling, selecting and implementing these products. Particular emphasis was placed on identifying and describing the specific levers and obstacles that have had an impact on their current strategies and their relationship to the possible valorization of these by-products in animal feed. The duration of the interview varied between 30 min to 60 min. This survey was complemented by case studies to further explore aspects related to the action strategy of the actors in the sector (Ritchie and Spencer, 2002; Baxter and Jack, 2008; Yin, 2017). It is based on a case study approach based on the collection and analysis of qualitative data from stakeholders in the sector to identify their strategies for the use of tomato by-products.

To carry out the analysis, we used the sector approach (Labonne, 1985; Terpend, 1997) for the organizational and regulatory aspects and the case study (Larsson, 1993; Chetty, 1996; Gomm *et al.* 2000) to further develop the technical, economic and strategic aspects of the actors in the sector in question. However, it should be noted that there are difficulties in accessing information and data on this emerging sector. The concentration of the activity is such that the information is so strategic and sensitive that it forces us to respect certain things in the analysis below where the names of the actors are not always reported.

RESULTS AND DISCUSSION

CURRENT STRATEGIES FOR THE VALORIZATION OF TOMATO BY-PRODUCT AND THEIR BRAKES

Self-valorization as an innovative additive in the food industry

This process has been highlighted by a large agro-industrial company because it allows it to self-valorize tomato pulp to produce an industrial ingredient for its production line for innovative products such as sweet harissa or sweet red pepper. This strategy of valorizing tomato pulp is innovative and generates a significant income for this company linked to its innovative products. The interest of incorporating tomato by-products as a food additive is linked to its richness in Lycopene (antioxidant) and vitamins B1, B2 and A (Suogi et al, 2003; Nollet and Toldrá, 2012). They can be an important source of dietary fiber (Alvarado et al, 2001).

To succeed in this operation of valorizing tomato pulp, the company has not set up any specific investment, because it uses the dryer of its apricot processing workshop. Drying is done directly after pressing the tomatoes during processing. The crushing is then carried out in the same

workshop using the existing crusher. Finally, it is stored in moisture-proof bags. In this case, recovery gives this industrial waste added value, because the cost of recovery is considered particularly low (only the cost of drying and packaging) if compared with the cost of managing this co-product as waste. Indeed, without this, the company must dispose of its waste daily to the public landfill. During the tomato production season, this company manages the equivalent of 82 tons per day of tomato waste, which requires time, equipment, personnel, and money. Besides, there is the management of other waste from fruit processing such as apricots. This is why this large company has opted for a self-valorization of tomato pulp even if the latter remains partial because the food additive market is highly difficult to penetrate by this company, which is content to use it on its products. It is also studying the economic feasibility of creating a livestock feed manufacturing unit incorporating its co-products (tomato pulp, apricot kernels). The seasonal nature of apricot and tomato production hinders the recovery of their by-products. The development of off-season production of industrial tomatoes in the south of the country, as well as the time lag between the harvesting and processing periods of tomatoes and apricots, now allow tomato canneries to reduce the seasonality and unavailability of these by-products. This is one of the main levers that could motivate this company to invest in their self-valuation, particularly in livestock feed. The presence of several by-products in the same company can pool investment costs, particularly in livestock feed.

A guarantee of farmer loyalty

The multiplication of the number of tomato canneries in the largest production basin in eastern Algeria and the resulting competition has led some companies to adopt an offensive strategy to capture a large part of the market. Such a strategy is considered effective in the context of the highly dispersed upstream market and its downstream concentration (Deshpande, 2005; Batte and Ernst, 2007; Tinguery, 2014).

