Grazing fodder species rich in bioactive secondary metabolites in small ruminants: health, zootechnical, economic and environmental benefits

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Abstract

For several years, small ruminant breeders have experienced significant difficulties in gastrointestinal strongyles control, a major disease in grazing sheep and goats. Indeed, parasites are becoming increasingly resistant to several families of antiparasitic. Moreover, treatments based on the use of synthetic anthelmintics have other environmental and societal limits. For 4 years, the CASDAR FASTOChe project has studied agroecological alternative solutions for the breeders based on the grazing of plants rich in bioactive secondary metabolites (BSMs), included condensed tannins. 3 species were tested: chicory, plantain and sainfoin. A lot of on-station experimentations, surveys and farm monitoring showed that the bioactive compounds in these plants have no significant effect on gastrointestinal parasite infestation levels in sheep and goats, contrary to what the literature suggests. Nevertheless, they are not lacking in zootechnical and agronomic interest with good animal performance and interesting forage production. The environmental benefits of sainfoin and plantain have also been demonstrated, with lower nitrogen emissions. Finally, simulations of production systems using grasslands based on bioactive plants showed that their economic interest is strongly linked to their production.

Keywords: Grazing - Bioactive plants - Small ruminants - Gastrointestinal strongyles - Functional food

1. Introduction

The sheep and goat sectors are facing fluctuations in production, rising raw material costs and price volatility, all of which are creating increasing economic constraints. While we need to produce more, we also need to produce better, with greater technical efficiency and fewer inputs. To achieve this, grazing is a favoured means of adaptation. It responds to new industry trends and consumer expectations, with more ecological farming systems that respect animal welfare and are associated with a good product quality image, while limiting production costs. However, there are a number of obstacles to its development on small ruminant farms, not least the difficulties involved in controlling parasitism. Infestation by gastrointestinal strongyles (GIS) is a major pathology in small ruminants on pasture, leading to production losses. In sheep, they have an average impact of 22% on milk production and 15% on lamb growth (Mavrot *et al.*, 2015). These parasitic worms are also responsible for significant drops in milk production in goats (Hoste and Chartier, 1993; Hoste *et al.*, 2010).

For several decades, control of these parasites has been based exclusively on chemical molecules with anti-helminthic activity (HA; Bordes, 2022). The inappropriate use of various families of HA has led to the

development of resistance to these treatments in SGI (Rose *et al.*, 2015, Jacquiet, 2012). This resistance, combined with restrictions on the use of these molecules in the dairy industry to avoid residues, could lead to therapeutic deadlocks in the medium to long term. What's more, some of them, such as avermectins, have been shown to be ecotoxic for grassland entomofauna (Lumaret *et al.*, 2012). In grazing livestock systems, there is therefore a need for alternative control methods for economic (direct costs of treatment, but also indirect costs), ecological and societal reasons.

Several studies carried out under controlled conditions in buildings have shown that the consumption of feed rich in BSMs (bioactive secondary metabolites) by small ruminants reduces parasite infestation by SGI, suggesting promising avenues for use directly on pasture (Hoste *et al.*, 2015; Hoste and Niderkorn, 2019). Initial trials and/or observations on farms are pointing in this direction, and farmers are increasingly asking for advice on the subject. In addition, several studies have shown that the consumption of plants containing various MSBs can also help to reduce the risk of weathering and the environmental impact of ruminant farming by reducing greenhouse gases (GHGs).

However, given the lack of operational references for pasture management, specific work needs to be carried out before 'turnkey' practices can be disseminated to farmers. The aim of the FASTOChe project was therefore to develop complementary solutions to current parasitism management, without which there is a risk that, despite public demand, farmers will turn away from grazing. It is part of the development of farming systems that reconcile economic, environmental and social performance.

To achieve this, 3 plants containing BSMs were studied: sainfoin, chicory and lanceolate plantain (referred as plantain in the rest of this article). A wide range of investigations were carried out through experiments at experimental stations, surveys and monitoring on farms.

The aim of the FASTOChe project was to study the benefits and practical application of grazing MSB-rich forage species on small ruminants: meat sheep (MS), dairy sheep (DS) and dairy goats (DG).

The Institut de l'Élevage is the project leader, working with twelve partners: Chambers of Agriculture 64, 71 and 87; CIIRPO (experimental site, 87); EPLEFPA de Olivier de Serre d'Aubenas with the Pradel farm (experimental site, 07), La Cazotte - Saint Affrique (experimental site, 12), Fontaine Sud Bourgogne-Charolles (experimental site, 71), Carmejane (experimental site, 04) ; INRAE UE 1373 FERLUS (Fourrages Ruminants, Environnement de Lusignan, site experimental, 86), INRAE de Theix (UMR Herbivore et Herbipôle, site expé, 63), INRAE/Ecole Nationale Vétérinaire de Toulouse (UMR IHAP INRAE/ENVT, 31) .

