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Drivers and Barriers for the Valorization of the Apricot Pit

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ABSTRACT

By mobilizing the socio-technical approach to innovation and semi-directive survey of 31 stakeholders, this paper analyzes the value chains that ensure the valorization of apricot pit by-products and the dynamics of their actors. Beyond the technical knowledge on the recovery of apricot by-products and their potential uses, this paper shows a multitude of strategies but also challenges that are barriers to this innovative sector development. It also highlights some of the drivers that these value chains can rely on for their further development. The results of this work show real economic opportunities that are available to operators in these sectors depending on the nature of the by-product but also the market targeted by them. It also shows that the diffusion of these innovations must be better coordinated on the market. To do so, the socio-economic and environmental interests related to the valorization of apricot pit by-products must be highlighted.

KEYWORDS
Apricot by-products; valorization strategies; innovation; barriers; drivers

Introduction

In response to the global food crisis and to strengthen its food security, Algeria, since 2008, has launched an Agricultural and Rural Renewal Program aimed for increasing production and improving farming and livestock techniques. Apricot production benefited greatly from this dynamic (Figure 1) and currently supplies the processing industry with juices, jams and confectionery weighing nearly 300,000 tons per year (Figure 2). Algeria ranks fourth among apricot-producing countries in the world (after Turkey, Uzbekistan and Italy) with an area covering more than 47,000 hectares.[1] Despite its important positioning in the fruit market at the national level, the Algerian apricot sector is not sure to make a place on the international market. The little export there is focuses mainly on processed apricot products. Apricot processing activity generates about 60,000 tons of waste (mainly pits), which are starting to create a serious environmental problem. Unlike large apricot producers who have developed the recycling of its waste as in Turkey (Önal, 2006; Özcan et al., 2011) or in Uzbekistan (Allobergenova, 2006), in the Algerian case, the regular final destination for this residue in the public waste dumps without any treatment to reduce their impact on the environment. However, some technical landfill sites cover them with the ground (Mezouari-Sandjakdine, 2011). In this case, organic matter degrades through fermentation over time that varies according to the conditions (temperature, humidity, soil type, etc.). The generated organic matter can be leached and can be a source of contamination for rivers and even groundwater. Other wastes are eliminated by incineration, which releases greenhouse gases on a global scale and locally causes many atmospheric discomforts (Benkahoul et al., 2017; Sahraoui et al., 2017). Restrictive environmental rules have been implemented to regulate manufacturers in the apricot processing (taxes, fines, controls) and may hinder the sector's development (Bouabdesselam et al., 2005).

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[1]Data from the Ministry of Agriculture and Rural Development http://madrp.gov.dz/

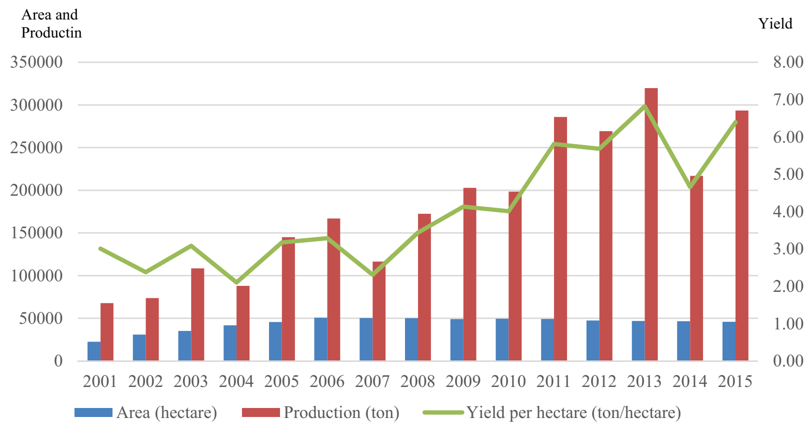

Figure 1. Evolution of annual apricot area, production and yield in Algeria.

Several studies around the world have shown that it is possible to avoid all the disadvantages resulting from the apricot-processing industry thanks to the recovery of its by-products (Das and Singh, 2004; Fitzgerald et al., 2017; Galanakis, 2012, 2015; Gowe, 2015; Gupta et al., 2015; Oliveira and Franca, 2008; Pascual et al., 2018; Sadh et al., 2018). Their collection is also a source of high-value creation (Galanakis, 2012; Gowe, 2015; Laufenberg et al., 2003). In addition, the separation of the by-production's various constituents makes their treatment easier and reduces the impact on the environment (Gerschenson et al., 2015). It is in this context stockholders, supported by the public authorities, are beginning to explore new ways of exploiting apricot pit by-products.

Our goal is to go beyond the already existing technical knowledge related to the recovery of apricot by-products and their potential uses resulting in the creation of a higher added value (Karlsson-Vinkhuyzen et al., 2018; Levering and Vos, 2019; Martini and Pellegrini, 2005; Meijer et al., 2019; Rijkens-Klomp, 2012; Tura et al., 2019). To do so, this article uses qualitative surveys of stakeholders in the agri-food sector. The objective is to provide an analysis of the drivers and barriers involved when creating incentives for the adoption and the dissemination of various valorization technologies concerning apricot pit by-products.

Contrasting with several other studies in the field that focus on the technical aspects of the apricot pits use (Alpaslan and Hayta, 2006; Fadhil, 2017; Femenia et al., 1995; Gooch, 2011; Hassan-Beygi et al., 2009; Kamel and Kakuda, 1992; Khodadadi et al., 2017; Korekar et al., 2011; Mennani et al., 2017; Özkal et al., 2005; Satayev et al., 2015; Seker et al., 2010; Wang et al., 2011), we analyze: (i) the main obstacles to the apricot by-products recycling at the processors and farmers' level; (ii) the levers of action that can be mobilized to encourage these actors to adopt innovative practices associated with their production system.

The barriers and levers are analyzed with regard to the different potential uses of apricot by-products and their interrelation. It should be noted that this work is based on technical work on the utility of apricot almond cake-meal in animal feed. However, initial observations in the field soon led us to take an interest in all apricot by-products, given their common origin and the complexity of the relationships between their processing and uses. That is why this paper provides an original analysis of the multiplicity processing and recycling routes for apricot waste. Our work tries to answer a central question: when it comes to the valorization of the apricot pit by-products, what are the drivers and barriers usually involved in the development of innovative sectors? This paper analyzes the current strategies found in Algeria and proposes improvements to encourage the emergence of these innovative value chains. We propose to articulate and structure the different apricot by-products value chains. Our paper is organized into three sections. The first section presents the theoretical approach