Some tomato canneries offer free of charge the tomato pulp generated by their activities to farmers who supply tomatoes. This practice allows them to retain their suppliers insofar as they cannot influence the purchase prices of tomatoes, which are set by the State. These two companies stand out from the others by offering a product that can be used in livestock feed to their suppliers/breeders. The cost of this operation is zero as long as the farmers come to collect these tomato pulps themselves to feed their dairy cows. The income from this valuation is not quantifiable but palpable by guaranteeing a certain share of the industrial tomato market. This strategy also allows these two companies to reduce the costs of managing their tomato waste. However, the scope of this strategy is limited to local farmers who can collect tomato by-products directly from the processing company. Otherwise, the cost of transport becomes a limit and adds to the lack of information and communication on the availability of by-products and the possibility of their recovery by farmers. Moreover, farmers who do not supply tomatoes to these companies are excluded from this almost free-trade relationship, as the quantities recovered through this strategy remain marginal and do not make it possible to exploit the potential that can have on the recovery of tomato by-products in the country.

A sale in their initial condition

The valuation of fresh tomato pulp by livestock is the most economical way because it does not require any conservation or processing costs before its use. It also has the advantage of maintaining the nutritional properties of the pulp intact before undergoing various biochemical phenomena that reduce its quality (Gasa et al, 1989; Hadjipanayiotou, 1996; Jamal and Abdallah, 2018). The sale of fresh tomato pulp by a number of tomato canneries at a rate of 3,500 DA per ton (26.2 €/t) from July onwards is profitable for one of the companies, which produces an average of 117 tons (or 3,064 €/year) annually, since it does not carry out any specific treatment or investments to sell this by-product. On the contrary, by doing so, the cannery saves the costs of managing its waste and disposing of it in the landfill. The same company was previously convicted for the mismanagement of its tomato pulp following a complaint from an environmental protection association. One of the oldest tomato canneries is adopting this strategy to save on the management of its tomato waste, mainly transportation costs, by disposing of it directly in the wild near its site.

This strategy of recovering tomato pulp for direct sale to farmers appears to be an alternative solution to reduce waste management costs. Although it deals with farmers, this company does not envisage any investment to integrate livestock feed manufacturing into its workshops, even though it produces other by-products in addition to tomatoes (citrus pulp, apricot stones). Its small size and financial situation prevent it from considering such an investment. Once again, this strategy is restrictive on two points: the first is the lack of investment for the possible conservation and/or processing of these pulps in order to increase the life span of this by-product (Hadjipanayiotou, 1996; Jafari et al, 2006; Chawla et al, 2008); the second is directly related to the first concerning the limited geographical scope of the sale of this by-product, which represents a handicap in this strategy. If canneries are considering investing in the conservation/processing of tomato pulp as an animal feed, they can expand the scope of sales and thus increase the valued qualities.

Incorporation into the livestock feed industry that is struggling to get off the ground

Despite the import dependency and competition that characterizes the livestock feed industry in Algeria, the demand for tomato by-products by industrialists remains

non-existent. This could be explained by a lack of knowledge of the usefulness of this potential raw material or by the failure to develop industrial formulas based on tomato pulp capable of conquering the livestock feed market. Some subsidiaries of the Eastern ONAB in collaboration with universities in the region have taken the initiative to test the incorporation of tomato co-products into livestock feed formulas, but this project has remained in its embryonic stage.

In reality, the rationality of the choice of raw materials by feed manufacturers is based on several criteria: an interest price and sufficient and regular availability in sufficient and regular quantities, a minimum quality that meets farmers' expectations (Peeters and Surry, 1997; Kaushik, 2000). The nutritional profile of tomato pulp does not give it a competitive advantage over traditional raw materials, particularly soybean meal. The nutritional value of tomato pulp varies according to the treatment used by the manufacturer. They only have 22% MAT (Total Nitrogenous Material) in their fresh state, while the same index rises to 18.7% for its silage form. If we assume a MAT value of 43% for soybean meal purchased by industrialists at 53,760 DA/t (402.39 €/t), we can calculate the interest price (without considering comparative protein profiles) of fresh tomato pulp at 27,500 DA/t (205.83 €/t) and 23,380 DA/t (175 €/t) for its silage form. These prices remain well above market prices (3,500 DA/t or 26.2 €/t). To this must be added the costs of drying or dehydration before it is incorporated into compound feeding stuff by livestock feed manufacturers. In any case, the market price is competitive with that of soybean meal to consider the valuation of tomato pulp on a large scale. At this stage, it seems that technical investment in the conservation of tomato pulp (a key operation for manufacturers) is an obstacle both to ensure its timely recovery and to ensure its recovery throughout the year.