2. Materials and method

2.1. A large and diverse study area

The project involved the 3 small ruminant sectors in 2 to 4 production basins, depending on the sector, to cover a diversity of soil and climate situations, breeding systems and IGS epidemiology. For example, work on MS involved the central-western (Limousin/Poitou-Charentes), south-eastern, Massif Central and central-eastern (Burgundy) basins; work on DS included the Rayon de Roquefort and Pyrénées-Atlantiques basins; and DG was studied in the central-western and south-eastern basins. In all, 8 separate study areas were involved.

2.2. Feedback from farmers

The first action was to draw up an inventory of sheep and goat farmers' practices in terms of managing gastrointestinal parasitism and the use of MSB plants on pasture; the second was to work with multi-stakeholder groups (farmers, advisors, etc.) to co-construct innovative solutions that could be applied on farms. To meet these objectives, an inventory was carried out of farmers' practices in terms of managing parasitism on pasture, their expectations and the conditions that need to be met before alternative grazing solutions can be put in place. In order to gather an overall picture, information was gathered at two levels for each study area: firstly, via collective meetings of technicians and secondly via surveys of farmers.

Operational Innovation Groups (OIGs) were set up in each study area to monitor the key stages of the project and to co-construct solutions, share experiences and formulate practical advice. In the end, 81 farmers and 83 farm technicians were involved as part of a survey and/or through the 6 OIGs and various technical meetings on parasitism management.

2.3. Experiments in controlled environments

The aim of this central action of the FASTOChe project was to develop, based on an ambitious experimental set-up, grazing practices based on the use of MSB-rich plants adapted to the two species and in different production basins. To achieve this, three levels of investigation were carried out in parallel:

- Animal production and health trials, to measure the effects of parasites and animal performance: 14 trials on experimental sites, including 8 for meat sheep, 2 for dairy sheep and 4 for goats. The grazing of sainfoin, plantain and chicory (pure sowing) was compared with that of grassland without MSB plants,
- Mini plot trials were carried out at several sites: Lusignan (86), Le Mourier (87), Euralis (64) and Carmejane (04). The vegetative behaviour of several plants, including chicory, plantain, sainfoin and trefoil, was studied, both in pure crops and in mixtures: establishment, fodder production and feed value,
- Additional *in vitro* measurements (45 samples) were carried out at INRAE in Theix with a dual objective: to examine the nutritional value of these plants through their degradability and the production of volatile fatty acids under conditions simulating the ruminal environment, and to measure environmental indicators through the production of enteric methane and ammonia.

2.4. Farm monitoring and technical and economic simulations

The aim of this action was to define the practical procedures for applying the solutions identified as being of interest on livestock farms and to assess their impact on the operation (crop rotation, grazing management, parasitism control, etc.) and performance of the systems (technical, economic and environmental). It includes two sub-actions :

- Monitoring on commercial farms: the practices tested on the experimental sites were deployed on commercial farms and/or farms run by agricultural colleges to determine the conditions for success in a variety of contexts. This involved: 3 meat sheep farms, 4 dairy sheep farms and 2 goat farms,
- A proposal for production systems using grasslands containing MSB plants known as "Alicaments": 8 simulations on case-types to assess the economic benefits.

3. Results

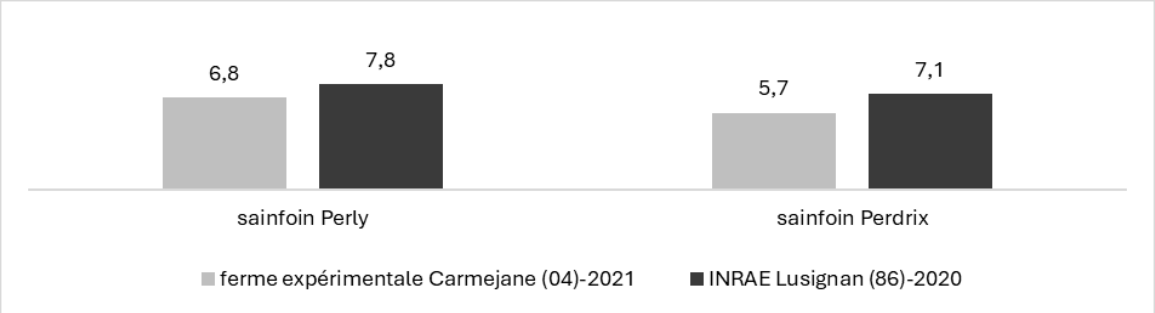
In this article, we present the results of the FASTOChe project based on the 3 plants studied, sainfoin, plantain and chicory, using the results of experiments and monitoring on farms.

3.1. Sainfoin

An agronomic interest

Sainfoin is a legume mainly grown in the south of France on limestone soils. It has the advantage of not causing weathering. It lasts for 2 to 3 years. It tends to be sown in spring, as late summer is riskier due to drought. Sainfoin is traditionally harvested as hay, but it can also be grazed after winter when it is put out to grass and in autumn even after the first frosts. It is, however, sensitive to trampling.