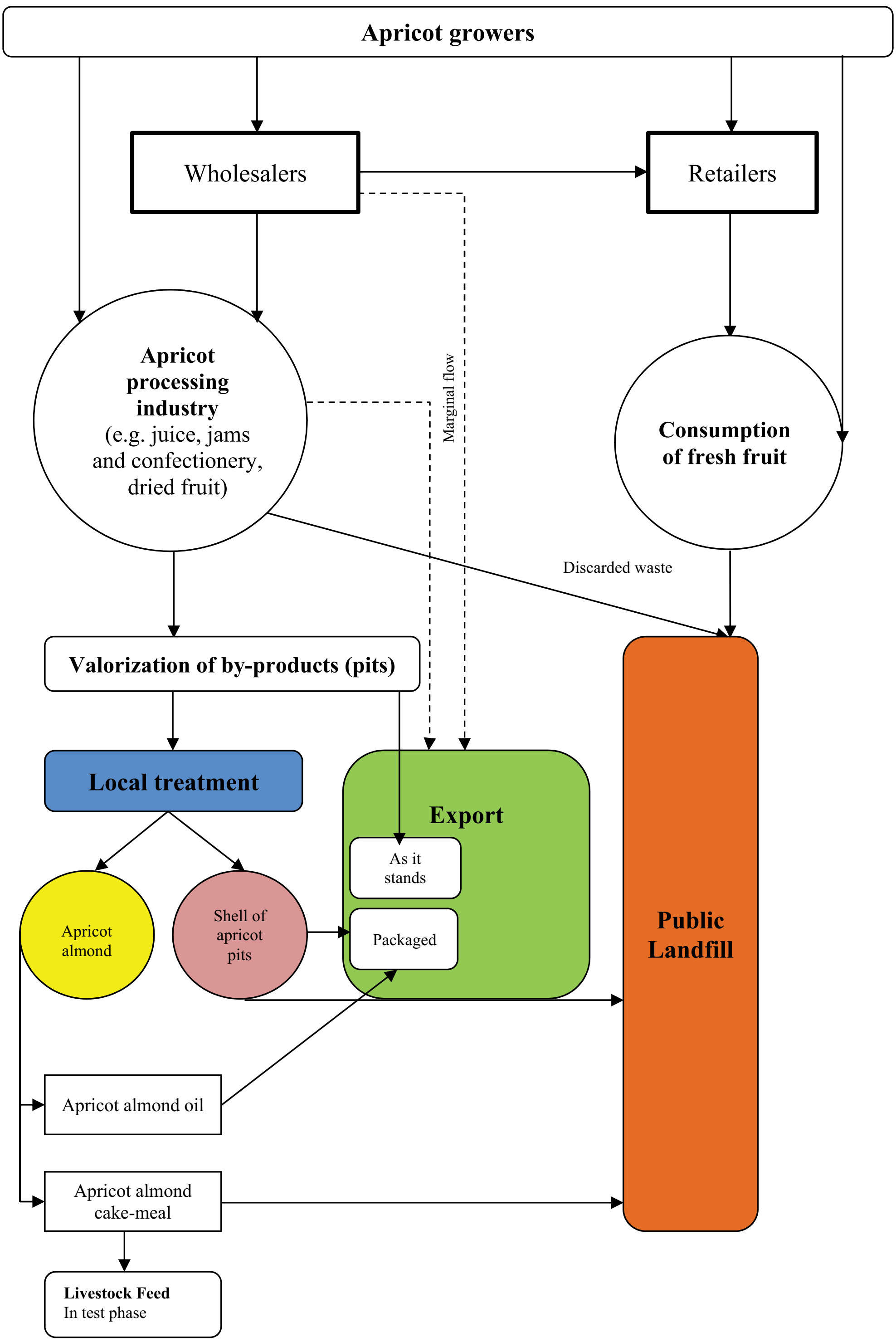

Figure 2. Functional organization of the apricot sector in Algeria.

of socio-technical system. The second develops the methodology of the study. The third section details different industrial interests of the valorization of the by-products of the apricot pits and various obstacles that this innovative approach faces. In this section, we propose the drivers on which the sector can rely to remove the constraints to its development.

Socio-technical System Approach Completed by an Evolutionary Paradigm

An analysis using the socio-technical approach focuses on the development process and appropriation by stakeholders of technological innovation. Several research currents of the socio-technical approach, such as the ethno-technological approach, the Actor Network Theory (ANT), Giddens' structuring theory, the socio-technical double mediation (Coutant, 2015), etc., rely on the same epistemological position. We are now going to go over the main common drivers of these schools of thought or sociological theories.

The socio-technical system approach studies the modes of coordination, the rules of operation, regulation and negotiation between the actors organized around this new technology (Flichy, 1995). Since it assumes that economic stakeholders are guided by a socio-technical system, its aim is to analyze the network that brings them together following an upstream to downstream flow, a "market chain". The goal is to understand the place and the role of each actor as he exercises his activity freely but also his interactions and his relationships of dependence on the functioning of this network (Belmin, 2016). A socio-technical system is based on networks of agents interacting in a specific technological field under a specific institutional framework to generate, disseminate and use a specific technology. Also, socio-technical systems are defined by their flows of knowledge or skills in addition to the ordinary goods and services one (Carlsson and Stankiewicz, 1991; Geels, 2004).

Additionally, the socio-technical approach makes it possible to analyze the transformations of practices where technological innovation gives rise to new production systems and new modes of economic management capable of ensuring the functioning of the new subsectors created around it (Chia and Deffontaines, 1999). In this case, the technical and organizational changes and the necessary adaptations on the part of the various economic operators involved, systematically imply the development of new socio-technical systems that partially or completely replace the ordinary technical operating models. The approach of the socio-technical system seeks to find a way to make the organization of the economic agents around new efficient technology and this requires considering the interdependent organizational and technical aspects. Due to the changes brought by the introduction of innovation, optimal arrangements that already exist for an existing technology may not always be optimal for the new one. Compromises must be found in the organizational design of a new socio-technical system so that can be effective (Fox, 1995). Changes in one element of the system trigger changes in other elements which, in turn, lead to other changes. This is called the cascade dynamic in the socio-technical system. These reconfiguration processes apply to all elements of the socio-technical regime (markets, users and practices, technologies, production networks, policies, etc.) (Geels, 2002).

Here, we can also talk about the notion of locking, which describes the difficulty of moving from one technical model to another because of the self-reinforcement mechanisms around the dominant ordinary technology. These mechanisms are based on interdependencies between economic operators in ordinary sectors and complementarity between technologies as well as the alignment of rules leading to the maintenance and strengthening of ordinary socio-technical systems to the detriment of new technologies (Geels, 2004). The difficulty of technological innovation is that it must be embedded in a favorable business model to economic operators in such a way as to ensure certain socio-economic viability that allows it to replace the usual business model imposed by ordinary technologies (Akrich, 1991). A socio-technical system is to decipher the new potentialities which emerge and develop them thanks to certain driving forces that accompany the emergence of new technology. It is also about identifying how the creation of products and values through innovation makes it possible to bring together a set of technological elements that are complementary to the emergence of a new socio-technical system organized around new ways of doing things and making it possible to satisfy a certain number of demands or needs.

