AZOLLA CULTIVATION IN LEBANON

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Abstract

Azolla is an aquatic fern that is characterized by its rapid biomass multiplication if the suitable requirements are provided. The results of this study concluded that azolla can be cultivated in all regions in Lebanon except in Baalbek and Beqaa. Due to its high nutritional value especially the protein, azolla can be used as alternative source of cattle feed. Its has been signified that if azolla is totally used as alternative source of feed it can provide (114.87 %) of the needed energy, 164.6% of the needed protein, 334 %,184% and 100% of the needed calcium, phosphorus, and magnesium with 27.08% as a maximum economical saving

Introduction

Classification of azolla

Azolla is a fern genus that floats in the water. Azolla is divided into two sub genera: Euazolla, which includes *A. fliculoides Lam*., *A. caroliniana Willd*, *A. Mexicana*, and *A. microphyll Kaulf*; and *A. Rhizosperma*, which includes *A. pinnat* and *A. nilotica*. (JSTOR 2021; Sadeghi and Zarkami 2013; USDA 2021).

Spatial distribution

A. Filiculoides can be found in southern South America and western North America up to Alaska (Svenson, 1944), and Azolla Mexicana, can be found on the west coast of the United States; Svenson (1944) declared that *A. Filiculoides* presents in southern South America and western North America up to Alaska; *A.Mexicana* can be found on the west coast of the United States ; *A. caroliniana* has been found in Central and South America, east of the Andes, and in western Europe (Lumpkin, 1987). It has also lately been brought to Egypt's Nile Delta (Yanni et al., 1994). Apart from tropical Africa, *A. pinnata* can also be found in Australasia and Southeast

Asia, while *A. microphylla* is restricted to the Galapos Islands (Lumpkin, 1987); *A. nilotica* is still an African species that can be found from Egypt to South Africa in eastern Africa. (Teixeira & Carrapico, 2000)

Factors affecting the growth of Azolla

The rate of growth and productivity of Azolla is affected by the combination of several growing conditions. If steady circumstances (light intensity, temperature, pH, etc.) are available (Hove (1989)

Humidity: The pace of Azolla growth is influenced by air humidity. For healthy growth and reproduction, Azolla requires a high level of dampness. Azolla began to emit an unpleasant odor at a relative humidity of 85 percent, which can encourage the growth of insects and fungi. The Azolla spread is shown to be modest at relative humidity levels of 65 and 85 percent; however, at 75 percent relative humidity, the growth rate is revealed to be quite promising. Some studies have also determined that to achieve desirable growth, the relative humidity needs to be changed between 70 and 75 percent (Bocchi & Malgioglio, 2010; Costa et al., 2009; Forni et al., 2001)

pH is the most important factor affecting Azolla growth rate. At a pH of 7, the fastest rate of growth is achieved. At pH levels higher and/or lower than 7, the Azolla grows substantially worse; nonetheless, a slightly acidic medium is better for Azolla development than a neutral one. Because of inhibited N2 fixation, adjusting the other parameters toward optimum condition had a good effect on Azolla growth and multiplication at acidic pH, however at pH higher than 7, it inhibited growth at any other parameter values. Moreover, slower growth at alkaline pH could be

attributed to a lack of iron and phosphorus, as well as a decrease in chlorophyll concentration in the alkaline pH range. (Golzary et al, 2021)

Temperature is one of the most important factors influencing Azolla's growth rate. The highest productivity was achieved at a temperature of 22 °C. Furthermore, other experts claimed that the ideal temperature for Azolla growth is between 20 and 25 degrees Celsius (Cary & Weerts, 1992). The temperature sensitivity of each Azolla species differs (Fernández-Zamudio et al., 2010; Liu et al., 2008; Serag et al., 2000). Azolla growth can be hampered or even stopped at high temperatures (e.g., above 30 °C), and azolla dies at low temperatures (e.g., below 4 °C) (Janes, 1998).

Light has the least impact on the pace of Azolla growth. The Azolla turns brownish-red, and the development rate slows dramatically at high intensity of 30 Klux. At lower intensities, however, it turns green. At high intensity of 20 Klux, the best growth rate is achieved. Azolla nitrogen fixation can be reduced under light intensities lower than 10–13 Klux (Bar et al., 1991; Costa et al., 2009).

In addition to these important factors water depth is considered an active factor in the growth of azolla, and according to Sadeghi et al, (2012), the optimum depth for the growth of azolla ranges between 0.3-1.2 meters.

Application of azolla

Azolla as sequester of co2

Azolla is considered one of the most important co2 sequesters; according to Houri and Hamdan, (2021), Azolla ponds can remove 21,266 kg of CO2 (as carbon) per 1 ha per year, which is 18

times more efficient than the equivalent area of Amazon Forest and it can compensate for any sudden rises in carbon dioxide levels, so the Azolla sequestration method has the potential to significantly lower the effects of global greenhouse gas emissions and global warming.