Less productive than alfalfa, the yields obtained in the trials are in the region of 4.5 to 6 tonnes of dry matter per hectare in the year following sowing (after deduction of 20% due to measurements in mini plots) (Figure 1).



Source: Idele/INRAE Lusignan/Carmejane experimental farm
** Annual yields from the spring following sowing. As these are yields obtained in small plots, it is commonly accepted to deduct 20% for open field cultivation.*
Figure 1: Yield of pure sown sainfoin (in tonnes of dry matter per ha*)

Interesting protein and condensed tannin values

The 10 sainfoin samples analysed as part of this study show a particularly high protein content, in line with INRAE tables at the early budding stage. In spring, it reached 157 g of total nitrogenous matter per kg of dry matter, compared with over 230 g in autumn. These values are respectively 23% and 60% higher in both seasons than those for plantain and chicory. The richness of sainfoin in condensed tannins was confirmed in this study, with an average of almost 50 g per kg of dry matter. This content appears to be much higher than in plantain and chicory, which contain less than 3g. It also varies (from 24 g to 60 g) and is more concentrated in autumn, with 53 g compared with 41 g per kg of dry matter in spring.

A good plant for the environment Sainfoin is an environmentally beneficial plant compared to a grass. Its consumption helps to reduce greenhouse gas emissions. On the one hand, because urinary nitrogen discharges and, consequently, ammonia production are lower; on the other, because enteric methane emissions are reduced. For the 3 species tested, there was little or no variety effect on all the chemical components and ruminal fermentation parameters. The period effects varied according to the plants and the sites where they were planted. For the same nitrogen content, the urinary nitrogen discharge indicator (NH_3) was lower when plantain and sainfoin were fermented. Finally, very marked interaction effects were observed between period and site on the one hand, and period and species on the other, for all the parameters studied.

Taken together, these results show that the effect of the harvesting period on the biochemical characteristics and digestion of these bioactive forage plants varies significantly depending on the geographical area of implantation and the species.

An antiparasitic effect to be demonstrated

Pure sown sainfoin grazing was tested continuously and in the form of 2-to-4-week courses on dairy ewes, renewal ewe lambs and dairy goats.

- In courses of 2-to-4 weeks in dairy ewes

At the end of the two 2-to-4-week cures carried out on a sainfoin plot in two consecutive years, the dairy ewes showed slightly higher excretion levels than those who remained on grass and legume-based pastures without sainfoin (table 1). Antiparasitic treatment was required in all cases, as the commonly accepted threshold of 500 opg (eggs per g) was exceeded. In addition, the average quantities of sainfoin consumed by the ewes during the 2 treatments were estimated at 0.9 kg of dry matter per ewe per day. Grazing sainfoin had no effect on their milk production and rates compared with ewes grazing without this legume. Changes in animal weight were also unaffected.

Table 1: Results with sainfoin grazing in the form of cures by dairy ewes (La Cazotte)

YEAR OF THE TRIAL	2019		2020	
CURE NO.	1	2	1	2

DATE	16/04 Start trial	15/05 End of trial	17/06 Start of trial	30/06 End of trial	21/04 Start of trial	11/05 End of trial	18/06 Start of trial	02/07 End of trial
BATCH TREATED WITH A PEST CONTROL PRODUCT	-	-	-	2200 opg*	2 opg	6 opg	177 opg	432 opg
UNTREATED BATCH WITHOUT SAINFOIN	1322 opg	2219 opg	-	958 opg	13 opg	5 opg	200 opg	592 opg
BATCH IN CURE OFSAINFOIN	1994 opg	1002 opg	-	1228 opg	0 opg	3 opg	209 opg	628 opg

**Opg: eggs per g of faeces*
Source: Idele/ENVT/lycée agricole de Saint Affrique (12)

- A 3-week course of treatment for replacement ewe lambs

Pure sown sainfoin grazing was tested with 4-month-old ewe lambs in the form of a 3-week course alternating with grassland without sainfoin. The results of the coproscopies showed very few strongyles' eggs. Three months later, the excretion rates of ewe lambs grazing sainfoin as a cure were 4 times higher than those of young females fed without tannins.

- Continuous in renewal ewe lambs

Continuous grazing of sainfoin does not eliminate the need for chemical antiparasitic treatment either. In the first trial, ewe lambs grazing grassland without sainfoin showed a low level of excretion (less than 200 eggs per g) compared with more than 600 eggs per g for those on sainfoin for nearly 3 months. In the second trial, the parasite load appeared to be reduced by sainfoin, as it was halved. However, with more than 1,000 eggs per g, the level of excretion exceeded the threshold of 500 opg, commonly accepted as a recourse to treatment. However, the number of animals said to be "excretors", i.e. with more than 500 opg of digestive strongyles, was lower when the ewe lambs had grazed sainfoin: 73% compared with 96% for ewe lambs eating grass only.