Our research program began with the study of the results of a zootechnics laboratory which evaluated the efficiency of a food ration based on apricot almond cake-meal compared to the classic reference ration made entirely from imported soybeans. This scientific question, the aim of the study, qualified as the technological paradigm in the approach of evolutionary economics (Dosi, 1988), led to promising experimental results: following under the experimental conditions, the growth of rabbits was significantly higher and the cost significantly lower. This new technological trajectory invited the social scientists to ask what conditions were needed for implementing a new value chain for these new coproduced goods derived from initial by-products.

This is the study of a particular innovation and the implemented survey methods are similar for the two theoretical approaches. The methods consist of the analysis of the technical operations to be implemented, the possible observation of competing industries, the strategies of actors and the prospects for demand, professional users or final consumers. Keeping this in mind, we are mobilizing this approach to analyze the drivers and barriers brought by the innovative process of valorizing Algerian apricot by-products coming from the processing industry.

Materials and Methods

The aim is to apply the existing socio-technical approach to the drivers and barriers to the value-creation of apricot by-products by using case studies shedding light on with the existing documentary literature (Chetty, 1996; Yin, 2017). Here, the purpose of this first analysis is to identify the industrial interests related to the use of apricot pit by-products as innovations, then in a second step, we use the socio-technical approach to identify the constraints and development drivers of these innovations related to the value-creation of apricot pit by-products. This part is based on qualitative surveys carried out in 2017 among stakeholders in the agri-food industry. Data were collected from 31 stakeholders through semi-directive interviews in seven case organizations (Table 1).

The interviews began with (i) an explanation of the purpose of the survey, and (ii) we asked their socio-economic characteristics as respondents and (iii) the interviewees to describe their role in the sector. They were then solicited (iv) to identify operations related to the use of apricot by-products in their own organization and (v) to describe the processes for developing, selling, selecting and implementing these products. Particular emphasis was placed on (vi) identifying and describing the specific drivers and barriers that have had an impact on their current strategies and their relationship to the possible valorization. The length of time of the interviews varied between 30 to 60 minutes. This survey was completed by case studies based on the collection and analysis of qualitative data from stakeholders to further explore aspects related to their action strategy (Baxter and Jack, 2008; Ritchie and Spencer, 2002; Yin, 2017).

However, it should be noted that it is difficult to access information and data on this emerging sector. The concentration of the activity is such that it makes the information is extremely strategic and sensitive. This required us to respect certain privacy rules during our analysis: below some names of the operators are not always indicated (see Table 1). The different stages of this study are described in Figure 3.

Results and Discussion

Industrial Interests of the Valorization of Apricot Processing By-products

Zootechnical Interest

For its high protein content (Wang et al., 2010), several research studies have demonstrated the technical utility of using apricot almond cake-meal in the livestock feed industry through partial and sometimes complete substitution of soybean cake-meal. In monogastric animals, the incorporation of

Table 1. Overview of our data sources.

Function in the sector	Stakeholders		Number of Staff	Number of membership	Tunover (€1000)	Processing capacity (ton/year)	Role in the use of apricot pits
Economic operators*	Apricot processors	Cannery 1	2000	/	200,000	5500	Producer of apricot pits
		Cannery 2	70		7000	2500	
		Cannery 3	130		2000	16,500	
		Cannery 4	4000		150,000	27,000	
		Cannery 5	150		5000	1000	
	Apricot pits processors	Processor 1	26	/	300	2000	Extraction of apricot almond oil
		Processor 2	3		50	50	
		Processor 3	5		150	500	Collection and packaging of apricot pits
		Processor 4	2		27	30	
	Livestock feed manufacturers (LFM)	LFM 1	109	/	21,525	34,320	Manufacturer of animal feed containing apricot almond cake-meal
		LFM 2	270		1700	3900	
		LFM 3	8		300,000	14,975	
		LFM 4	67		6658	31,200	
		LFM 5	5		100	5000	
		LFM 6	59		470	7800	
	Agricultural cooperatives	CAS Souk-Ahras	40	1500	54	/	Feed dispenser containing apricot almond cake-meal
		CAPS Sedrata	32	714	7320		
		COOPSEL	99	1330	1050		
Scientific and technical support	Technical institutes	ITELV Annaba ITELV Alger	/	/	/	/	Experimentation, training and technical extension on the use of apricot almond cake-meal in animal feed.
		ITMA Gulema					Experimentation, training and technical extension on apricot production and valorization
	Chambers of Agriculture	Souk Ahras Oum Boughi	/	/	/	/	Technical extension on apricot production and valorization
	Public research institutes	Univ. El Tarf ENSA-Alger INRAA	/	/	/	/	Experimentation, training and scientific research on apricot production and valorization
Public regulation	Public agricultural administrations	Direction du Commerce	/	/	/	/	Inspection and quality control of processed products
		Inspection Vétérinaire					Inspection and quality control of feed and animal products
		Direction de Environmental protection, waste management and recovery					l'environnement
		Ministère d'Agriculture					Accompaniment and support for apricot production and its valorization
ENVREDET	Accompaniment and support for innovative enterprises						

*: the names of the economic actors are not indicated because their information is too strategic and sensitive (confidential).

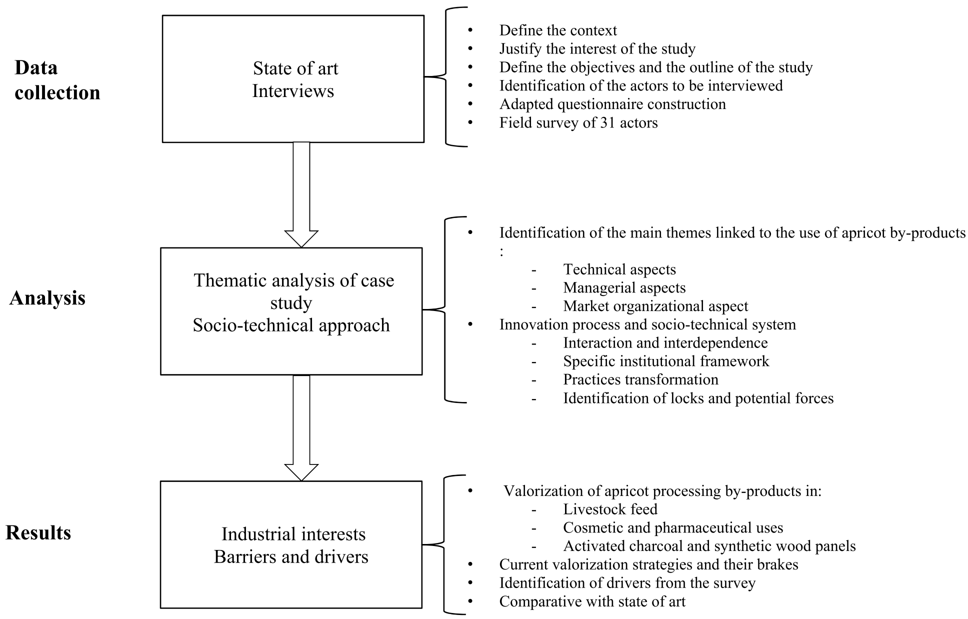

Figure 3. Our study stages to identify drivers and barriers to valorize apricot pit by-products.

detoxified apricot almond cake-meal (Arbouche et al., 2007) can be considered up to 60% as a substitute for soybean cake-meal (Arbouche et al., 2007, 2012, 2014; Mennani et al., 2017) and 100% for small ruminants, particularly sheep, which are the dominant livestock in semi-arid areas. These regions correspond to the main party of the Algerian agrosystem.

