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SOCIEDADE DE CIÊNCIAS AGRÁRIAS DE PORTUGAL

Positioning Portugal into the context of world production and research in grain legumes

Posicionando Portugal no contexto mundial da produção e investigação em leguminosas para grão

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R E S U M O

Apesar dos benefícios que as leguminosas de grão apresentam para a saúde e sustentabilidade do meio ambiente, o seu cultivo e consumo na Europa encontram-se em declínio desde 1961. Para compreender os desafios nacionais foi efetuada uma avaliação das tendências de produção, comércio e consumo de leguminosas de grão em Portugal, recorrendo a dados estatísticos nacionais e internacionais dos últimos 50 anos. Os esforços de investigação por equipas portuguesas dedicadas às leguminosas de grão foram também quantificados, analisando a produção científica dos últimos 25 anos. Isto permitiu-nos caracterizar o potencial científico para ultrapassar as atuais limitações na produção/consumo. O feijão, a fava, o grão-de-bico e o tremoço são as leguminosas de grão mais importantes em Portugal. Infelizmente, Portugal seguiu a tendência europeia e tornou-se num país importador de leguminosas de grão, apesar de possuir recursos genéticos e capacidade científica de potencial elevado para reverter esta situação. A situação nacional actual reflete os acontecimentos históricos e as preferências dos consumidores, com promissores mercados alternativos (ervilhas para consumo em fresco) e já com algumas mudanças positivas recentes na produção nacional (ex. grão-de-bico), embora ainda incipientes. Provavelmente, o que falta é um investimento consciente e sério na segurança alimentar e sustentabilidade ecológica de Portugal.

Palavras-chave: Comércio; Consumo; Europa; Fabaceae; Leguminosas para grão; Mundo; Portugal

A B S T R A C T

Despite the health and ecological benefits of grain legumes (also named pulses), their cultivation and human consumption throughout Europe has been in a constant decline since 1961. To understand the present Portuguese challenges, we performed an evaluation of the Portuguese grain legume production, trade and consumption trends through the analysis of Portuguese and international statistical data from the last 50 years. Portuguese grain legume research efforts were also quantified through the analysis of the bibliographical outputs over the last 25 years. This allowed us to characterize the Portuguese research potential to overcome the identified present production/consumption weaknesses. In the Portuguese context, common beans, faba beans, chickpeas and lupins are the most relevant grain legumes. Unfortunately, Portugal has followed the European trend and became a net importer of grain legumes, although it holds highly potential genetic resources and scientific expertise to reverse this trend. Portuguese grain legumes situation reflects a specific historical framework and consumer's preferences, with alternative markets, as consumption of green peas, and a few recent promising changes, as seen in national chickpea production, although still in an incipient way. Probably what is really missing is a conscious and serious investment in the Portuguese food security and ecological sustainability.

Keywords: Consumption; Europe; Fabaceae; Grain legumes; Portugal; Pulses; Trade; World

INTRODUCTION

Grain legumes, also called pulses, are annual crops belonging to the family Leguminosae (or Fabaceae) yielding grains or seeds used for food and feed. The denomination "grain legumes" should be limited to crops harvested for dry grain only, excluding, therefore, crops harvested green for forage, used for grazing or as green manure, and also crops harvested green for food (green common beans, green peas, etc.), which are considered vegetables. Also excluded from this group should be those leguminous crops whose seeds are used exclusively for sowing purposes, such as alfalfa and clover (FAO, 2016). As defined further by the Food and Agriculture Organization (2016), grain legumes also exclude those that are used mainly for the extraction of oil, e.g., soybeans. This definition, however, is presumed based on the main uses of the crop in consideration of world statistics. It does not necessarily declassify soybean and other leguminous crops as grain legume crops in certain countries. For the purpose of simplification in all the grain legumes statistics presented in this review (if not otherwise clearly stated) we followed the FAO definition.

Grain legumes like faba beans (*Vicia faba*), chickpea (*Cicer arietinum*), and lentils (*Lens culinaris*) were deeply rooted in the agronomic and culinary culture of Asian and European civilizations (González-Bernal & Rubiales, 2016). More recently common bean (*Phaseolus vulgaris*) has been introduced following the arrival of the first Europeans in America and is presently one of the most consumed grain legumes in Europe.

Grain legumes are suitable for sowing in a wide range of climate and soil conditions, meaning that the associated benefits to agriculture are available worldwide (Araújo *et al*., 2015). For example, beans (mainly *P. vulgaris*) are well-adapted to semi-arid and subtropical climates, and cultivated throughout the Mediterranean basin and in Portugal over summer. Faba beans and pea (*Pisum sativum*) cultivars do not tolerate subtropical and semi-arid climates being cultivated in temperate (cool season) climates across Europe, North American and Australian regions. In India, one of the main legume food crop is chickpea, although lentil and peas are also cultivated, reflecting the diversity of climatic conditions available (Cubero, 1994). These cool season grain legumes are cultivated in Portugal during winter or spring.

The present review aims to illustrate the current position of Portugal into the world grain legumes context. To accomplish this goal, a comparative evaluation of the Portuguese, European and World grain legume production, trade and consumption trends was performed through the analysis of Portuguese and international statistical data from the last 50 years. In addition, Portuguese grain legume research efforts were also quantified through the analysis of the bibliographical outputs from the last 25 years. This allowed us to identify the present production/consumption weaknesses, characterize the present challenges, and define potential strategies to overcome the main Portuguese grain legumes constraints.

Several weaknesses and constraints are hampering full exploitation of grain legumes contribution to sustainable agriculture

Despite the nutritional value in terms of protein that grain legumes provide for both humans and livestock, the cultivation of grain legumes in Portugal (as well in the rest of Europe) has been constantly decreasing over the last 50 years. It has become urgent to reverse this trend, since legumes play a key role in developing future sustainable farming systems.

The unique ability of legumes to fix atmospheric N_2 via symbiotic relationships with soil bacteria (rhizobia), thus with no requirement for N-fertilizers, makes grain legumes relevant partners in intercropping systems. Moreover, their diversifying effect in cereal-rich cropping systems reduces the requirement for pesticides and so grain legumes mitigate the adverse effects of agricultural production on the environment (Jensen *et al*., 2012). Grain legume seeds are rich in protein (up to 40%) and could thus have an increasing geopolitical importance as they could improve Europe's autonomy for this commodity, as it imports ca 70 % of its requirements in protein-rich products used for feeds (20-25 Mt of meals + 15 Mt of soybean seeds). Beside protein contents, legume seeds are also rich in slowly digestible starch, soluble sugars, fibre, minerals and vitamins, as well as secondary metabolites such as isoflavonoids,

playing a major nutritional role with the further benefit of anticancer and other health-promoting compounds (Arnoldi *et al*., 2015), being key components of the Mediterranean diet (Vaz Patto *et al*., 2015). Definitely, legumes offer a number of services that render their increased consumption and cultivation desirable. However, while legumes represent the second most important family of crop plants after Poaceae (grass family), accounting for approximately 27% of the world's crop production, with an annual production area of ca 85.6 Mha worldwide and a total production of 77.6 Mt (FAO, 2014), the lack of competitiveness of grain legumes in Europe (including Portugal) has resulted in a small area of production of these crops.

To tackle this challenge, several national and European research consortia counting with the Portuguese participation have been recently established. A non-exhaustive list of these research projects since 2006 may be found in Table 1.

Several factors, including less investment in breeding, have combined impacts in grain legumes yields, and consequently their profitability is lower and more variable than those of other crops, largely due to susceptibility to biotic and abiotic stresses. This reduces their attractiveness to farmers, despite the many services they offer, and has limited their availability for consumers to a level far below its potential (LEGATO project). Portugal has an extreme external dependency in what concerns grain legumes, as already mentioned at European level. Consequently, grain legumes local production has an increasing geopolitical importance not only to reduce the external dependency on vegetable protein and on N fertilizers but also to potentiate their role on addressing consumers concerns related to environmental sustainability of agricultural systems and the quality of locally produced varieties.

Although grain legumes contribute to well-being, we assist to an extreme national consumption decline

The nutritional benefits of grain legumes are well and globally recognized by governments and health organizations. Despite a daily legume intake is being widely recommended as part of healthy diet, we presently notice a downward trend in legume consumption even in the most traditional markets (such as India and Spain). Possible explanations of this phenomenon rely on emergence of new food habits and lack of innovation and low attractiveness of current grain legume food products (Vaz Patto *et al*., 2015). This has been paralleled by an increase in the same health and chronic disease issues faced by non-traditional markets like North America (Curran, 2012). Unfortunately, Portugal is not an exception and we assist to a reduction not only of grain legume national production but also on its average intake.