- A cure for dairy goats

The grazing of sainfoin on goats has been tested in cures in 4 trials. The results confirm that the anti-parasitic effect has yet to be demonstrated. At the Lusignan site, the number of opg excreted (905 in the sainfoin batch at the end of the trial) increased in parallel for the sainfoin and control batches in 2019 and tended to decrease over the trial in 2020 (158 *vs* 315 at the end of the trial) (Caillat *et al.*, 2022a). This difference between the 2 years can be explained by a different proportion of sainfoin in the grassland (60% in 2019 *vs.* 86%). In the two trials carried out on the Pradel site, a slight drop in the level of opg excretion for goats grazing sainfoin was measured (176 opg at the end of the 2020 trial) with relatively low levels of parasite load. Overall, the trials showed that cures of at least 2 weeks grazing on sainfoin grassland, with the quantity ingested at grazing maximised, are not a substitute for anthelmintic treatment. However, the dairy response is good. With the same protein content in the grassland, no difference in milk production was measured at Lusignan. In addition, better persistency was recorded when the sainfoin stage was advanced. Finally, there was no difference in milk quality criteria: protein rate, butyrate and cell level.

Limited economic interest

The integration of sainfoin into the forage system of the Saint Affrique agricultural college (12) was simulated. A total of 6.5 ha of grassland (including 1.6 ha of sainfoin, 1.6 ha of hybrid ryegrass and 3.2 ha of a grassland mixture) was planted for grazing at the end of the milking period, replacing a plot currently used to build up fodder stocks. Stock requirements would thus be reduced by increasing the proportion of ewes grazing in the spring. Purchases of concentrates and dehydrated alfalfa would also be reduced by 10 tonnes of dry matter per year. However, the economic loss at farm level is estimated at €2,000 (or 0.5% of the farm's total income).

3.2. Lanceolate plantain

A productive plant

In combination with one or more legumes, plantain helps to produce productive grassland with a very good protein content. Plantain can be planted in all types of soil. It lasts for around 3 to 4 years. Although it is mainly used for grazing, it can be harvested with the same precautions as legume-rich grassland when harvesting the leaves. Trampling does not seem to affect its long-term survival. Although some farmers sometimes mention a learning curve, plantain is a palatable plant. It does not cause weathering and does not require any special grazing precautions.

The results of this study suggest that plantain should be sown as a mixture with one or more legumes and possibly a grass. Except for areas that are clearly unsuitable for plantain cultivation, the yield of plantain sown pure with a sowing rate of 12 kg per ha varies almost twofold depending on the area and variety. With an input of 50 U of nitrogen per ha (aim for 100 U per ha to optimise yield), average annual production reaches 6 tonnes of dry matter per ha (after deduction of 20% due to measurements in mini plots). Mixing with one or more legumes adapted to the area (alfalfa, sainfoin, white clover, red clover, trefoil) resulted in an increase in annual yield from 3% to 68%, depending on the year of sowing.

Furthermore, as plantain is a plant that takes a long time to establish, combining it with other species limits the number of weeds. For example, at the CIIRPO experimental site at Mourier (87), the count of miscellaneous plants in the year following sowing drops from 14% when plantain is sown pure to 10% when it is combined. The Groupement de Valorisation Agricole (GVA) in Mézières sur Issoire (87) has developed three types of mixtures that are particularly successful in the north of the Haute-Vienne. Other combinations tested in this study are also possible.

Good protein content but low in BSM

Although the total nitrogen content of plantain is still much lower than that of sainfoin, it reached 138 g per kg of dry matter on average in the 12 samples analysed. This is equivalent to that of a natural lowland meadow or English ryegrass at the early heading stage. Plantain also has a higher nitrogen concentration in autumn than in spring, with a difference of 11%. In the absence of available predictive equations, Digestible Protein values in the intestine have not been calculated. Unlike sainfoin, plantain is low in condensed tannins. The secondary metabolites it contains are from a different type (iridoid glycosides).

A fairly positive environmental record

Plantain consumption has a beneficial effect on reducing greenhouse gas emissions. In fact, its consumption reduces urinary nitrogen emissions and therefore ammonia production, compared to a grass. To a lesser extent, enteric methane emissions are also reduced.

Plantain grazing: the same vigilance against digestive strongyles as with grasses

Pure plantain grazing was tested continuously and in the form of 2–3-week courses in finishing lambs and renewal ewe lambs. Digestive strongyles excretion rates, assessed by faecal sampling of all the animals every fortnight, were compared with those of young lambs grazing grassland without plantain. Growth rates were also measured. Monitoring was also carried out on three livestock farmers in the Haut-Vienne region, using less stringent measures. The plantain was sown in a mixture with alfalfa and white clover.

- In courses of 2 to 3 weeks

At the end of the two 2-week cures carried out on a plantain plot for two consecutive years, the lambs showed excretion levels either equivalent to or higher than those remaining on permanent grassland (table 2). An antiparasitic treatment was required in all cases, as the number of eggs counted exceeded the commonly accepted threshold for antiparasitic treatment (500 opg). Two trials were carried out in 2020 and 2021 with dairy goats at the INRAE FERLUS site. The low total nitrogenous matter content of the

plantain grassland affected the milk production of the goats. Due to low levels of OPG excretion at the start of the trial, it was not possible to conclude on a potential effect on gastrointestinal strongyles (Caillat *et al.*, 2022b).