It is these results that are at the origin of our study. The interest of this substitution depends of course on the "zootechnical" performance defined by the growth rate of the animal, the transformation rate, the share of detoxified apricot almond cake-meal in the ration, but also on the functioning of the animal feed chain and the alternative uses of these by-products which define the different price levels. The price of imported soybean cake depends on the world market and Algerian import policy. The price of detoxified apricot almond cake-meal may be limited to the cost of processing if the destination of the pit is a landfill, but may be higher if a market is created. The collection carried out by the canning industry creates an essential externality for the recovery of these pits, while the collection of pits from the domestic market is clearly irrelevant in today's economic context. Thus, Mennani et al. (2017) demonstrated the economic interest of substitution based on their experimental results and observed real prices: "taking account of the four formulae used in our study . . . the opportunity cost of incorporating the by-products is quite high, at – 9% on the price of a quintal of feed produced for an incorporation rate of 30%".

To this end, the apricot processing industry can provide an important source of raw material for livestock feed. Algeria produces annually the equivalent of 73,700 tons of apricot pits containing 26,532 tons of total nitrogenous matters (188 g DIP/kg DM[2]). This potential is highlighted to address the Algerian protein forage deficit, amplified by the extensive nature of the fodder production constituting the basic ration. This explains the country's recourse to the import of raw materials for livestock feed. This dependence imposes a choice of suppliers that respects quality, price, delivery time, taking into account international trends of prices and the state of the market in response to growing food security needs (Senoussi and Behir, 2010). The supplementary rations for ruminants and the single rations for monogastric animals are directly

[2]DIP: Digestible Intestinal Proteins is the unit of measurement of the nutritional value of protein present in Dry Matter intended for animal feed (DM).

linked to the only protein source used in Algeria, soybean cake-meal. Entirely imported, it hinders the development of all kinds of animal production and limits the availability of animal protein to a fringe of the low-income population.

Cosmetics and Pharmaceuticals

The cake-meal is obtained after extraction of the oil from the apricot almond. The extracted oil represents 25 to 40% of the weight of the crude almond, which is equivalent to 26,532 tons of so-called neutral oil capable of being input in cosmetics as a diluent for essential oils. It is also used in massage products because it is scentless. It is also an excellent substitute for sweet almond oil because of its lipid composition close to sweet almond oil's (Femenia et al., 1995; Ferradji et al., 2001; Helmy, 1990; Johansson et al., 1997; Özcan et al., 2011). Its volatile essences such as benzaldehyde and hydrocyanic acid are employed in medicine and perfumery (Cassiem, 2015), hence its interest.

Bitter almonds are also used for the production of flavors (Yada et al., 2011). Their consumption with measured amounts reduces the risk of cardiovascular disease (Moayedi et al., 2011).

The shell resulting from the breaking of the pit is made of raw cellulose and lignin. It is used as a natural support for face masks. It is also incorporated for the manufacture of textile fibers. It is part of the traditional cosmetic recipes of the region, so these pharmaceutical virtues have been known since antiquity (Bouquet, 1930).

Other Interests: Activated Charcoal and Synthetic Wood Panels

Apricot pit shell, made of lignocellulosic fiber, is highly valued as a raw material in the synthetic wood manufacturing industry in the form of "medium density fiberboards" (MDF) (Hassan-Beygi et al., 2009). The shell of the apricot pit is one of the most resistant and environmentally friendly new materials used in the sustainable building materials manufacturing industry (Peters, 2014; Pizarro, 2013).

Otherwise, apricot pit shell is a very interesting raw material for the manufacture of activated charcoal employed in the wastewater treatment industry (Hameed and Rahman, 2008; Sekirifa and Hadj-Mahammed, 2005; Soleimani and Kaghazchi, 2008; Youssef et al., 2005; Zarrouki, 1990). It has highly appreciated physicochemical characteristics that give it an impurity absorption capacity of 99.04% (Trachi et al., 2014). Its comparative performance in terms of maximum adsorption capacity compared to other adsorbents shows promising results that can contribute to the decontamination of industrial effluents (Abbas, 2015). The process of manufacturing activated charcoal from apricot pit shells is less expensive than the conventional process (Ioannidou and Zabaniotou, 2007). Indeed, it is economic and efficient to use the shell of the apricot pit to manufacture activated charcoal that is integrated into the rapidly expanding market of water pollution control (Mohan and Pittman, 2006; Rafatullah et al., 2010).

Barriers of the Sub-sector Development for the Apricot Pits Valorization

As we have mentioned above, the recovery of apricot pits can have several destinations depending on the nature and composition of the various raw materials derived from them. We can distinguish three by-products of the apricot pit: the shell is the protective layer of the almonds, the almond provides both oil and cake-meal. The production of the apricot pits itself depends on apricot processing technology. At this stage, the process does not set any obstacles as long as the industrialists separate the flesh from the pit (Figure 4). The classic socio-technical system used in apricot processing and preservation activities does not require any adaptations for new practices or technologies to provide the raw material (apricot pits). The challenge is preparing this raw material to be suitable for its recovery and valorization in the following part of the chain.

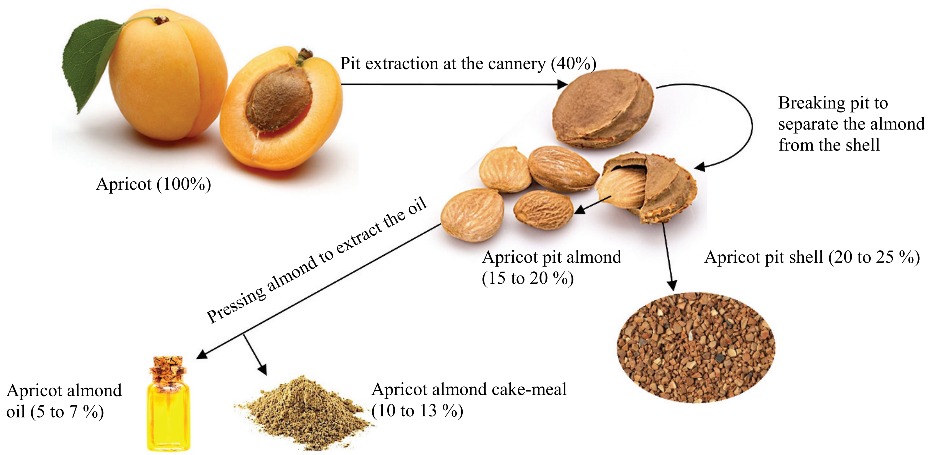

Figure 4. Apricot pit valorization process.