Grain legume consumption in Portugal has declined in an unstable way over the last 30 years. During the 80´s we assisted to an almost duplication

Table 1 - National and European research projects counting with the participation of Portuguese research teams

Funding Institution	Project Name
Fundação para a Ciência e a Tecnologia (FCT)	LATHYROMIX -"Exploiting transcriptional variation to identify genes underlying quantitative resistance to major grain legume pathogens"
	"Deciphering grain filling mechanisms in *Phaseolus vulgaris* L. under water deficit"
	BEGEQA -"Exploiting Bean Genetics for food Quality and Attractiveness innovation"
	QUALATY -"Deciphering the grass pea (*Lathyrus sativus*) quality riddle. How can the omics technologies contribute to a demand-driven improvement in legume quality?"
European Comission (EU)	FP6 GLIP -"Grain Legume Integrated Project"
	ERA PG LEGRESIST -"Exploiting genetic variability of resistance genes in major European food legumes to improve varieties for sustainable agriculture
	FP7 ARIMNET MediLEG -"Breeding, agronomic and biotechnological approaches for reintegration and revalorization of legumes in Mediterranean agriculture"
	FP7 EUROLEGUMES -"Enhancing of legumes growing in Europe through sustainable cropping for protein supply for food and feed"
	FP7 LEGATO -"LEGumes for the Agriculture of Tomorrow"

of average intake (3.8 kg/inhabitant/year in 1883/84 (30.000 t in total) to 6.9 kg/inhabitant/year in 1991/92 (69.000 t) (INE, 2016). However, a steady and worrying reduction on these values was detected from the 90's onwards, with a present average consumption of 4 kg/inhabitant/year (2014/2015 data), representing a total of 41.000 t consumed per year (INE, 2016).

Although there are many different grain legumes that are part of the Portuguese traditional gastronomic culture, the national statistical data repository refers that the most consumed grain legumes are common bean and chickpea (INE, 2016). Common bean consumption over the last 30 years follow closely the overall grain legume downwards consumption trend, with a present (2014/2015) average consumption of 3.1 kg/inhabitant/year (with a total of 32.000 t). Chickpea consumption showed however a slightly different tendency. During the 80´s there was a steep increase on the average intake till 0.9 kg/inhabitant/year in 1986/87 and this value was kept more or less constant until now (with 0.9 kg/inhabitant/year, with a total of 9.000 t, 2014/2015 data) (INE, 2016).

The last available records on the Portuguese food balance (2008-2012) indicated that grain legumes represented on average 0.6% of the daily food intake (INE, 2016), although the advisable figure should be 4%. The Portuguese reduction in grain legume intake has been associated with a tremendous increase in meat consumption. Average values in 1981 of 58.5 kg/inhabitant/year have been almost duplicated in 2015, with 111.2 kg/inhabitant/year (INE, 2016). In this context, an increase consumption of grain legumes for animal feed took place to face the increased demand for meat. However, since there was no Portuguese grain legume production increase during this period (please check following sections for details), the grain legume needs must have been overcome by an increase of the Portuguese imports (especially soybean) as in other European countries, with no clear investment on the development of the national grain legumes production (González-Bernal & Rubiales, 2016). Indeed the Portuguese level of self-sufficiency on grain legumes is extremely low nowadays (11.5% in 2013/2014, and with low fluctuation since the year 2000), but during 1985/1986 it was around 100% (INE, 2016). This means that we are presently importing 88.5% of our grain legume consumption needs. There is a low availability of high quality raw material of local origin for the processing industry and the Portuguese industries rely completely on foreigner raw materials.

Portuguese grain legume production has been following, to a certain extent, European trends in contrast to other regions of the world

During more than 100 years, and until the 60´s, we assisted to a steady increase in the Portuguese grain legumes production (Freire *et al*., 2016). During the 60's profound social and economic alterations took place in Portugal that contributed to changes in the agricultural production systems. With many technological advances (as chemical fertilizers and tractors becoming more available) and the abandonment of the most poor land, cool season grain legumes (faba bean, chickpea, lentil, grass pea and lupins) that were used in cereal rotations, for human but especially for draught animals feed, were not needed anymore (this applied in particular to faba bean) (Freire *et al*., 2016). On the other hand warm season grain legumes, like common beans, requested a lot of water and labor since they were intercropped with traditional maize varieties. As consequence of the expansion of hybrid maize monoculture during this period, also these intercropping systems almost disappeared (Freire *et al*., 2016).

Nevertheless, Portuguese food habits have also changed as we already mentioned. In the last 30 years, we assisted to a rapid increase of meat consumption from 58.5 to 111.2 kg/inhabitant/year. Consequently, this has boosted Portuguese animal meat production, which more than triplicate especially from the 70´s onwards (from 262.700 t in 1970 to 877.208 t in 2015) (INE, 2016), as well as the associated consumption of plant protein by the feed industry.

After the entry of Portugal in the EU (1986), the Portuguese agriculture that used to be highly protected from external market competition suffered radical changes with the removal of many importation barriers (Sedlmayr, 2008). Grain legumes imports, and especially of soybean (meal and also seeds), did not stop to rise until nowadays, creating an extreme dependency on the

external market (please check following sections for details).

Grain legume production in Portugal has been steadily declining during the last 50 years (FAOSTAT, 2014). In 1961, 125.421 t of grain legumes were produced in Portugal. The 2014 census showed that this value does not exceed the 22.500 t. This has been associated with a reduction in the grain legume harvested area (from 576.745 ha in 1961, to 26.950 ha in 2014) especially abrupt during the middle 80's, coinciding with Portugal entry into the EU. Interestingly, during the same period a progressive increase on Portuguese grain legumes yield occurred (from 2,04 t/ha in 1981 to 6,33 t/ha 1989, being presently 8,35 t/ha, 2014). Somehow, this contributed to hamper the steeper decrease in production area compared to the observed production downward trend (Figure 1a).

During the last 50 years, our grain legumes exports fluctuated from 20.000 t in 1961 till the present 19.274 t, with a clear minimum (1.556 t) during the 80's. In this way, an expectable steady increase was also observed (from 1.293 t in 1961, to 65.667 t in 2013) in our grain legumes imports, with a steeper slope during the 80´s due to the historical changes already explained (Figure 1a).

This situation was more or less similar to what went on during the last 50 years in Europe, when we do not consider soybean (FAOSTAT, 2014). Grain legume production increased in Europe until the beginning of the 60's as well as their cultivated area, with a maximum of 13,76 Mt and 17,49 Mha in 1964, but presently is not going over 6,99 Mt and 3,56 Mha (2014). Contrary to what happened in Portugal, European grain legume production had an increase during the 80's, as well as their dedicated area, with a maximum at the beginning of the 90's (16,81 Mt and 8,29 Mha). During the same period, a small increase on European exports and imports was noticed with values that were more or less maintained until now. However still during the 90's, European grain legume production and area went on declining (Figure 1b). When we analyze the chronological evolution of grain legumes yield at European level we observed the same trend seen in Portugal but in higher levels. European grain legumes yield reached the 6,68 t/ha in 1961. A sudden increase during the 80's - beginning of

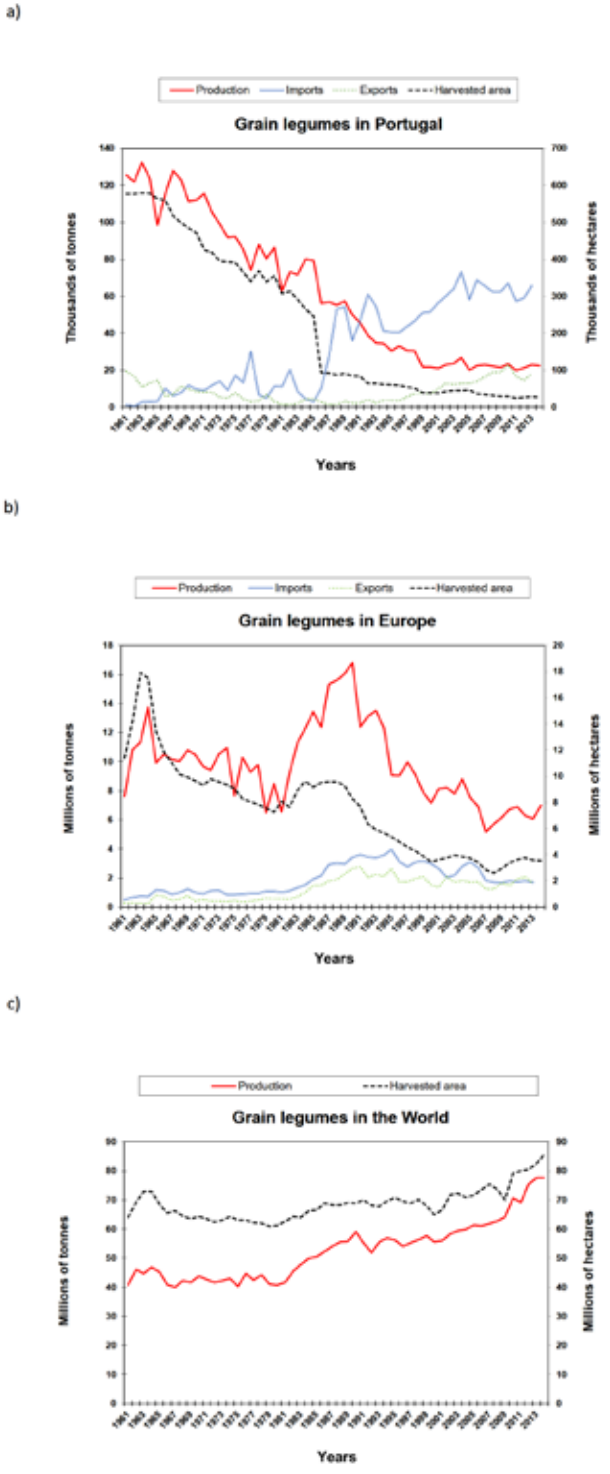


Figure 1 - Chronological evolution of production, harvested area, imports and exports of grain legumes in Portugal (a), Europe (b) and in the World(c) during the last 50 years. Average values were retrieved from FAOSTAT, accessed on the 21st November 2016.

the 90's (with a maximum of 22,85 t/ha in 1993) was also noticed. After that we assisted to a strong variation of these values with a present 19,65 t/ha (2014) (FAOSTAT, 2016). Of course we are not considering soybean production or importation on these figures. Please see a subsequent section for details on soybean.