Table 2: Results of trials grazing plantain for 2 weeks on fattening lambs (INRAE Theix)

YEAR OF THE TRIAL		2019			2021		
TYPE OF GRASSLAND GRAZED Continuously grazed natural grassland		+ PLANTAIN CURE FOR 2 WEEKS		Trend with/without grass	+ PLANTAIN CURE FOR 2 WEEKS		Trend with/without grass
		WITHOUT	WITH		WITHOUT	WITH	
NUMBER OF EWE LAMBS PER BATCH		24	24		24	24	
EXCRETIONS OF DIGESTIVE STRONGYLES EGGS	At the start of the trial	415 opg*	453 opg	=	75 opg	63 opg	=
	At the end of the trial	863 opg	933 opg	=	1200 opg	1500 opg	+
GROWTH		184 g/d	179 g/d	=	184 g/d	205 g/d	+

**Opg: eggs per g of faeces*
Source: Idele/ENVT/INRAE de Theix

- Continuous grazing

In the three trials conducted in continuous mode with 100-day-old lambs, plantain grazing led to a reduction in the number of eggs (opg) counted in the faeces: from 100 opg to 400 opg depending on the trial. However, in two of the trials, the reduction was not sufficient to save on antiparasitic treatment. In fact, the threshold of 500 opg, commonly accepted as an indicator of the use of chemicals, was well exceeded. Monitoring carried out on the 3 farms shows the same trend. In addition, an increase in the population of worms counted in the digestive tract was recorded for lambs that grazed plantain compared with those that did not. Lastly, lamb growth was 66% lower than in the batch of lambs treated with a non-remanent antiparasitic every six weeks.

On-farm monitoring shows mixed results for renewal ewe lambs, but no significant effect of plantain on the level of digestive strongyles egg excretion (table 3).

Table 3: Monitoring results for 3 farmers with continuous grazing of mixed plantain by renewal ewe lambs

BREEDING		GAEC Raymond (16)	GAEC Dussouchaud (87)	GAEC Lorgue (87)
TYPE OF GRASSLAND		Plantain + alfalfa + white and red clover (known as the "GVA 87 mix")		
GRAZED AREA		3 ha	3 ha	3.7 ha
NUMBER OF EWE LAMBS		141	100	123
AVERAGE DATE OF BIRTH		December 2019	January 2020	March 2020
MONITORING START DATE		4 May 2020	22 June 2020	30 June 2020
WEIGHT AT START OF FOLLOW-UP		39.9 kg	36.2 kg	24.9 kg
WEIGHT ON 20 OR 22 JULY 2020		48.8 kg	42.0 kg	29 ,7 kg
GROWTH		193 g/d	116 g/d	222 g/d
EXCRETIONS OF DIGESTIVE STRONGYLES EGGS	At the start of the trial	209 opg*	375 opg	262 opg
	At the end of the trial	136 opg	388 opg	613 opg
TREND AT END/BEGINNING OF TRIAL		=	=	+

**Opg: eggs per g of faeces*
Source: Idele/ENVT/CA

An economic interest linked to the agronomic potential of plants

Given the technical results, plantain offers an economic advantage provided that the plant has an agronomic interest. This is precisely the case in the simulations carried out on two farms, one with 500 ewes in the Limousin zone, the second with 960 ewes in the Burgundy grassland zone. The mixtures of plantain, alfalfa and white clover sown annually are particularly productive and more resistant to drought than those based on grasses and legumes. As a result, significant savings in concentrated feed have been made on the ration for finishing lambs. In the end, savings amount to €3,500 in one of the simulations and €2,500 in the second, including the cost of seed (2023 price context).