High Technological and Technical Constraints in the Preparation Process of Apricot Pit By-products

Quick-drying or removal: induced equipment costs: the conservation of the pits before their recovery is a key operation. They need to be dried in a short period of time, failing to do so means that the pits will be attacked by the mold and lose their value. A generic industrial dryer can be used to dry them. However, most industrialists do not own one and the investment cost is considerable and constitutes an obstacle to the valorization of the apricot pits. The investment risk and the resulting slow depreciation rate discourage the integration of new practices (drying and packaging) for preserving apricot pits by canneries. For the National Agency for the Valorization of the Results of Research and Technological Development (ANVREDET): "The main constraint is the mastery of processing technology, especially in developing countries, add to this the financial component that must be taken into consideration, because the by-product must be sufficiently profitable to encourage companies to invest in processing equipment". This finding corroborates with the results of several studies on the change in practices required for the adoption of innovation (De Coninck et al., 2008; Huertas-Bermejo and Dorca-Duch, 2008).

For most cannery cases, apricot pits are not dried before the sale. Potential buyers of apricot pits must collect their goods as soon as possible, in principle 48 hours after their separation. This imposes on both sides time and logistical constraints in addition to the seasonality and variability of the quantities released by apricot canneries. The investment in such an operation is considered costly by canneries as long as they do not have stable demand that can make their investment profitable. The new socio-technical system in its present state does not allow for the creation of incentives for the development of activities around apricot pits as it is not considered a reasonable investment for the future (Basalla, 1988). Indeed, resource endowed operators must be persuaded that their interests and values are best served by investing in this emerging sector, rather than maintaining their existing old practices in their usual socio-technical regime (Smith, 2006). This is why new companies have specialized in the preparation of apricot pits recovery. They dry and sometimes even break, sort, package and ship to companies that value almonds and shells.

Breaking: specialized machines needed: in principle, the breaking is carried out by a specialized husker as for other achene fruits. However, the shape and size (the physical and morphological characteristics) are specific to the apricot pit, which requires a specialized machine. However, the atomicity of this market has not allowed the development of a specific technology that can ensure less costly breaking. Companies that valorize the apricot pits use different techniques that are sometimes complementary, such as breaking by a non-specialized hulling machine, supplemented or not by manual stripping or even manual breaking. In any case, this operation, which is essential for the valorization of the pits, is costly and remains for the moment ineffective in terms of quantitative and qualitative yield. It constitutes in itself a lock to improve both the quality of the resulting by-products and their profitability. The staff assigned to this operation are not in a position to benefit from external expertise or specialized training due to a lack of skills in this area. Learning by doing seems to be the solution taken by these small enterprises to create a new routine compatible with the new socio-technical system (De Greene, 1991; Meadowcroft, 2009).

Difficulty of upstream sorting: The next step is sorting, which normally consists of separating bitter almonds from sweet almonds. This also seems to be a technical barrier as long as manufacturers are unable to develop a technique that can perform this function, especially to enhance the value of apricot cake-meal. It should be noted that bitter almonds contain amygdalin, a cyanogenic substance that is toxic in animal and human food. Some companies are currently adopting a sorting technique based on the size of the almonds (bitter almonds vary between 8 and 10 mm, mixed almonds between 10 and 12 mm and sweet almonds between 12 and 14 mm) and on the origin. But the validity of this technique remains controversial by researchers and industrials. The only way to ensure the absence of toxins (hydrocyanic) is to systematically detoxify the cake-meal produced. This requires expensive technical means (detoxification by heating at 250°C) (Arbouche et al., 2012; Hosoya et al., 2010). This partly explains the loss of interest in the valorization of apricot almond cake-meal.

Lack of links with the activated carbon industry, process quality problems: the apricot pit shell can have several outlets in niche markets such as activated charcoal for water purification or synthetic wood panels. Indeed, the apricot processing sector lacks a close relationship with potential buyers of this raw material to be able to create a collective learning process to develop technologies and the knowledge necessary to control its recovery (Devaux et al., 2007). As mentioned above, the breaking of shells is currently a problem for its recovery since it determines the quality of the final product and therefore its market value. The control of granulometry is essential to create added value in this recovery process (Bouhamed et al., 2012; Horgnies et al., 2012), otherwise the apricot pit shell becomes a generic waste destined for landfill. Based on our investigations, research is underway to provide the knowledge and skills needed to address this problem and its results should be an important step for the expansion of the new socio-technical system toward its successful exploitation.

Limited Technical Skills in the Extraction of Apricot Almond Oil

The extraction of oil is the main destination of apricot pits. The technical resources necessary for this activity are available and accessible to investors regardless of their size, which explains its success. However, the control of the parameters of extraction that determine the quality of the oil and this seems to be an essential factor for the development of this high added value activity (Azcan and Demirel, 2012; Gayas et al., 2017; Özkal et al., 2005). Temperature, pressure, acidity and purity are far from being self-regulated in the presses used to extract apricot almond oil. It seems that the absence of a customized validated extraction step, which crucially affects the final quality of the products, is a major obstacle to the valorization of apricot by-products (Tsiaka et al., 2020). Also, to enhance the environmental friendliness of recycling apricot by-products, enzyme-assisted extraction coupled with the use of water as a solvent instead of organic chemicals is recognized as a more environmentally friendly technology for extraction and oil (Puri et al., 2012).

Companies that acquire this new technology, apart from the cost of investing in machinery, must train their staff in the best practices necessary to master this technology. Workforce training is seen as an effective means for process improvements and maybe product innovations. Increased dissemination of knowledge through training can also be expected to contribute positively to the performance of the companies that have acquired a technological innovation and thus facilitate the transition of its socio-technical system based on its usual production routine (Lin and Chen, 2000; Madanmohan, 2005; Nikas et al., 2007).

There are international standards that refer to the various parameters mentioned above. The transfer of knowledge and skills remains very limited for the moment given the sporadic development of this activity in the form of a niche market. Yet it tries to look like to the more structured sector that extracts sweet almond oil. The interest of companies developing this type of industrial process within the traditional sweet almond oil extraction chain is justified by the scale of demand and its international development. This not yet the case for apricot almond oil. The sharing of experiences between the two competing sectors can only be done if a company plans to carry out both activities in parallel. At this time the main concern is getting structures, agents and processes that reproduce a socio-technical system and reproducing the technic and practices used in the extraction of sweet almond oil. The new socio-technical system is not rooted in the sense that it does not benefit from the same market opportunities and importance, greater institutional support and better integration with other social practices (Rip and Kemp, 1998; Russell and Williams, 2002; Smith and Stirling, 2008).