Nevertheless at world level, grain legume production and harvested area has been increasing during the last 50 years (from 40.78 Mt and 64.01 Mha in 1961, to 77,6 Mt and 85,63 Mha in 2014) (Figure 1c). Although world grain legume yield has increased slowly since the 60's, they are presently still below the European levels, very close to the Portuguese levels (9,06 t/ha 2014) (FAOSTAT, 2016).

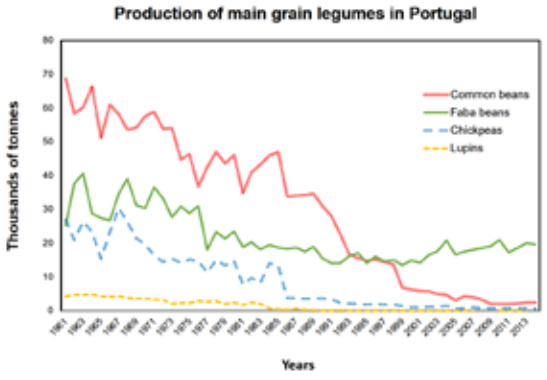
Common beans, faba beans, chickpeas and lupins are the main national grain legumes

At the beginning of the 60's, common bean Portuguese production was about 70.000 t, chickpea reached 30.000 t, faba bean 40.000 t and lupins 4.800 t (see Figure 2a). Portuguese production of both warm and cool season grain legumes was drastically reduced since then (FAOSTAT, 2014). Grain legumes like grass pea, lentils and peas were even removed from the Portuguese statistics because of their low relevance and there was no continuity for the statistical series initiated in the XIX century (Freire *et al*., 2016).

Presently and after 50 years of decline, faba bean looks like the only cool season grain legume that has reached a more or less steady production since the beginning of 2000 decade. Although, production is 50% less than in the 60's and 19.620 t are produced presently (FAOSTAT, 2014). Associated to this was also a decline on the harvested area from 76.121 ha in 1963 to 21.890 ha in 2014. More than 54.000ha are no longer cultivated with faba beans, which represent more than 70% of area reduction. Nevertheless, this was somehow compensated with an increase on the yield levels (532,9 kg/ha in 1963 to 896,3 kg/ha in 2014 as seen in Figure 2).

Although there are no statistics for Portuguese faba bean consumption, we may suspect that this decline in production has contributed to the aggravation of our external dependency on plant protein. We are presently importing 2.698 t of faba bean (FAOSTAT, 2013). This strongly contrasts with

a)



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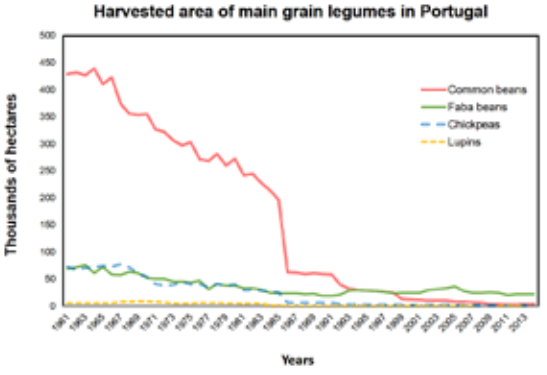

c)

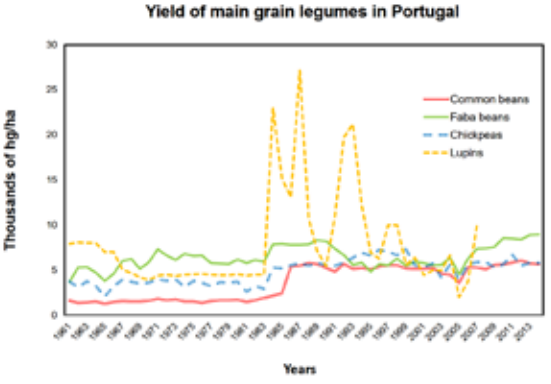

Figure 2 - Production (a), harvested area (b) and yield (c) evolution of the main grain legumes in Portugal. Average values were retrieved from FAOSTAT, accessed on the 21st November 2016.

our faba bean imports in 1961 that were almost negligible (0.016t) (Figure 3).

When we compare the Portuguese situation with the European or World level, faba bean has also suffered a decline in its European production until the 80's, but a quick restoration of the 60's levels took place during this decade, probably due to an increase on yield since the harvested area did not increase accordingly during this period. Nevertheless, also during the 80's, European faba bean imports increased dramatically, but have been decreasing since then. After the 80's we assisted to a steep decline in European faba bean production that lasted until the beginning of the year 2000. Since the year 2000, and contrary to what is observable in Portugal, European faba bean production increased although following an irregular path, with maximums achieved during 2005 and 2011. This has been associated also to an increase in European faba bean exports (Figure 4b).

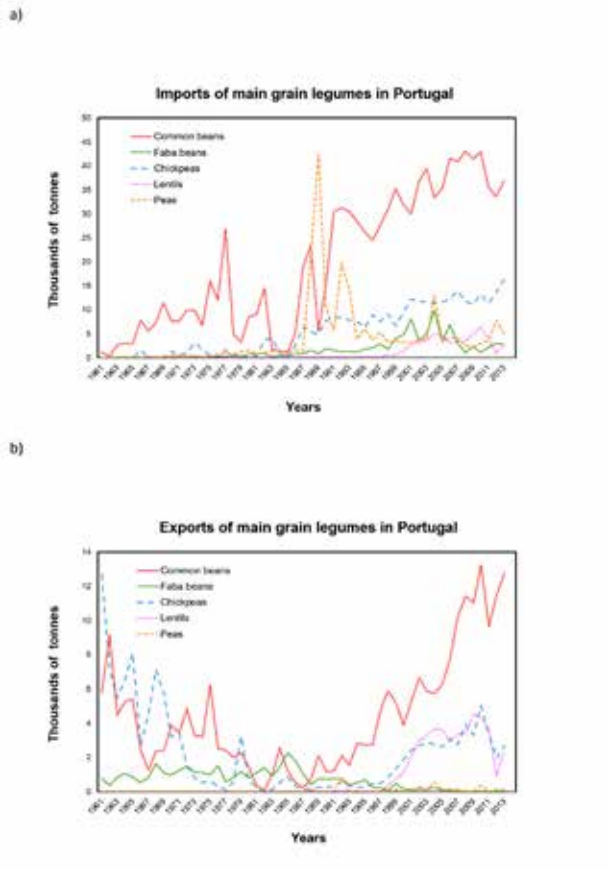

Figure 3 - Production (a), harvested area (b) and yield (c) evolution of the main grain legumes in Portugal. Average values were retrieved from FAOSTAT, accessed on the 21st November 2016.

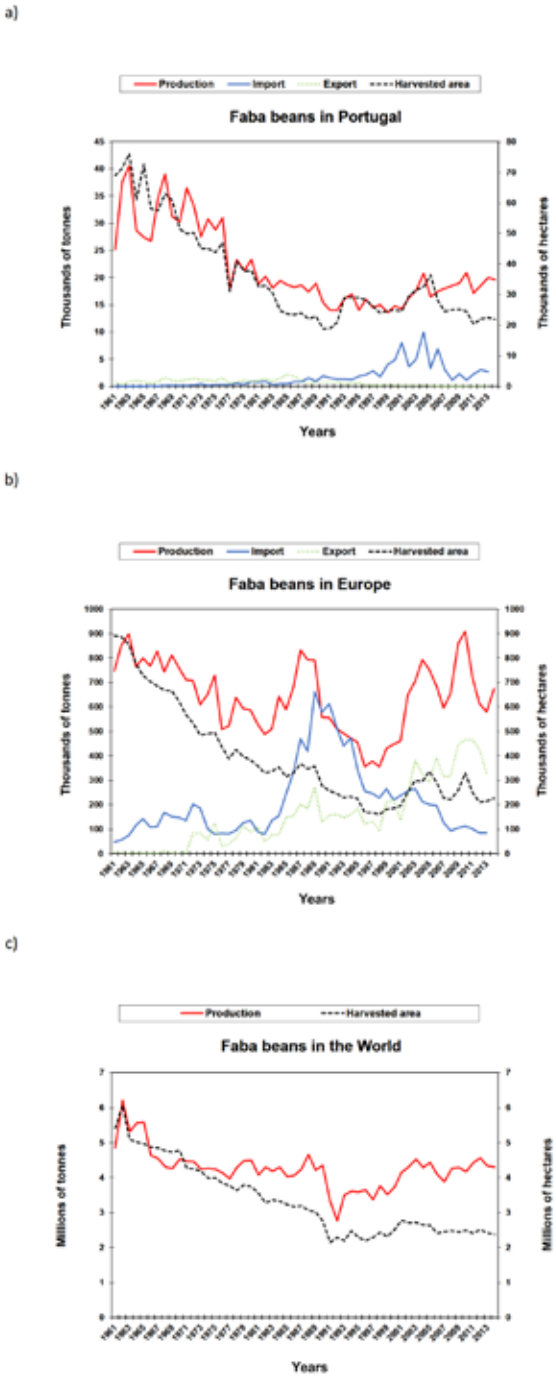

Figure 4 - Chronological evolution of production, harvested area, imports and exports of faba bean in Portugal (a), Europe (b) and in the World (c) during the last 50 years. Average values were retrieved from FAOSTAT, accessed on the 21st November 2016.