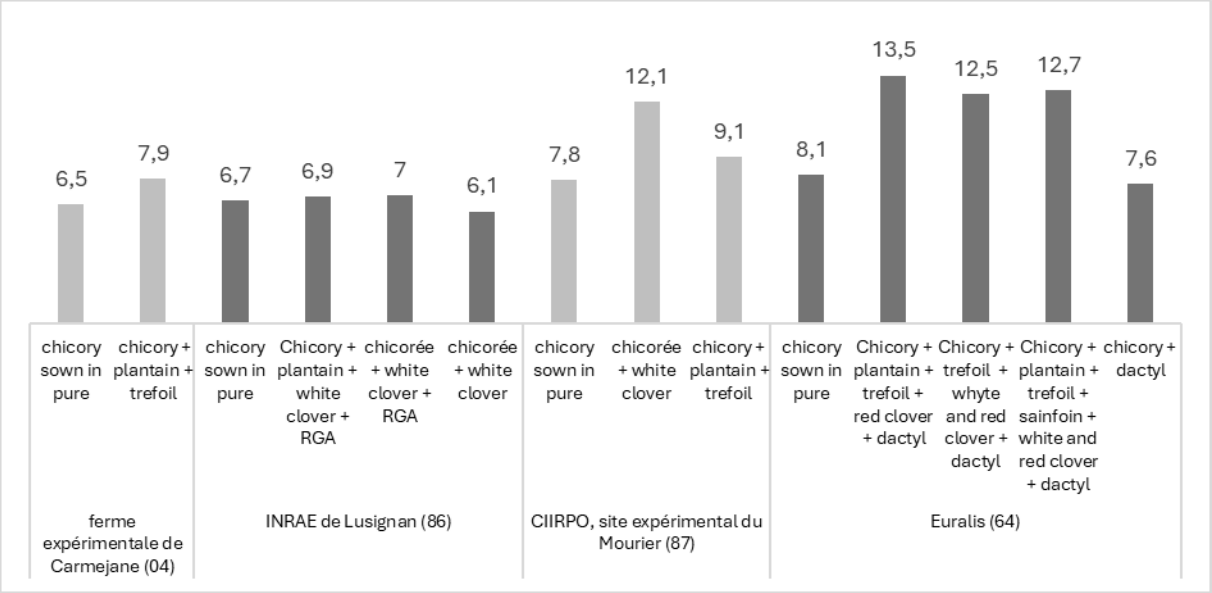
3.3. Chicory

Chicory: a pasture plant

Chicory thrives in all types of soil (pH from 5.5 to 7). However, it does not tolerate moisture well. It is therefore better to plant it on plots that drain easily. It is also highly resistant to water stress. It lasts for at least 3 years and is sometimes difficult to get rid of. Chicory can only be harvested as silage, and grazing is preferable. It is palatable but rises quickly and is not very easy to grow. Chicory should only be grazed on a rotational basis, with returning to the plot every 3 weeks to prevent the stalks from rising. Moreover, this plant does not cause weathering and does not require any special grazing precautions.

The results obtained in this study suggest that chicory should be sown in a mixture with one or more legumes and possibly a grass (Figure 2). In fact, pure yields at a sowing rate of 10 kg per hectare vary by a factor of two depending on the variety and the level of nitrogen input. In our study, mixing with white clover or trefoil at sowing resulted in an increase in annual yield depending on the year of sowing of between 22% and 59% in 3 out of 4 sites.

Furthermore, as chicory is a plant that takes a long time to establish, combining it with other species limits the number of weeds. For example, at the CIIRPO, experimental site at Le Mourier, the count of miscellaneous plants in the year following sowing drops from 12% when chicory is sown pure to 8% when it is combined with white clover. Several associations tested in this study with white clover or birdsfoot trefoil are also possible.



Source: Idele/CIIRPO/INRAE Lusignan/ferme expérimentale de Carmejane/Euralis
Annual yields depending on the year and seeding rate: 10 kg/ha, with the exception of the Carmejane experimental farm with 12 kg/ha.
Figure 2: Increased yields when chicory is sown in a mixture with a legume (in tonnes of dry matter per ha)

Good protein content and no effect on greenhouse gases

Although the total nitrogen content of chicory is still much lower than that of sainfoin, it reached 140 g per kg of dry matter on average in the 19 samples analysed. This is equivalent to that of a natural lowland meadow or English ryegrass at the early heading stage. Moreover, chicory has a higher nitrogen concentration in autumn than in spring, with a difference of 16%. In the absence of available predictive equations, Digestible Protein values in the intestine have not been calculated.

On the other hand, chicory is low in condensed tannins, unlike sainfoin. The secondary metabolites it contains are of a different type (sesquiterpene lactones). Under the conditions of this study, chicory has a neutral environmental balance compared with that of a grass. In fact, indicators of pollutant emissions such as enteric methane and urinary nitrogen emissions remain relatively unchanged.

No significant effect on digestive strongyles in lambs

The grazing of pure seeded chicory was tested continuously and in the form of 2–3-week courses in finishing lambs and renewal ewe lambs. Digestive strongyles excretion rates, assessed by faecal sampling of all the animals every fortnight, were compared with those of young lambs grazing pastures without chicory. Infestation rates were measured in two trials by counting worms in the digestive tracts of 4 lambs per batch.

- In courses of 2 to 3 weeks

At the end of the two 2-week cures carried out on a chicory plot, the lambs had excretion levels that were either equivalent to or slightly lower than those of the lambs that remained on permanent grassland (table 4). In the second case, antiparasitic treatment was required, as the number of eggs counted exceeded the commonly accepted threshold for antiparasitic treatment (500 opg) with almost 1,000 opg. Growth rates remained relatively equivalent between the trial batches.