The Incorporation of Apricot Almond Cake-meal into Animal Feed Is Not Well Known by Professionals in the Sector

The technology and practices necessary for the development of the apricot almond cake-meal value chain are not sufficiently known and controlled (canneries and livestock feed manufacturing units). Extracting apricot almond oil is still the main economic interest when it comes to apricot pit valorization and pit cake-meal have not yet found its place on the raw materials market.

Technical investment is less costly from an economic point of view, but the lack of control over its use and the lack of knowledge of this by-product by final consumers (livestock farmers) slows down the development dynamics of this sub-sector. The construction of prior demand in the livestock farming community is a key element to accelerate the process of adopting this by-product in animal feed. The current challenge is to demonstrate the technical and nutritional utility of using this apricot almond cake-meal in the farming environment. This may require a progressive transition phase (Angeon and Chave, 2014; Law and Liang, 2019) to move away from the current socio-technical system that is almost only based on the use of traditional raw materials (maize and soybean meal). This can be achieved by gradually introducing apricot almond cake-meal through, for example, experimentation on voluntary farms. Lack of links with the activated carbon industry, process quality problems: the apricot pit shell can have several outlets in niche markets such as activated charcoal for water purification or synthetic wood panels. Indeed, the apricot processing sector lacks a close relationship with potential buyers of this raw material to be able to create a collective learning process to develop technologies and the knowledge necessary to control its recovery (Devaux et al., 2007). As mentioned above, the breaking of shells is currently a problem for its recovery since it determines the quality of the final product and therefore its market value. The control of granulometry is essential to create added value in this recovery process (Bouhamed et al., 2012; Horgnies et al., 2012), otherwise the apricot pit shell becomes a generic waste destined for landfill. Based on our investigations, research is underway to provide the knowledge and skills needed to address this problem and its results should be an important step for the expansion of the new socio-technical system toward its successful exploitation.

There are of course differences in the assimilation of this by-product by the different farmed species (monogastric, ruminants). This impacts the specific substitution rates for each species. The tolerance or substitution thresholds for apricot almond cake-meal in livestock feed is a fundamental parameter that farmers must ensure to succeed in their feed composition formula and therefore in the expected performance of the farm. The socio-professional profile of Algerian livestock breeders, characterized by often traditional breeding and practices inherited from father to son without prior professional training, does not allow the necessary technical skills to be acquired for the adoption of apricot almond cake-meal as a raw material for livestock feed production. Removing this obstacle requires support and extension services in the field.

The seasonality of apricot production and therefore the apricot almond cake-meal, does not offer the possibility of stabilizing feed formulas for the manufacturing of livestock feed. This translates into organizational changes for livestock farmers and feed manufacturers, whether in terms of supply, raw material storage or formulation. This has also been observed by other authors regarding the use of new raw materials in the feed industry (Pathumnakul and Piewthongngam, 2010; San Martin et al., 2016).

Diversity of Actors and Organizational Forms

Despite their dependence and complementarity, the sub-sectors for the valorization of apricot pits by-products are characterized by specialization and functional segmentation. Thus, the organization of exchanges between their actors requires complex circuits and various forms of arrangements. The introduction of a new socio-technical system needs to be aligned with the policy and strategic issues. Because the sector is highly disaggregated meaning many different levels of sectors and sub-sectors that lead to extensive technological details (Nursimulu, 2015). This is referred to as a focus on horizontal integration where collective intersectoral strategic action is needed to address the skills gap related to the acquisition and ownership of an innovation (Lafferty and Hovden, 2003).

The relevant sub-sectors supply markets that are quite specialized and distant in terms of expectations of end consumers. The shell of the apricot pit is used in the synthetic wood or activated charcoal for the wastewater treatment industry. The Algerian wood industry is dominated by the public group Wood Manufacture, including 22 companies that have no industrial fabric for the manufacture of synthetic wood, usually intended for the furniture, construction, DIY (Do It Yourself) and packaging markets. Indeed, the only destination of the shells of the recovered apricot pit is to be exported to Europe. However, the increase in logistics costs (transport and packaging) has led to a decrease in the margin achieved by companies exporting shells, which has led to the abandonment of this recovery method in the absence of local demand that could substitute export. The market for activated charcoal obtained by the physico-chemical treatment of ligno-cellulosic residues such as apricot pit shells is a very strong market due to the growing demand for this product in the wastewater treatment industry. Yet, companies active in this field pay little attention to the valuation of apricot pit shells, not because of a lack of technical skills, but because of the geographic dispersion of supply, its irregularity and the lack of professional structures that can bridge the gap between the apricot processing and water treatment industries. The development of these operators requires closer trading relationships to ensure the regularity and the supply and the quality of the raw material. In addition to logistical issues, geographical dispersion is more constraining for building trust relationships and then exchange between the different actors involved in the socio-technical system (Grenci, 2000; Hoonakker et al., 2011). The adoption of this innovation becomes then easier with the creation of market conditions in favor of the investment in technology and the practices necessary for its introduction into the usual routines of companies.

This is also the case for the sub-sector for the valorization of apricot almond cake-meal, where coordination between training, research and economic operators is required to introduce the use of apricot almond cake-meal in animal feed. In this sense, technical institutes such as ITELV (Algerian National Technical Institution of Breeding) and the Chamber of Agriculture (extension service), having long shown the usefulness of the valorization of apricot almond cake-meal in animal feed, have never partnered with the ONAB (National Office of Animal Feed) to promote this sub-sector, knowing that the latter has a very important industrial fabric and market share in animal feed. The lack of coordination and communication on technical, economic and even environmental aspects in the initial phase of this project reduces readability for industrials and ultimately compromises the chances of adoption of this innovative feed material in the feed industry. Interactions and coordination between stakeholders in the by-product development chain can be based on a global approach. Unfortunately, the observation during the survey shows a dysfunction between the actors of the apricot sector and the sub-sector of the valorization of apricot pits. Some canneries are still evacuating the apricot pits to the landfill since they have no buyer and so do not communicate on the availability of these by-products at their level.

In addition to the lack of market coordination, the flow of information between stakeholders in the feed manufacturing chain appears to be inadequate. The various public agricultural information and extension services, which often organize information and awareness days, fairs, open days and local, regional, national and international meetings, have never dealt with this theme of promoting apricot pits. The relative success of the valorization of apricot almond oil suggests the existence of a sub-sector structured around harmoniously organized actors. Our field surveys show the opposite. Its functioning is just as complex as the other sub-sectors. The absence of formal contractual arrangements, irregularity of exchanges and instability of supply are its main constraints. It seems that the success of this sub-sector is due to the solvency of its outlets. This is a raw material with high added value conveyed by exports to the cosmetic industry. Indeed, whatever the route made via the various intermediaries or their arrangements on the market, downstream is a major asset since it offers very profitable prices allowing upstream players to make their investments profitable and ensure the sustainability of their activities. Consequently, failure to take into account the complexity of the sector of apricot pits valorization and its various segments and the technologies and knowledge inherent in their operation does not allow either the transition necessary for the appropriation of the new socio-technical system or its hybridization or coexistence with that of the status quo (Furlong, 2014).