At World level, we observed a decline in faba bean production during the last 50 years. Production fluctuations have been much smaller, and since the end of the 90's we assist to a steady recovery, probably due to an increase in yield since the harvested faba bean area did not improve since the 60's (Figure 4c).

More drastic was the decline in the other cool season chickpea and warm season common bean Portuguese production. During the last 50 years, the chickpea production of Portugal declined 97% (26.892 t in 1961 to 700 t in 2013), with an associated loss of more than 71.000 ha harvested area (from 72.258 ha in 1961 to 1.200 ha in 2013) (Figure 5a).

Importantly, we assisted to an awaking of chickpea production in Portugal during the last two years (2014-2015) (INE, 2016) not yet clear at the FAOSTAT 2013 data. Chickpea yield has increased more than 50% in the last 2 years (from 558 kg/ha in 2013 to 854 kg/ha in 2014), an aspect not seen in the other main Portuguese grain legume, common bean (Figure 6). Nevertheless, chickpea imports suffered a severe increase during the last 50 years reaching 16.432 t in 2013 (Figure 5a).

European production of chickpea has also decreased until the 90's. However, we recently assisted to a steady increase in European chickpea production, especially from 2005 (Figure 5b). Such increase was mainly due to increases in yield, since the harvested area has not increased as much. European chickpea imports have been increasing since the 60's, but also exports, especially during the last 10 years where we assisted to a very abrupt increase (Figure 5b). At the world level, chickpea production has been increasing, especially after 2000, being this increase has been associated with an increased harvested area (Figure 5c).

The most consumed grain legume in Portugal, common bean, also suffered a strong reduction (96%) in the national production (68.629 t in 1961 to 2.350 t in 2014). More than 425 000 ha dedicated to common bean production were lost from the 60's onwards (Figure 7a). Importantly, the Portuguese common bean yield has more than triplicated during the last 50 years (from 159,8 kg/ha in 1961 to 567,6 kg/ha in 2014), but quite constant during the last two years contrary to what was seen in chickpea. Despite the yield improvement seen, this was not enough to reduce the actual and extreme external dependency. Common bean imports have dramatically increased (more than 3.000%) from

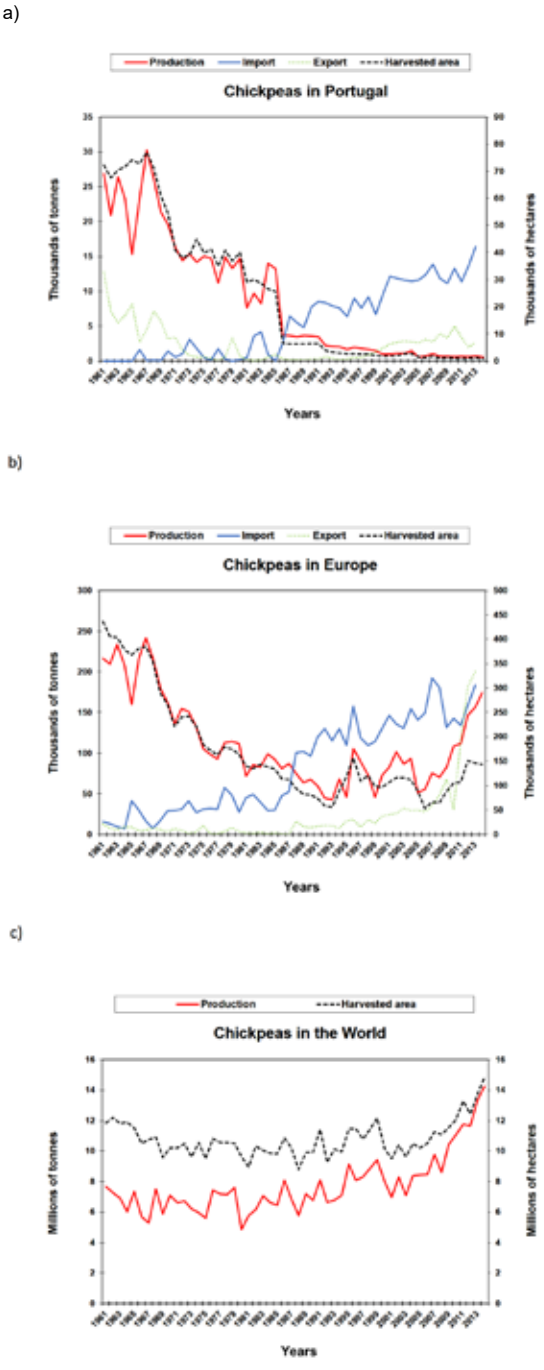

Figure 5 - Chronological evolution of production, harvested area, imports and exports of chickpea in Portugal (a), Europe (b) and in the World (c) during the last 50 years. Average values were retrieved from FAOSTAT, accessed on the 21st November 2016.

1.150 t in 1961 to 36.921 t in 2013. A slight increase (duplication) also in our exports (from 5.832 t in 1961 to 12.774 t in 2013) (Figure 7a), although this migh be a reflection of some resaling of imports.

Common bean production has however increased at the World level, with an associated harvested area increased (Figure 7c). At European level the situation is more similar to Portugal. There was a dramatic decline in the harvested area, associated with production decay until 2007, but this scenario has been probably compensated with a yield improvement. After that year we assisted to a recovery in the European common bean production that hopefully will start to counteract the steady imports increases (Figure 7b).

In Portugal, lupin production, a well-adapted grain legume to the great majority of Portuguese acidic soils, has also suffered a drastic production reduction being nowadays not almost cultivated (from 4.200 t in 1961, the last year with statistical data is 2007 with 15 t) (Figure 8a). Similarly, the same was observed in relation to its harvested area. Data showed that in 1961 5.300 ha were cultivated with lupins but nowadays the cultivated area is almost negligible. As described for the other Portuguese important grain legumes, lupins yield has been increasing, although with strong irregularities. During the 80's, yield maximums of 2.299 kg/ha in 1984, 2.716 kg/ha 1987 and later on 2.118 kg/ha in 1993 were described. Those were alternated with minimums of 1.305 kg/ha in 1986, 544 kg/ha in 1990 and 625 kg/ha in 1996. Unfortunately, there is no data available on Portuguese lupins imports and exports to be able to understand how this production trend has influenced our external dependency.

When we compare the Portuguese situation with the European or World level, lupin has suffered a drastic production decay at European level but however we assist to a recovery on production and associated harvested area since 2000 (Figure 8b). At World level, lupin production has increased heavily during the 80's and 90's. Nevertheless, presently the world lupin production and associated harvested area are decreasing in an irregular way (Figure 8c).

Lentils and peas although with no statistics on Portuguese production, yield and harvested area, are important grain legumes. Peas imports have been particularly relevant at the end of the 80's, beginning of the 90's reaching a maximum of 42.481 t in 1989. Then their importation has abruptly decreased and maintained at the level of 4.999 t in 2013. Lentils mainly started to be more imported from the year 2000 onwards and represented 2.794 t in 2013 (Figure 3).

Pea production in Europe has increased until the

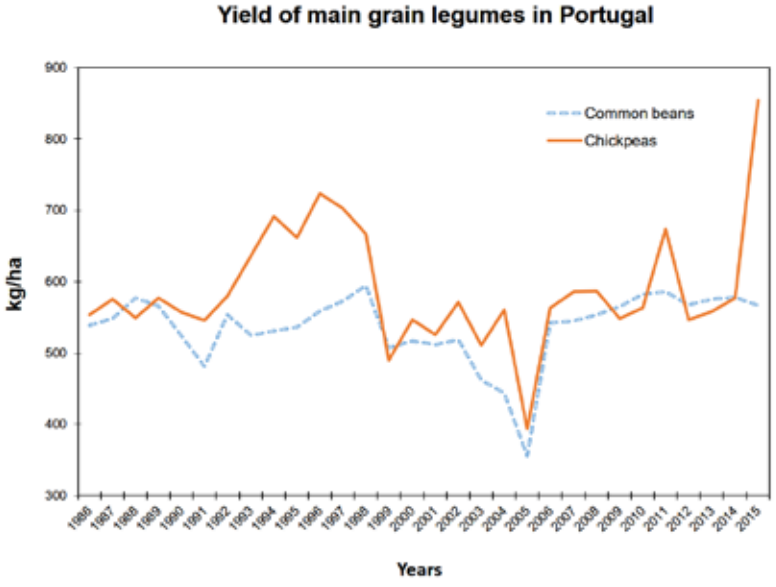

Figure 6 - Chronological evolution of yield of the two main grain legumes in Portugal with data from 2014-2015. Average values were retrieved from INE, accessed on the 21st November 2016.