If feed manufacturers manage to acquire the technology necessary to preserve this by-product, a total substitution of soybean meal will require the equivalent of 2.4 million tons/year of tomato pulp, which is not technically feasible in the field. As it is acidic in nature, incorporation rates of 10% (low rate) and 40% (high rate) should be considered as a maximum to respect the good nutritional conditions of the animals. In the low incorporation scenario, the feed chain will require the equivalent of 60,000 t/year of tomato pulp and 240,000 t/year for the high incorporation rate. With an available quantity of 87,000 t/year of tomato pulp, the feed industry will be able to save the equivalent of DA 2.34 billion (€16.83 million) annually in imported soybean meal. Unfortunately, this argument is not put forward to motivate the actors in the sector to develop the deposit available at the national level.

Coordination between the actors at the heart of the structuring process of the sector

Coordination helps to improve the performance of sectors, manage production and market risks, rebalance trading powers and reduce transaction costs. It is necessary to ensure the proper functioning of the tomato pulp recovery sub-sector and to ensure its success. On the other hand, institutional and organizational constraints make it difficult for stakeholders to be involved and hinder the visibility of the rules of the multiple constraints of coordination of sectors. As we have shown above, coordination between the actors in the livestock feed sector and what releases tomato pulp remains weak and does not help to promote this by-product in animal feed.

Improve the visibility of tomato pulp supply and demand

The two ways of promoting tomato pulp in animal feed are structured in spot markets or relational contracts. The exchange flows in question do not involve any processing or even logistics intermediaries. Tomato pulp is valued directly by farmers, which should normally increase the efficiency of this short circuit as is the case in some non-conventional feed supply chains (NRC, 1983; Devendra and Thomas, 2002; Negesse et al, 2009). However, these recovery methods are not always compatible with the structure of the livestock feed market, which is often concentrated upstream and fragmented downstream. The two routes used so far limit the scope of this market, as only farmers located in the industrial tomato processing basin can access the supply of tomato pulp and in a limited time during the high season in the absence of treatment for storage and conservation. There is also a gap between supply and demand, as large livestock production areas are not necessarily located near the industrial tomato production and processing area. The intervention of intermediaries and the visibility of supply and demand then become necessary to give economic operators in the livestock feed sector the opportunity to optimize their trade relations and make the most of the available tomato pulp pool. The same constant is done by (Fontenot and NRC, 1995; Egilmez et al, 2014) for the waste recycling sector.

Currently, feed manufacturers do not have information on the quantity available or the period of availability. However, the industrial waste exchange set up by the National Waste Agency (ADN) since 2017 can play a central role in coordinating the supply and demand for tomato pulp. This information system can actively contribute to the launch of the large-scale valorization of tomato pulp in animal feed. This is a platform where generators or waste holders can put offers (free, almost free or for a fee) to potential waste reclaimers. This platform can mark a major evolution in the functioning of this innovative sector, especially in its networking dimension for stakeholders and transparency in terms of prices and quantities of by-products available on the market. The various actors in the by-product recovery chain can find refuge there to interconnect information and compare supply with demand. The success of this exchange depends on the willingness of these actors to link the links in such a way as to form an innovative and above all structured sector. The DNA

accompanies any project that revolves around the recovery and recycling of industrial waste. This is, therefore, an opportunity for livestock feed manufacturers to seize this opportunity to integrate the value of tomato by-products into their workshops, especially with a market price that is widely accessible compared to the interest price that could be envisaged in the case of substitution for soy meal.