Vertical Integration Is a Possible Strategy but Not Adopted by Manufacturers of This Sector

In a complex socio-technical system such as that of the valorization of apricot pit by-products, vertical integration is necessary to secure its functioning. This allows for better control of the diffusion of decision making from top to bottom and a better flow of information from bottom to top, thus constituting feedback loops adapted to the objectives of the upper levels of the system and the capacities of its lower levels (Rasmussen, 1997). It seems that the small size of the companies is detrimental to the vertical integration strategy to use apricot pits. This was found in our surveys of canneries that process apricots as a secondary product in limited quantities and where the apricot pits often end up in the landfill instead of being recovered. The counter hypothesis is that a large company could valorize apricot pits given the volume at its disposal. The leading company in apricot processing in Algeria, with 27,000 tons per year, does not self-valorize this by-product. But it preferred to put it on the market at 100 € per ton (Boumali, 2018). This choice is justified by the lack of technical and human resources – main components of socio-technical system – necessary to integrate the recovery of these by-products into the company's activities (See the traditional theories on "make or buy" as "make or sell", mainly the transaction cost theory). It is more profitable for it to sell it directly to price-takers whose activity is totally dependent on this by-product. It is also the case for the second leading company in apricot processing, whose processing activities produce a quantity of 530 tons/year of apricot pits. This company follows the same marketing strategy as the first one. Here, it is obvious that the oligopoly exercised by these two companies gives them a strong position by allowing them to set the selling prices of apricot pits. One might think that there are other potential suppliers of apricot pits in the region, but they remain small in scale, geographically dispersed and will not be able to meet the needs of apricot pits buyers. In any case, the vertical integration of apricot pits processing to produce livestock feed is not considered efficient, even by companies that extract apricot almond oil whose activity systematically generates apricot almond cake-meal. Faced with these difficulties, the export to Italy, Turkey and France of raw or semi-processed (shelled and dried) pits remains the most preferred route both for canneries and for new intermediaries for the valorization of apricot by-products (€1400/ton in the hull state, €2000/ton for shelled pits). Although it constitutes an important outlet, this marketing option is of less benefit to local stakeholders in terms of added value and economic dynamics.

Official Approval or Recognition Is an Institutional Lock-in

In addition of the sub-sector organization complexity to valorize apricot pits due to the multiplicity of its by-products and their industrial uses, there is a low level of coordination of its actors that remains a central problem given the functional interdependence between the different concerned subsectors. It is still early to consider the agreement of exchange relations to overcome the problem of coordination and exchange of information, because private economic operators, particularly agri-food companies, do not yet seem ready to take up the torch of the promotion of innovative products derived from the apricot pit, which has not yet been officially recognized on the market. None of the above-mentioned by-products are covered by a regulatory or normative text allowing them to be recognized as a potential source of raw material for manufacturers. The absence of a specific institutional framework for the valorization of apricot pit by-products does not stimulate economic operators to invest in long-term contractual relations. They are then confined to informal coordination relationships (oral contracts or spot markets). These forms of trade coordination are in themselves an obstacle to industrial investment (equipment, training) which is necessary for the development of these innovations. This is what several authors (Foxon, 2014; Hiteva and Watson, 2019; Kinder, 2000; Pomares, 2019) put forward on the relationship between the specific institutional framework, forms of coordination, investment and the diffusion of innovation.

Moreover, this institutional vacuum does not allow the emergence of specialized professional organizations and does not encourage the implications of those in place. The consequence is the loss of synergy and the strength of collective action necessary to structure the activities of the various stakeholders in these innovation chains. In the case of animal feed, agricultural cooperatives or livestock organizations can play a key role in the physical, financial and informational flows necessary to appropriate practices for the adoption of this raw material in the livestock feed industry. Public and private employers' and sectoral organizations can play a central role in the process of institutional legitimization of their activities that relate to innovations induced by the valorization of apricot pits (Fonseca and Pereira, 2014; Petersen and Silveira, 2017; Solarte-Vásquez and Nyman-Metcalf, 2017).

Drivers for the Development of Apricot Pits Valorization

Real Economic Opportunities for Manufacturers

So far, only apricot almond oil has been of great interest in the industrial sphere where extraction operations can generate a 45% net margin of the turnover of this activity. This performance could be more important if a great investment was made with economies of scale. The solvency of buyers of apricot almond oil and the strong demand for this raw material in the cosmetics industry, often located in Europe, enable this sub-sector to make its activities profitable even if its potential has not yet been fully exploited. Investment in the apricot almond oil processing industry at the local level could enable extractive companies to improve their performance by increasing their share of added value. Such a strategy could be possible by creating an alliance with local cosmetics industry groups. Due to the fall of oil revenues, the Algerian government has imposed since 2014 austerity policies that have restricted the raw material that local cosmetic groups can access (Allegret and Benkhodja, 2015; Escribano, 2016). This is also the case for other sub-sectors such as the wood processing industry, hydraulic filters and animal feed.

The valorization of apricot pits by-products could represent a real boon for these local industries which are very dependent on the import of raw materials from abroad. Our estimates made for the production cost of certain raw materials show very attractive prices compared to import prices. For the valorization of apricot almond cake-meal, one ton costs on average the equivalent of €84 compared to €385 on import for products with fairly comparable nutritional intakes (source of vegetable protein). Technical and economic studies must be carried out for the remaining by-products, in particular the shell of the apricot pit, under different scenarios to determine the potential in terms of creating added value and to solicit more interest from local manufacturers for its recovery. New ways of recovery are also to be explored, especially in high value-added markets such as in the parapharmaceutical and cosmetics industry, or the subsector of apricot almond oil extraction, which is experiencing a real boom (Dan et al., 2016; Esteki et al., 2017; Khodadadi et al., 2017; Rudzińska et al., 2017; Zhou et al., 2016). In the Mediterranean context where most of the world's apricot production is concentrated Kasapoğlu et al. (2020) and Tsiaka et al. (2020) have shown the importance of apricot by-product recycling chain to provide fractions and bioactive compounds according to the needs of different industrial sectors. Lemes et al. (2016) in their review of the latest advances in the extraction of encrypted bioactive peptides (e.g. oil) from agro-industrial wastes confirm that the development of appropriate techniques for the large-scale recovery and purification of peptides will increase their applications in the pharmaceutical and food industries.