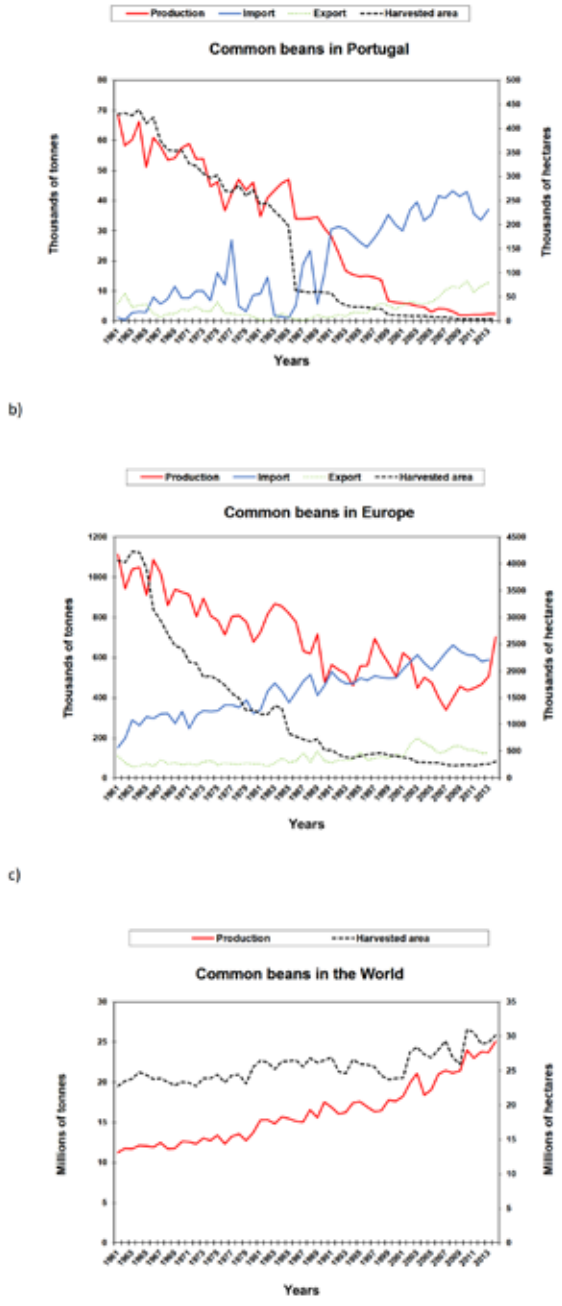

Figure 7 - Chronological evolution of production, harvested area, imports and exports of common bean in Portugal (a), Europe (b) and in the World (c) during the last 50 years. Average values were retrieved from FAOSTAT, accessed on the 21st November 2016.

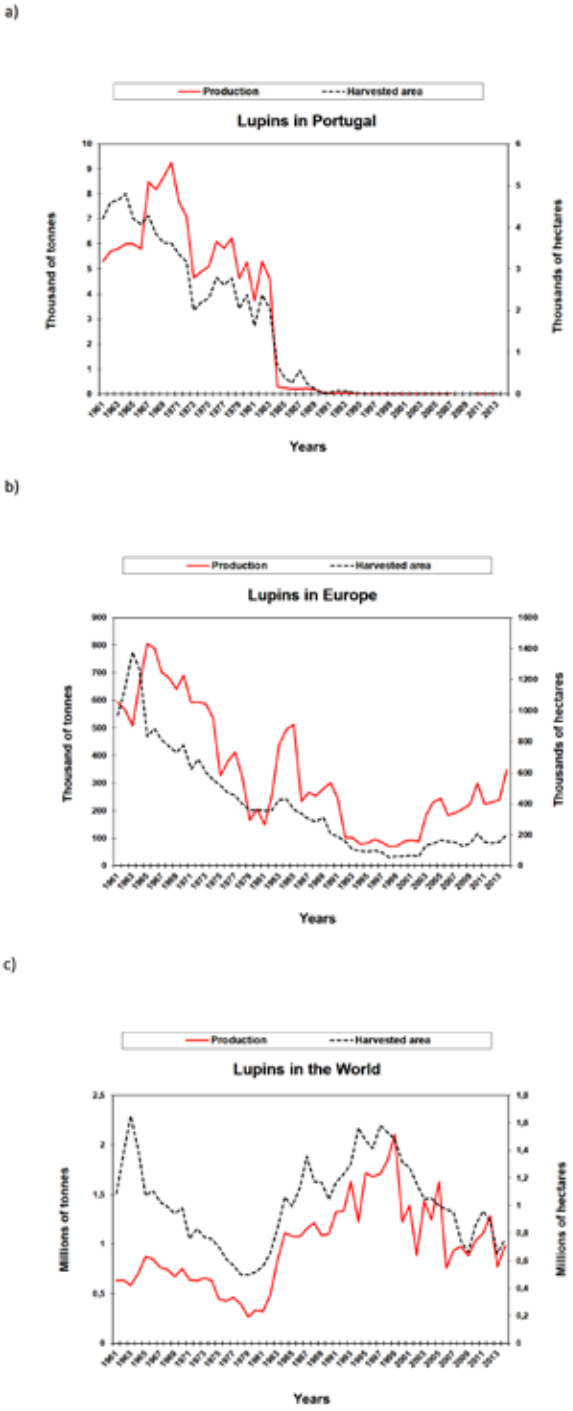

Figure 8 - Chronological evolution of production, harvested area, imports and exports of common bean in Portugal (a), Europe (b) and in the World (c) during the last 50 years. Average values were retrieved from FAOSTAT, accessed on the 21st November 2016.

beginning of the 90's but since then we assist to a steady decline coupled also with a reduction in the harvested area, exports and imports (Figure 9a). Pea production and harvested area has also rise at world level during the 90's but the decrease after that was not as abrupt as the one observed in the European case (Figure 9b).

World lentil production and harvested area have been improved more or less steady, during the last 50 years (Figure 10b). Increasing steadily has been also European lentil imports during the same period. On the other hand, European lentil production and harvested area have been declining specially after the end of the 80's and only recently, from 2009, we assist to same kind of recovery (Figure 10a).

And what about the alternative grain legume market for fresh/green consumption?

Although not considered in FAO grain legumes statistics, it is also interesting to take a look at the situation of main grain legumes when consumed fresh as vegetables. In what concerns Portugal, data is only available for common bean and peas, so we will compare it to the World and European situation.

During the last 50 years, the World production and harvested areas have been increasing for both fresh commodities as described for grain legumes consumed as dry seeds, especially since the beginning of the 90's. It is noteworthy to highlight the case of common bean. In this particular commodity, World production has increased more than eightfold since 1961, being presently of 21.4

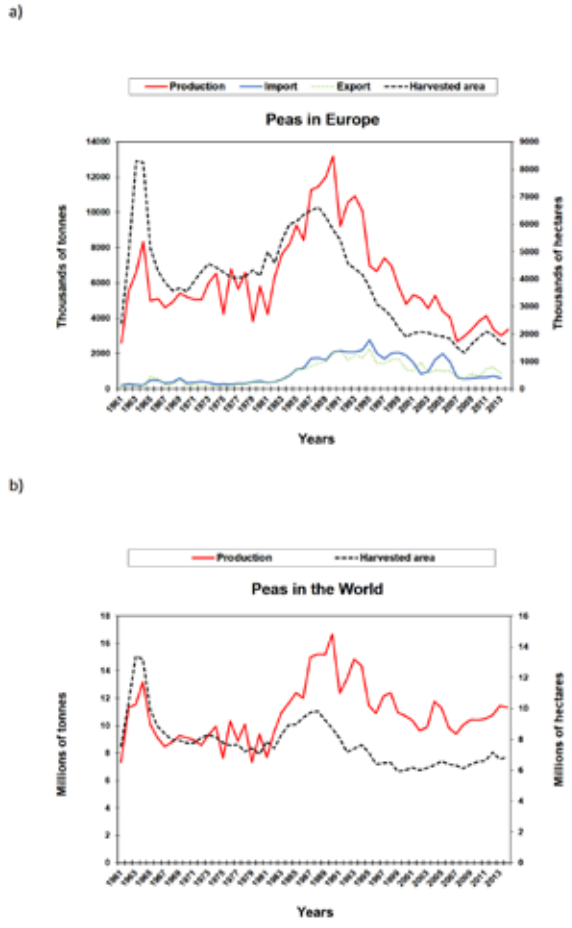

Figure 9 - Chronological evolution of production, harvested area, imports and exports of peas in Europe (a) and in the World (b) during the last 50 years. Average values were retrieved from FAOSTAT, accessed on the 21st November 2016.