Contract to strengthen the effectiveness of public action in the sector

The State allocates subsidies for economic operators in the industrial tomato sector (2 DA/kg for producers and 1.5 DA/kg for processors, i.e. successively 0.015 and 0.011€/kg), but it does not intervene to solve the problems of harmonization of regulations and individual actions taken by these economic operators. As a result, there is almost no coordination between the actors in the tomato sector and therefore the actors in the sub-sector for the valorization of tomato pulp.

The establishment of written contracts, by the State, between industrial tomato producers and canneries is intended to maintain traceability of the public subsidy, but control remains insufficient. Due to a lack of technical and human resources, public services are unable to monitor the quantities produced declared for the subsidy, which reduces the effectiveness of the funds allocated to this action. To this end, the industrial tomato sector does not benefit fully from the public funds dedicated to its development. However, the recovery of tomato pulp from processing can increase the shelf life of these products and thus the scope of public subsidies, which are becoming more efficient. The State may introduce across compliance clauses on the producer-processor contract to promote the recovery of tomato pulp, which will result in the extension of public action towards recovery.

The preferred method of coordination at present is the spot market for direct sales to farmers without going through intermediaries or the relationship contract which is in addition to the farmer-supplier supply contract in the case of the unfunded offer made by certain tomato canneries. One of the other (absence of a written contract) is to be explained by the absence of a regulatory mechanism allowing the marketing of this by-product. This also explains the lack of investment intention in the valorization of tomato pulp by canneries but also by livestock feed manufacturers. This situation is not very favorable for the granting of investment credits that industrialists may request from banks to finance the development of activities relating to the valorization of tomato pulp in animal feed. In the same way, several studies have shown the importance of contracting in the supply chains of new agricultural raw materials (Andræ and Beckman, 1987; Rao et al, 2007; Chengappa, 2013; Febrianda and Tokuda, 2017; Luo et al, 2017)

Involve cooperatives as coordination intermediaries between the upstream and downstream end of the supply chain

Agricultural cooperatives are levers for the development of upstream agricultural activities. Their purpose is to enhance the value of the cooperators' activities as much as possible, through the pooling of certain investments, but also the consumption of inputs (cheaper group buying), the collection, processing, and marketing of their products. Indeed, as reported by several authors, cooperatives can play a central role in waste recycling and recovery activities (Grann,1997; Lino and Ismail, 2012; Dos Santos Ferreira et al, 2018) but also in the adoption of new raw materials in animal feed (Gopal, 1992, Hall, 2016; Govaerts, 2018). Cooperatives play a decisive role in livestock production activities where they are responsible for providing livestock feed, the main raw material for livestock production. Some cooperatives themselves have a livestock feed manufacturing unit, such as the COOPSSEL cooperative, which, in addition to the traditional raw materials used in animal feed: soya, corn, grain barley, uses several agro-industrial by-products (straw treated with urea, wheat bran) to solve the problem of ex-factory prices and accessibility for its members.

COOPSSEL puts into perspective the incorporation of tomato pulp into the food it produces, but before that, it must make the necessary investments to achieve this, particularly for conservation and storage. This unique case can set an example but cannot drain all the available deposits. The majority of livestock production cooperatives, particularly dairy production cooperatives, subcontract the supply of livestock feed to private or public manufacturing units while retaining bargaining power over prices and consequently over the quality of the products supplied to their members. Cooperatives can, therefore, use this power to require the incorporation of cheaper local raw materials such as tomato pulp. Unfortunately, their suppliers do not have the industrial infrastructure specific to this operation, which hinders this perspective unless the cooperatives take over the logistics (transport, conservation, storage) and the incorporation of tomato pulp. This is the most likely scenario for the development of this feed sub-sector.