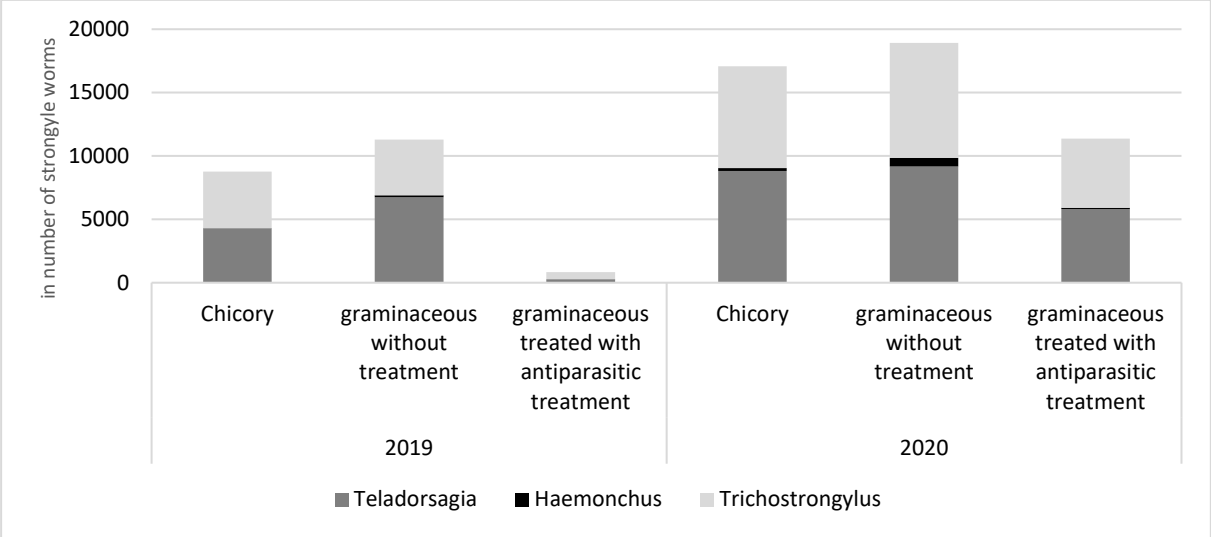
Table 4: Results of 2-week chicory grazing trials on fattening lambs (INRAE Theix)

YEAR OF THE TRIAL		**2019**			**2021**		
TYPE OF GRASSLAND GRAZED **Continuously grazed natural grassland**		+ CHICORY CURE FOR 2 WEEKS		Trend with/without chicory	+ CHICORY CURE FOR 2 WEEKS		Trend with/without chicory
		WITHOUT	WITH		WITHOUT	WITH	
NUMBER OF EWE LAMBS PER BATCH		24	24		24	24	
EXCRETIONS OF DIGESTIVE STRONGYLES EGGS	At the start of the trial	415 opg*	426 opg	=	75 opg	72 opg	=
	At the end of the trial	863 opg	885 opg	=	1200 opg	990 opg	-
GROWTH		184 g/d	171 g/d	=	184 g/d	196 g/d	=

**Opg: eggs per g of faeces*
Source: Idele/ENVT/INRAE de Theix

- Continuous grazing

In the three trials, continuous grazing of pure seeded chicory by 100-day-old lambs appeared more favourable in terms of reducing digestive strongyles. The number of eggs counted in the faeces was reduced by 300 opg to 400 opg compared with lambs on grassland without chicory at the end of the grazing period. The number of worms counted in the lambs' digestive tracts confirms this trend, being between 10% and 20% lower (Figure 3). Finally, lamb growth rates increased by 19% to 34% depending on the trial. However, compared with the batch of lambs that received antiparasitic treatments every six weeks, all these indicators remained less favourable. For example, the number of worms identified in the abomasum and intestine increased by a factor of 1.5 and 10 in the two trials. Growth rates followed the same trend, falling by 30% on average.



Source: Idele/CIIRPO/ENVT

Figure 3: Populations of the 3 most common types of digestive strongyles counted in the digestive tracts of lambs (number of worms) (CIIRPO trial)

Economic interest

The economic simulations for the Pyrénées-Atlantiques dairy sheep model show that the area available for developing MSB-rich forage plants is too limited to have a significant effect on the system and the farm's economic results. However, the better performance of chicory in summer means that ewes can graze more securely during this period.

In the case of the goats in the west-center of France, the development of 'alicament' grassland based on plantain, chicory, trefoil, alfalfa and medicinal plants means that the goats can graze longer in July and October. The reduction in the need for concentrates and stored fodder means a saving of around €2,000 a year.