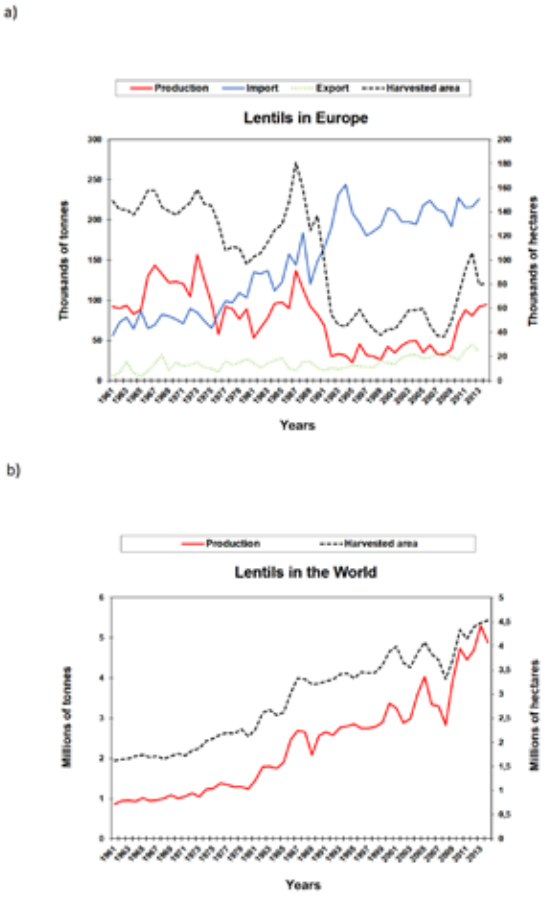

Figure 10 - Chronological evolution of production, harvested area, imports and exports of lentils in Europe (a) and in the World (b) during the last 50 years. Average values were retrieved from FAOSTAT, accessed on the 21st November 2016.

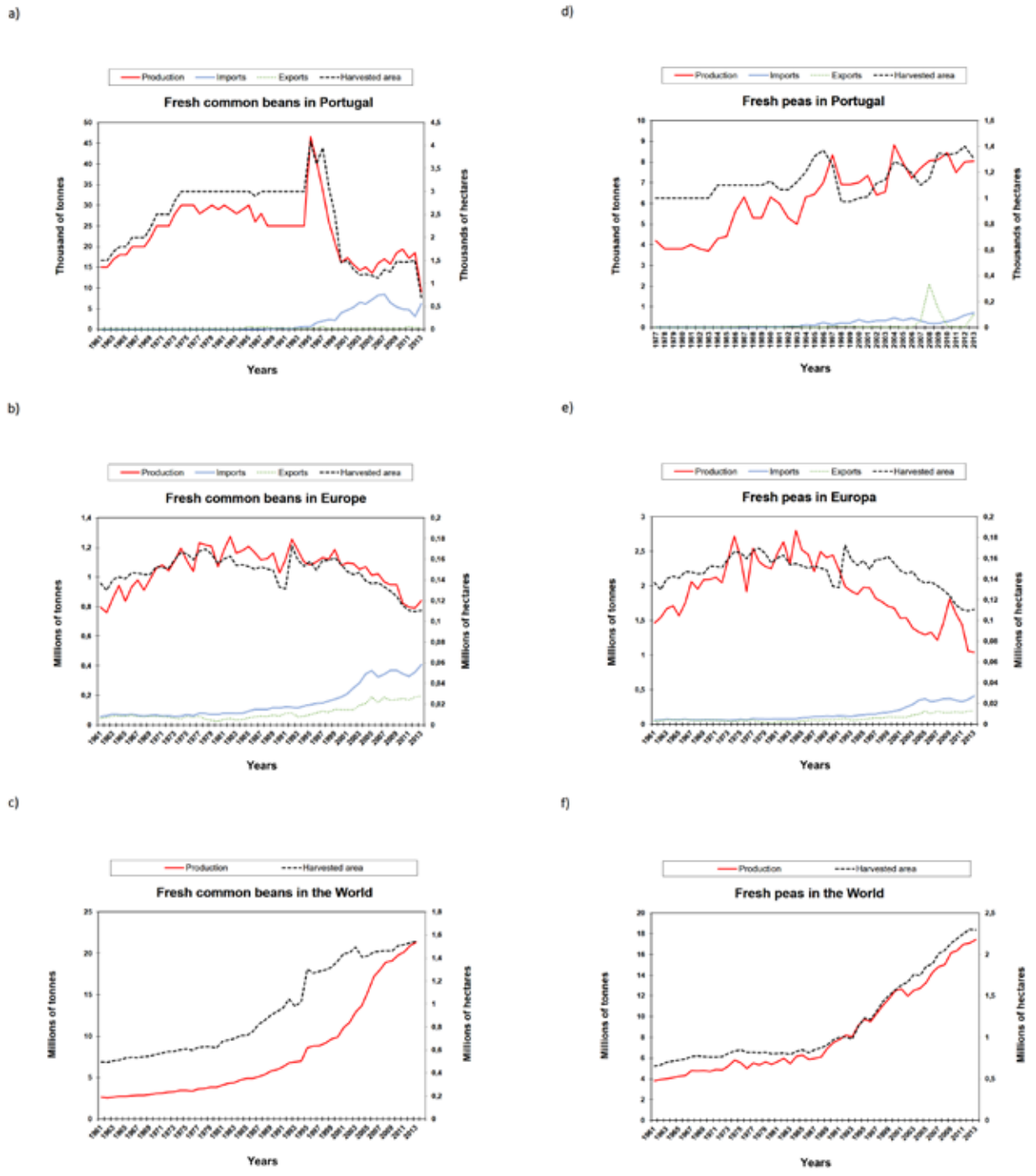

Figure 11 - Chronological evolution of production, harvested area, imports and exports of fresh common bean and peas in Portugal (a,d), Europe (b,e) and the World (c,f). Average values were retrieved from FAOSTAT, accessed on the 21st November 2016.

Mt (2013) (Figure 11c). The world production of green peas has during the same period increased about 4.5x (Figure 11f). This has been associated with a constant yield improvement in both commodities. Nevertheless, such aspect is more relevant in common bean (with a more than 2.5x increase in yield during the last 50 years) than in pea (1.3x increase in yield during the same period) and especially from the beginning of the 90's (FAOSTAT, 2016).

At the European level, after a clear increase of the respective production and harvested areas until the beginning of the 80's, we observed a decrease in the fresh grain legume production and harvested areas. This is similar to what is happening with the dry seeds counterparts. European fresh pea production is presently smaller 1.46 Mt (FAOSTAT, 2013) than 50 years ago (1.04 Mt in 1961). The fresh pea yield in 2013 is not very different from the one in 1961, due to a decay in yield observed since the end of the 90's (FAOSTAT, 2016). European fresh common bean production values are very similar to the ones in the beginning of the 60´s (0.84 Mt in 2013 and 0.79 Mt in 1961) (Figure 11b). This softer decline probably reflects a constant increase on yield being presently about 1.3x bigger than 50 years ago (FAOSTAT, 2016).

In Portugal, we also observed a decrease in the production and harvested areas of fresh common beans similar to the decline of the dry common bean production. Present fresh common bean production levels are even lower (9 kt in 2013) than 50 years ago (15 kt in 1961). As expected, this has likely contributed to shift our imports since the beginning of the 90's.

However in the case of fresh peas, Portugal is facing a complete different progression than the European average, more similar to the World trend. The Portuguese production and harvested areas, although fluctuating, have duplicated during the last 36 years (4.4 kt in 1977 and 8.03 kt in 2013). This likely lead to some sporadic increases of this commodity exports (2.10 kt exported in 2008) (Figure 11d). Additionally our fresh peas yield, and contrary to what has been faced by the average of Europe, has also been constantly improving during the same period, being presently (2013) 1.5x bigger than in 1977 (FAOSTAT, 2016).

The particular case of soybean: the most imported and most produced legume in Europe

Soybean is not considered as a grain legume by FAO statistics. Beside its role on human consumption, soybean is essentially trade for animal feed and oil extraction purposes. Nevertheless, soybean is the most imported grain legume in Portugal, which reflects our extreme external dependency on this dual use commodity. Consequently, we found relevant to analyze soybean situation in a Portuguese, European and world context.

There are no data to what concerns soybean cultivation in Portugal. Contrary to all the other (warm or cool season) grain legumes, soybean production has in the last 50 years increased both in Europe (from 0,4 Mt in 1961 to 9 Mt in 2014) and in the World (26,9 Mt in 1961, 308,4 Mt in 2014) (Figures 12a and 12b). Indeed it is the only grain legume area that is still increasing in Europe and especially since the year 2000 (Figure 12a). Soybean represents the grain legume with the bigger acreage in the continent, bigger than all the other legumes together (Rubiales & Mikic 2015).

The increase of soybean production in Europe (mainly on the Danube region countries, where water is available through rain during summer) has probably contributed to a more or less stabilization of European imports in the last decade (from 2003) (Figure 12a). Nevertheless, import levels are still very high (16,43 Mt in 2013) in comparison with the local production, making the EU external dependency on this commodity extreme.