Information Sharing and Coordination are the Main Drivers for the Creation of New Innovative Sectors

Shani et al. (1992) emphasize the importance of information-sharing mechanisms in the socio-technical system. They associate with any technological and organizational change the need to allow information sharing between all actors involved in the socio-technical system (suppliers, processors, intermediaries, etc.) to facilitate coordination between each of its decision-making centers. The role of interactions in technological development, the need for coordination between the spheres of training, research and production are essential to boost the new sub-sectors for the valorization of apricot pit by-products. In this sense, the Algerian National Technical Institution of Breeding (ITELV), aware of the usefulness of the valorization of apricot almond cake-meal as a partial alternative to the import of soya cake-meal, must work jointly with the National Office of Animal Feed (ONAB) and the public structures of the sector to promote this technological innovation as a new source of supply of raw material in animal feed. In this sense, providing detailed information on nutritional interests in the market is necessary to obtain products that best meet the expectations of end consumers, in this case "breeders" (Kumar, 2015).

The various public authorities responsible for the sectors in question, in particular the Ministries of Agriculture, Industry, Environment, Water Resources and Trade, must coordinate their programs for the development and enhancement of local resources initiated as part of the policy to diversify the national economy away from hydrocarbons (Abbas, 2010; Cavatorta and Tahchi, 2019). In doing so, they will jointly draw up a national strategy capable of promoting investment in these new innovative sectors and their structuring. The launch of discussions on a national plan for the development of a medium-density fiberboard (MDF) industry by the Ministry is a real opportunity to integrate the potential of the apricot processing sector as a supplier of raw materials (shells). In addition, the launch in 2017 by the Ministry of the Environment of an Internet platform "industrial waste exchange" now provides economic operators with information on the real-time availability of apricot pit by-products and thus facilitates their coordination and the structuring of sub-sectors for the recovery of its by-products. The intervention of the professional organizations involved in the sector as a vector of technical information or as a relay for physical or financial exchanges makes it possible to pool efforts and strengthen the capacities of local actors to adopt the techniques necessary for the adoption of these technological innovations that create added value. The idea of a common platform between the actors of the innovative sector is known in socio-technical systems as a real alternative for the exchange and sharing of information, but also as an organizational tool for the coordination and governance of innovation and the resulting relationships (Baccarne et al., 2014; Borrás and Edler, 2014; Geels, 2005; Kim et al., 2015; Tilson et al., 2012)

Strengthening Public Action and Research and Development Actors in the Sector

Several studies underline the key role that public action playing both as a regulator and as a support in the functioning of socio-technical systems around innovation (Angeon et al., 2014; Bui et al., 2016; Cooper et al., 1996; Van Oudheusden, 2014; Weerasinghe and Jayawardane, 2019). The initiative to promote apricot pit by-products in animal feed is part of a relevant and very favorable Algerian context. Since 2008, the public authorities have launched an Agricultural and Rural Renewal program aimed at enhancing local resources and improving farming techniques and ensuring food security. This has created an economic and social dynamic that encourages the emergence of thoughtful, calculated and topical initiatives (encouraging the cultivation and processing of apricots in rural areas, creating employment, etc.). Public structures have played a leading role in launching the apricot pit upgrading activity with an increase in supply and the mobilization of technical and financial knowledge for investment in innovation. Thus the Chamber of Agriculture supported the called “Rivaldi” project which led to the creation of the first apricot almond oil extraction company in the country, by organizing the agricultural profession, animation, information, extension. The Departments of the Agricultural Services of the wilayas contribute to the promotion and sponsorship of the initiative among local and central authorities and fruit farmers. In this way, Tavakoli-Hosseinabady et al. (2018) in their study of the value of the apricot pit shell in water and soil detoxification, emphasize the importance of public demonstration by professional organizations to promote the adoption of this environmentally friendly technology on an industrial scale.

The development of apricot almond cake-meal in the livestock feed sector has been promoted by the research and development work of universities and technical institutes of National Technical Institution of Breeding (ITELV) and Algerian National Institution of Agronomic Research (INRAA), but without finding an industrial partner capable of integrating apricot almond cake-meal into its industrial processes. The lack of coordination and communication on technical, economic and even environmental aspects reduces the legibility of the economic interest for applicants and ultimately compromises the chances of adoption of this innovative feed material in the feed industry. Quite the opposite is true of the canneries that extract apricot pits, where the communication made by public structures on the economic benefits linked to the valorization of their by-products has finally motivated them. For processors, as providers of funds and traders of nature, solving their waste management problem with an additional inflow of money, makes them allies of the initiative while being beneficiaries. According to our surveys, the lack of a legal framework governing these newly emerging market activities is pushing these companies (canneries) to take the informal route to sell their by-products. They do not declare the sale of apricot pits and they do not use contracts when marketing their waste, otherwise, they risk being monitored by public authorities (fraud prevention services, hygiene services, etc.). Indeed, there is an urgent need to create a regulatory framework compatible with the development of activities for the valorization of agro-industrial by-products such as apricot pits. This is an approach that consists of gaining professional administrative and institutional recognition for these emerging sub-sectors that carry products that have hitherto been unknown on the market. Market coordination must be strengthened by a better circulation of information on the socio-economic and environmental interests related to the valorization of apricot pits by-products. This last condition can only be achieved under an institutional framework defining a regulatory and normative status for the products of these subsectors.

Conclusion

In response to the global food crisis and to strengthen its food security, Algeria, since 2008, has launched an Agricultural and Rural Renewal Program aimed at increasing agricultural production. Apricot production has benefited greatly from this dynamic. But wastes, (resulting in mainly apricot pits) are starting to create a serious environmental disposal problem. This study is part of the work aimed at creating alternative routes to avoid all the disadvantages resulting from the waste of the apricot-processing industry and mainly thanks to the recovery of its by-products.

Based on the previous work showing conclusive technical and economic results of the different uses of apricot by-products and to understand the functioning of the innovation chains and therefore of the by-product chains to become co-products. We have highlighted the various obstacles to these industrial innovations, where a lack of technical competence and low technological investment are the main obstacles to their development. Besides the lack of coordination and flow of information between these actors, a specific institutional framework seems to be lacking as well. This analysis also highlights some of the drivers that can be used by these sectors to develop. They are all based on real economic opportunities for economic operators linked to the valorization of the by-products of the apricot pits in the national and international markets.

Also, the diffusion of innovation results from the sharing of knowledge, which requires more coordination between the spheres of education, research, and production. Market coordination must be strengthened by a better circulation of information on the socio-economic and environmental interests related to the valorization of apricot pits by-products. The learning mechanisms that have been created following the redesign of the socio-technical system contribute to the development of these new forms of use of apricot waste. The design of industrial processes as a socio-technical system must take into account their spatial characteristics, technological infrastructures, individual needs, as well as norms and institutions and their mutual interdependence. In the end, sociotechnical systems related to the valorization of apricot by-products are dynamic processes that are constantly adapting, evolving and changing and deserve to be further studied in their evolutionary trajectories. Although this work, which provides an original analysis of the multiplicity of processing and recycling routes for apricot waste, will require further work to refine price mechanisms, the role of sales channels in relation to local and international usage routes, industrial links, etc., it will also be necessary to develop a new approach to the treatment of apricot waste.

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