4. Discussion and conclusion

The FASTOChe project has concretely demonstrated the interests and limitations of the three bioactive plants studied. A summary based on trials and surveys (Versavaud, 2019) and on-farm monitoring reveals the following points:

- Sainfoin is a plant that is non-acidogenic, has an annual yield of around 5 tonnes of dry matter per hectare, has a high protein content, is rich in condensed tannins and has a beneficial effect on the environment. Grazing sainfoin in the form of cures has no significant effect on digestive strongyles excretion. In continuous mode, a reduction in excretion was measured in one trial and an increase in the other. In both cases, chemical treatment was required, as the 500 opg threshold was exceeded.
- As far as plantain is concerned, the results show that it is preferable to sow it in a mixture with at least one legume. It has a high nitrogen value and grazing it has a beneficial effect on greenhouse gas emissions. Grazing plantain in the form of cures has no effect on digestive strongyles excretion. In continuous mode, a reduction of 100 opg to 400 opg was measured depending on the trial. In two of the three trials, chemical treatment was necessary.
- Chicory should also be sown in a mixture with at least one legume. Its nitrogen value is very good, but grazing it has no effect on greenhouse gas emissions. Grazing it in the form of cures did not reduce the excretion of digestive strongyles in the lambs. In continuous mode, a reduction in

excretion and infestation was measured in the 3 trials. In 2 of them, however, the 500 opg threshold was exceeded.

As measured during the project, the BSM content of the 3 plants studied on grazing is subject to numerous factors of variation (date of use, weather conditions). It would therefore seem difficult to use them in livestock farming solely for pest control purposes. In view of the results obtained in this study, grazing these plants does not appear to be a preventive solution and is not a substitute for anthelmintic treatment.

The results obtained as part of the PARALUT project (led by the Centre Départemental d'Élevage Ovins and funded by the Nouvelle-Aquitaine region 2018-2022) point in the same direction. Its aim was to study the trough feeding of plants rich in condensed tannins to fattening lambs, renewal ewe lambs and ewes. It showed no benefit in reducing the level of parasite excretion over periods ranging from 3 to 9 weeks (Bordes, 2022).

This finding can be largely explained by the dilution of the active substances during grazing, given that the literature accepts that the concentration of tannins in the daily ration should be in the region of 2% to 3% (Hoste *et al.*, 2006). In the FASTOChe and PARALUT trials, levels were always below 1%. To reach higher levels, the distribution of feed rich in tannins would be unrealistic due to its cost and dietary imbalance. One of the ideas put forward by feed manufacturers might be to distribute or graze the feed throughout the year to prolong the effect of the BSMs. However, this would require major adaptations to the breeding system and its real effects have yet to be demonstrated.

Despite the results of the FASTOChe project, the issues are still very much present, with the problem of the sustainability of IGS control in grazing animals and the urgent need to introduce new management methods that do not rely exclusively on the use of synthetic chemical products.

The results of several trials conducted in this study and in the PARALUT project show that individuals live very well with parasites without any zootechnical disadvantages (Jacquiet *et al.* 2022). Selective treatment is undoubtedly an avenue to be developed by periodically weighing the animals and/or regularly measuring milk production. Genetics is also a key area for the future. It is moving towards the introduction of a new selection criterion that will make it possible to value the animals that are most resistant to parasitism.

Finally, it now seems established that the control of gastrointestinal strongyles in small ruminants requires integrated management based on various practices: preventing and limiting infestations in grasslands, improving animal resilience and eliminating gastrointestinal strongyles through rational deworming practices. At the same time, this management must ensure optimum use is made of the grassland ecosystem, since grassland is where animals are infested by parasites, with a view to animal welfare and the technical and economic sustainability of grazing livestock systems.

Many deliverables have resulted from this study, all of which can be consulted on idele.fr in the FASTOChe section.

Ethics
The authors declare that the experiments were carried out in compliance with the applicable national regulations.

Declaration on the availability of data and models
The data supporting the results presented in this article are available on request from the author of the article.

Declaration on Generative Artificial Intelligence and Artificial Intelligence Assisted Technologies in the Drafting Process.
The authors used artificial intelligence in the translation process from French to English.

Authors' contributions
This article was written by Denis Gautier, and reviewed and amended by all the authors.

Declaration of interest
The authors declare that they do not work for, advise, own shares in, or receive funds from any organisation that could benefit from this article, and declare no affiliation other than those listed at the beginning of the article.

Acknowledgements
Thanks to the technical partners of the FASTOChe project: Idele ; Chambres d'Agriculture de la Haute-Vienne, de la Saône-et-Loire, des Pyrénées- Atlantiques ; Centre Interrégional d'Information et de Recherche en Production Ovine (CIIRPO, 87) ; EPLEFPA de Olivier de Serre d'Aubenas avec la ferme du Pradel (07), La Cazotte - Saint Affrique (12), Fontaine Sud Bourgogne (71), Carmejane (04) ; INRAE UE 1373 FerLus (Fourrages Environnement Ruminants Lusignan, 86), INRAE de Theix (UMR Herbivore et Herbipôle, 63), INRAE/Ecole Nationale Vétérinaire de Toulouse (UMR IHAP INRAE/ENVT, 31).

And to the breeders and technicians who took part in the study.

Declaration of financial support
This study was carried out with funding from the Compte d'Affectation Spéciale "Développement Agricole et Rural" of the French Ministry of Agriculture and Food, CASDAR project IP 5845 - FASTOChe, managed by the Institut de l'Elevage.

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