Mobilize extension and agricultural advisory services in the livestock sector

This lever is directly or indirectly linked to the previous one. The extension service can be provided by farmers' cooperatives to enable them to acquire the knowledge and skills necessary to use the new methods on their farms (Vanclay and Lawrence, 1994; King and Rollins, 1999; Kroma, 2006; Rivera and Sulaiman, 2009; Chowa et al, 2013; Yang et al, 2014). The extension provided by the various professional agricultural organizations can play a catalytic role in the process of adopting and disseminating innovative practices in agriculture such as the use of

tomato pulp in animal feed (Black, 2000; Anandajayasekeram et al, 2007; Reed, 2007; Agwu et al, 2008; Rivera and Sulaiman, 2009; Taylor and Bhasme, 2018).). In our case, the ITELV (Technical Institute of Livestock) and the Chamber of Agriculture have an essential role in agricultural extension and advice. Research on the technical and economic feasibility of valorizing tomato pulp in animal feed has been carried out by ITELV. The objective was to provide farmers with the necessary information on the nutritional and economic usefulness of using tomato pulp in animal feed. These services are unable to disseminate this innovative technique more widely due to the lack of field monitoring and the centralization of their antennas. In our eastern area, where the largest industrial tomato processing and animal production basins are located, there are only two ITELV branches, which allows it to reach only a tiny fraction of farmers and slows down the process of adopting tomato pulp as an input to animal feed. Thus, neither the Chambers of Agriculture nor the cooperatives currently have technicians specialized in animal feed to promote new feeding techniques to farmers. On the other hand, private veterinary practices, which often have closer relationships with livestock farms, can play a catalytic role in facilitating the introduction and spread of the use of agro-industrial by-products in animal feed. These private structures can also provide field monitoring of the zootechnical performance and health risks that may arise from the adoption of these new animal feed sources.

CONCLUSION

Faced with the challenge of food security in developing countries, the valorization of agricultural by-products in animal feed is an effective strategy if several conditions are met by the various actors in the agro-industrial sectors. Beyond the technical knowledge on the nutritional values of this by-product and its potential use in animal feed, this article shows that the coordination of the actors in the sector remains the key to creating incentives for the adoption and dissemination of this new animal feed technique. This study contributes to enriching the recent scientific literature on obstacles and levers to the development of innovative practices with low environmental impact (Hueske et al, 2015; Pinget et al, 2015; Suprun and Stewart, 2015; Granoff et al, 2016; Coreynen et al, 2018; Karlsson-Vinkhuyzen et al, 2018) particularly in agriculture (Pissonnier et al, 2016; Smith, 2016; Tran and Weger, 2018; Caffaro and Cavallo, 2019; Magrini et al, 2019).

First of all, we have shown that the livestock feed market, given its chronic dependence on imported raw materials and its functioning, opens up the field and creates real opportunities to develop the tomato pulp produced by canneries. Despite the interests that this presents for operators in the livestock feed industry in Algeria, the lack of technical knowledge and technological investment necessary for the valorization of this by-product remains an obstacle to the development of a structured sector. The main strategies currently implemented by food manufacturers for the recovery of tomato pulp remain sporadic and do not offer the possibility of expanding the market for the recovery of tomato pulp. Coordination helps to improve the performance of sectors, manage production and market risks, rebalance trading powers and reduce transaction costs. It is necessary to ensure the proper functioning of the tomato pulp recovery sub-sector and to ensure its success. Thus, the involvement of physical and monetary exchange intermediaries can improve the visibility of the supply and demand for tomato pulp and is one of the pillars of an overall strategy to structure this sector. The contract is another way for economic operators to manage their risk and create the investment incentives necessary to maintain their exchange relationships. In this sense, the involvement of cooperatives as a channel for exchange in this innovative sector can contribute to the pooling of investments and the equitable distribution of added value in the sector. All these actions will not succeed in the absence of the technical and institutional support necessary for the dissemination and diffusion of this innovation in the agro-industrial sector and especially in the livestock sector.

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