Portugal is not an exception and we are net importers of all grain legumes and in particular of soybean. These imports are mainly consumed by the Portuguese feed industry supporting the livestock production. Since the 80's, our soybean imports have drastically increased, with some fluctuations, from 215.918 t in 1981 to 927.707 t in 1985) arriving to a maximum of 1261.790 t in 2007. After that we observed a small reduction with a present import value of 781.908 t (2013) (INE, 2016). Since Portugal almost do not produce soybean, it relies on a strong external importation with noteworthy impacts in the Portuguese food security.

The possibility to expand soybean cultivation in

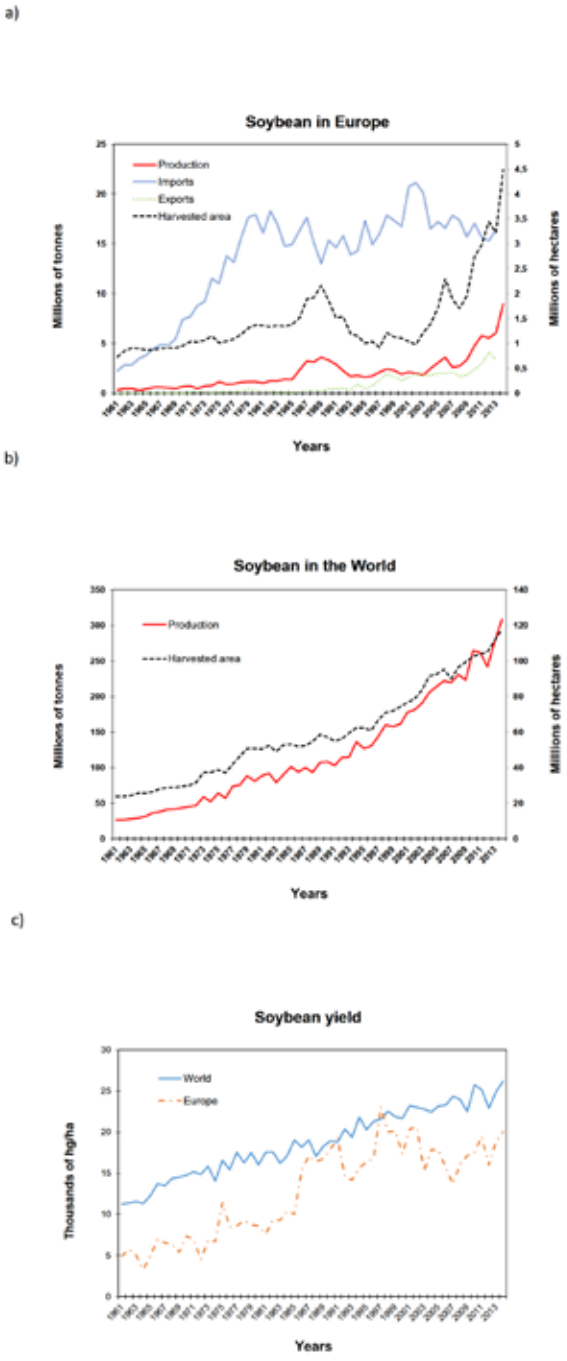

Figure 12 - Chronological evolution of production, harvested area, imports and exports of soybean in Europe (a), in the World (b), and yield progression (c). Average values were retrieved from FAOSTAT, accessed on the 21st November 2016.

Portugal, as well as in other southern countries of Europe, is very limited. Since soybean is a warm season crop with high water demand, its cultivation requests irrigation that will compete with local maize production. The only alternative will be, in a medium-long term, to develop varieties adapted to winter sowing or with less water requests (González-Bernal & Rubiales, 2016).

Grain legume research in Portugal: Quo vadis?

Portugal presents the same downwards trend seen at the European level in what concerns grain legume production, in particular in common bean and lupins and to a certain extent, faba beans and chickpeas. While we are already observing a certain recent recovery in the grain legume production at European level, such aspect is still not very visible in Portuguese statistics. This may only reflect on an even greater external dependency of Portugal on those commodities and is a concern particularly for chickpea and common bean, which are the most important grain legumes in terms of national intake. Contrasting to this adverse situation is the situation of Portuguese fresh pea production increase trend, that opposing to the European decline follows the world rising tendency. The extreme dependency of Portugal on grain legumes and particularly soybean imports is risking our balance of payment but also threatens our food and feed security. The Portuguese livestock and meat production industry is dependent of the world soybean market and prices fluctuations. This situation is becoming even more alarming since China has started to exponentially importing soybean form the world market, causing extreme instability to world prices (González-Bernal & Rubiales, 2016).

Portuguese grain legumes potential has been underexploited. As a result of little breeding efforts, grain legumes still present low and variable yields, being less attractive to farmers. Grain legumes based food products diversity for consumers is also limited reflecting local gastronomic preferences, despite their well-recognized impact on a healthy diet. Similarly to other Portuguese social-economic aspects, investment on food innovation to attract consumers has also been hampered.

Presently the European Union is trying to correct this extreme external dependency with a series of

supportive measures such as the "greening direct support". In some extend, these measures can benefit grain legume local cultivation, through the promotion of environment beneficial practices like increasing crop diversity. This has raised European farmers' interest in cultivating grain legumes again. However, this unexpected increase of the market demand has highlighted the problem of the lack of certified, high quality, modern varieties adapted to our conditions (González-Bernal & Rubiales, 2016).

An analysis of the Portuguese grain legume research of the last 25 years allowed us to identify the major key problems addressed and highlighted the national efforts conducted to overcome some of them.

The Portuguese grain legume research has produced 309 original research articles during the period 1990-2016, as described in Figure 13. Among those, the majority of publications described research accomplishments in lupins (35%), peas (22%) and common bean (15%). Research on the remaining grain legumes did not overcome the 26 papers per crop during the last twenty years.

When considering the chronological evolution of the total number of publications per grain legume species, some interesting aspects were also noticed. A consistent increase in the number of publications in grain legumes was observed till 2006 (Figure 14). In this timeframe, the majority of the published studies were conducted in lupins. Lupin research followed the same trend as previously described for its production. After 2006 to the present days, a decline in the total number of published studies was noticed, likely reflecting the economic constraints that Portugal is facing since then. Grain legume research became more diversified in terms of species, with special emphasis in recent research conducted in pea, lathyrus and common bean.

Portuguese research in grain legumes has been focused on particular disciplines (Table 2). Research conducted on lupins and cowpeas has been mainly focused on physiological and biochemical aspects dealing with their adaptation and responses toward abiotic stresses. It is noteworthy to emphasize that a considerable amount of research in lupins has been devoted to the non-food use of their seed proteins, namely as fungicides or therapeutic molecules. A considerable research effort has been undertaken to develop local faba bean genetic resources, as well as, the biochemical properties of their storage proteins with impact on animal nutrition.

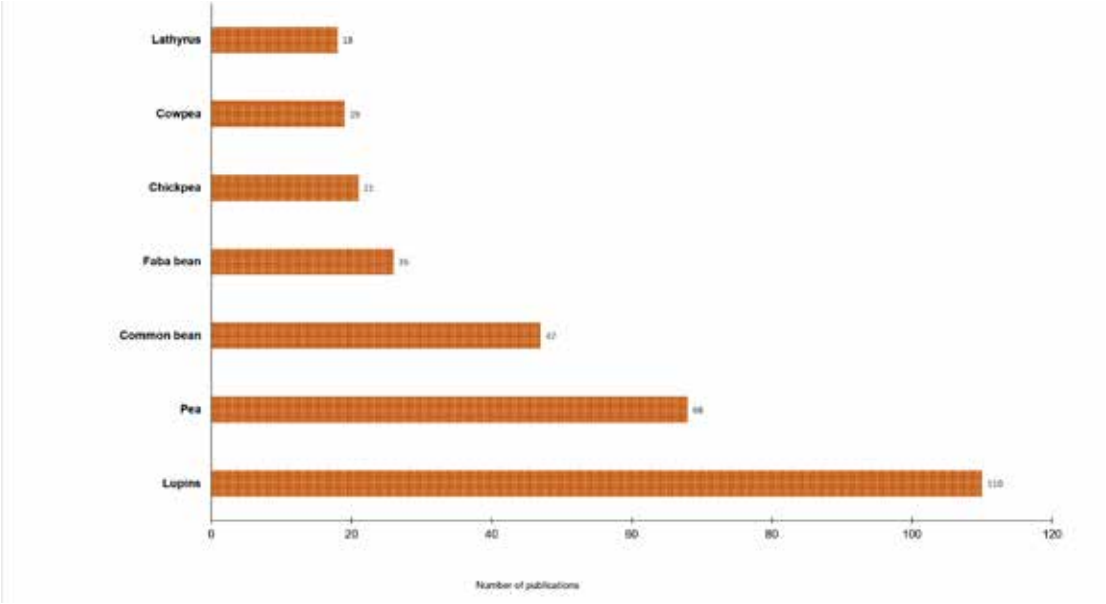

Figure 13 - Query of research scientific papers on major grain legumes published by Portuguese researchers found in Scopus (http://www.scopus.com) between 1990 and 2016. The search was performed individually for each grain legume (*Phaseolus*, *Vigna*, *Faba*, *Pisum*, *Lupinus*, *Cicer*) using the following settings: TITLE, ABSTRACT, KEYWORDS (e.g. *Lupinus*) AND AFFILCOUNTRY (Portugal) AND DOCTYPE (article) AND SUBJAREA (life sciences & health sciences) AND PUBYEAR (> 1989). Reviews manuscripts were not included. The search was conducted on 4th December 2016.

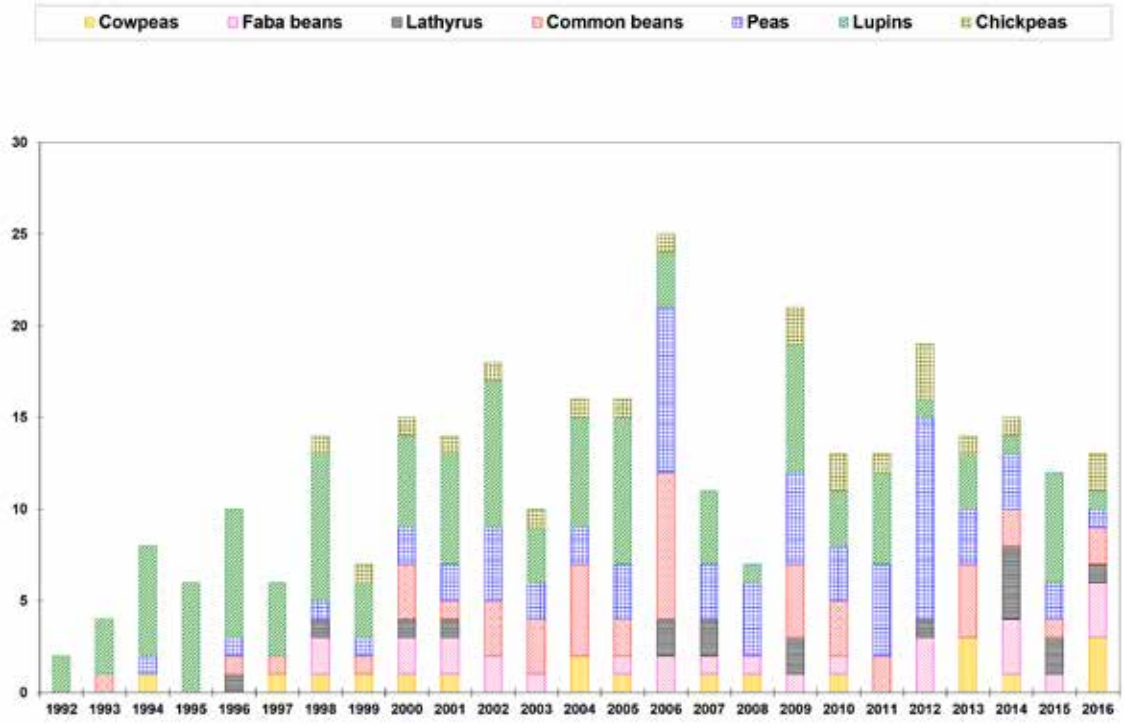

Figure 14 - Total number of research scientific papers on major grain legumes published by researchers based in Portugal found in Scopus between 1990 and 2016.

Research in lathyrus is looking for natural sources of resistance to fungal diseases, as well as, to understanding the molecular mechanism behind the outstanding ability of these legumes to tolerate harsh environments. The majority of studies in common beans were focused on the study of nutritional and quality aspects of seeds for human consumption. Portuguese peas research showed a quite equivalent research on physiology and biochemistry, food and feed uses. Likely, such concerted research efforts highlights the multiple end-uses of pea as a dual purpose crop. Interestingly, a relevant amount of the Portuguese chickpeas research has been focused on the study of the symbiotic associations here included on the physiological & biochemical discipline. From this bibliographical analysis we may conclude that expertise on a diversity of research subjects and grain legumes species exists in Portugal. Indeed, research efforts reflect the main expertise of Portuguese research teams, the end-uses of each grain legume and major production constraints of the target species studied.

National grain legumes resources and expertise for Portugal sustainable development: Opportunities and challenges

As previously reviewed, there are several research groups dedicated to different grain legume aspects, and long running grain legume breeding programs in Portugal. Around 35 cultivars from more than 10 different grain legume species are presently registered in the National Catalogue (CNV, 2016). Most of the cultivars registered belong to common bean, pea and chickpeas. However, from the grain legume cultivars registered at the national catalogue, it is not certain how many are presently licensed and available commercially to the Portuguese farmers. In addition, Portuguese grain legume production does not necessarily resign only on certified seeds, since many farmers do not buy seed for sowing every year.

In front of such a reduced grain legume national production, Portuguese grain legume breeding programs have still a lot to do to reduce grain

Table 2 - Distribution of the research scientific papers on major grain legumes published by Portuguese researchers among the major disciplines. Results came from a query made in Scopus between 1990 and 2016. Data represent the percentage (%) of articles belonging to the respective discipline among 47 papers in common beans, 26 paper in faba beans, 19 papers in cowpeas, 18 papers in lathyrus, 68 papers in peas, 110 papers in lupins and 20 papers in chickpea.

Disciplines	Common bean	Faba bean	Cowpea	Lathyrus	Pea	Lupins	Chickpea
Breeding & genetics	17,0	23,1	10,5	16,7	5,9	6,4	5,0
Physiology & biochemistry	21,3	30,8	57,9	22,2	29,4	56,4	45,0
Diseases	8,5	3,8	5,3	33,3	8,8	1,8	10,0
Pests	0,0	3,8	0,0	0,0	1,5	0,0	0,0
Cropping	8,5	0,0	5,3	5,6	1,5	3,6	5,0
Soil biology	4,3	0,0	10,5	0,0	1,5	5,5	0,0
Feed composition & quality	4,3	19,2	0,0	16,7	26,5	6,4	20,0
Food composition & quality	34,0	3,8	10,5	5,6	25,0	7,3	5,0
Non- food or feed uses	2,1	15,4	0,0	0,0	0,0	12,7	10,0

legume external dependency and bring to the different end-users more attractive varieties.

Part of the solution must pass by the development of more attractive modern grain legume varieties by harnessing Portuguese well adapted grain legume genetic resources. The new varieties should be able to match our location-specific growing conditions, and the needs of households and local and global consumers (higher quality), farmers (higher and stable yields), the processing and the seed production industry.

Besides the necessary increased support to research for productivity and resilience enhancement (breeding), also the strengthening of supply chains of high quality grain legume seeds is needed, as stated in the GPC 10 years strategic plan recently released (GPC, 2016). The valorization of supply chains from breeders to farmers, and from farmers to markets and end users (consumers and the processing industry) is needed, including the diversification of grain legume markets. Support should be also given to a stronger integration of improved grain legumes varieties and better management techniques into cropping systems, with the maintenance or further development of supportive measures as the greening direct support at European Union level. By adding grain legumes to a cropping system, total productivity of all crops will be enhanced by increasing the availability of nitrogen and other mineral nutrients, disrupting pest, weed, and disease cycles, enhancing nutrient and water use efficiency, reducing the impact of weather extremes, and augmenting system diversity (GPC, 2016).

Grain legumes should also be further integrated into our food systems by reinventing traditional gastronomy to more attractive, ready-to-eat food formulations. Grain legumes are still central to Portuguese traditional gastronomy. With rapid increases in global food needs, the role of grain legumes will become even more significant, especially with regard to dietary protein and micronutrients. Their increased consumption and cultivation will finally lead to a reduction of the global economic burden caused by prevalent chronic diseases and lessening the environmental impact of agriculture, diversifying protein supply and increasing Portuguese autonomy and agriculture sustainability. However, relevant, effective innovation for increasing grain legume production and consumption requires multidisciplinary approaches that combine well-targeted breeding and agronomy with socio-economic and market knowledge (GPC, 2016). For instances, consumers can be supported to incorporate more grain legumes into their diets, reducing their meat consumption, but grain legume production, especially at local level, will need to keep pace with any increased demand in terms of quantity and quality.

CONCLUSIONS

Portuguese grain legume situation reflects the European trends, in which production and cultivated areas are decreasing and the dependency

on grain legume imports is increasing. Portugal has tremendous underexploited genetic resources and the necessary scientific expertise to reverse this trend, but more investment in grain legume research and grain legume breeding is needed. Possible approaches include not only productivity and resilience enhancements but also the strengthening and valorization of supply chains. Innovative and more attractive food products need to be formulated, to stimulate both grain legume consumption and indirectly its local production as part of a healthy and environmentally friendly diet. Farmers need to have new varieties able to deal with local environmental conditions, but also with enhanced quality that would be an attractive source of income. Some alternative promising approaches are the cultivation of grain legumes to be used as fresh commodities or the use of grain legumes as partners in intercropping agricultural systems.

The current crisis scenario aggravated our dependency on external grain legumes resources, since it hampered both Portuguese grain legume research programs and agricultural production. Several EU initiatives are tackling this challenge by promoting research in grain legumes or its use in agricultural systems. Portuguese decision-makers, as well as, consumers need to be (more) aware of the risks of having our food autonomy and safety driven by the fluctuations of a global market ruled by the strong emerging economies. Today we still have an option to import grain legumes but tomorrow this reality seems to be uncertain. "Quo Vadis?"

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