Azolla as biofertilizer

Azolla biomass can be used as a biofertilizer and a soil amendment product to boost the organic content of soils, enhancing crop output and quality. (Hanafy et al. 2018; Kaur and Purewal 2019). Moreover, according to Ali et al, (1998), Under mild climate circumstances, Azolla alone or in conjunction with a modest dose of chemical-N can be utilized to boost grain output in a rice-wheat cropping system.

Azolla as water purifier

The *A. filiculoides* biosystem can be utilized as a biofilter to remove phosphorus and lead from urban wastewaters (Cost et al,2009). Also, a study done by Jamuna and Noorjahan, (2015), discussing the use Azolla microphylla for purification of sewage wastewater, they found that azolla was able to reduce BOD, COD, and heavy metals such as copper, zinc and chromium, also they added that bio treated sewage water can be reused after treating it with A. *microphylla*.

Azolla as animal feed

according to Subudhi and Singh (1977), that azolla can be used as a feed for birds, they found that after adding 5% of azolla to the commercial feed, the growth of the birds became faster than those who took only commercial feed without azolla, and they got higher weight where after 14 weeks the mean weight of birds who took azolla became 614g, which is more than the birds who

took only commercial feed where their mean weight became 494g, also they added that azolla can replace 20-25 % of the commercial feed. In addition, according to Kumar et al. (2020), that studied the application of azolla pinnata as an alternative source of feed for Crossbred dairy cows, they found that replacing the commercial feed by 15-25 % of azolla pinnata can increase the fat percentage and milk production in range between 7-13 %. Moreover, by absorbing significant levels of Selenium (Se) and Zinc (Zn) from wastewater, azolla can also offer micronutrients for animals, making it a suitable choice to be used as feed additives (Li et al., 2020), where in both people and animals, Se and Zn deficiency has a variety of unfavorable health consequences, including an increased risk of cancer mortality, impaired immunological function, and cognitive decline (Lavu et al., 2016)

Examples of Azolla around the world

Rice-Azolla-fish and rice-Azolla-duck agricultural ecosystems have been used in China for a long time in some areas. (Watanabe & Liu, 1992). In addition, in China, India, southeast Asia and tropical Africa, Azolla have been used as fertilizer where it should be ploughed into the soil like any fertilizer before planting crops. Another application of azolla as fertilizer when used as a monocrop during the fallow season in Davis, California, Azolla enhanced rice yields by 112 percent over unfertilized controls, and by 23 percent when used as an intercrop with rice, and when used as a monocrop and an intercrop, it increased yield by 216 percent (Peters, 1978).

In Lebanon, azolla have been used in Bnaiyye as poultry feeds where according to Bnaiyye municipality, 2021, they were supply the feed to poultry with 30-40 % savings. This article aims to study the possibility of applying azolla cultivation in Lebanon based on temperature and humidity of Lebanon’s regions, and to relate the nutritional value of azolla to the nutrients

needed by cows to investigate the possibility of applying it as an alternative source of feeding to find at the end the economical saving of applying it as cows feed

Methodology

First, azolla's requirements to grow and sustain the maximal growth will be derived from some google scholar's academic articles. Second, some variables in Lebanon including the average temperature and humidity in the Lebanese governates will be extracted from a website called weather and climate, then these variables along with the latitude and longitude of the regions (that will be extracted from google maps), will be combined together to make a map that specify the acceptable and non-acceptable regions where azolla can be cultivated using QGIS software, the needed GIS data ,that describes the Subnational Administrative Boundaries will be taken from Data.Humdata website. These variables along with the essential requirements to grow azolla will be compared together. Third, comparative results will be analyzed to decide whether azolla could be cultivated In Lebanon. Then the nutritional compositions of azolla will be collected, so it will be compared with the nutritional needs for livestock to find the possibility of mixing azolla with livestock food. Finally, the costs of feeding of livestock will be calculated before and after applying azolla to find the economical savings. It is worth mentioning that the cost of azolla cultivation, how azolla is being used and the ingredients of the commercial feed mix will be gathered by interviewing cattle farm owner and azolla farm owner in Lebanon**.**

Result and discussion

The aim of this study is to specify the places where the azolla can be cultivated among Lebanon. This research will further compare azolla's nutritional compositions to the nutrients needed by cows. The goal of this comparative analysis is to explore whether it is possible to mix the azolla with the commercial food given to cows and depends on it as an alternative source of feeding to find at the end the economical saving of this process.

Places where azolla could be cultivated

Azolla needs

Temperature	20-25 ºC; can reach 30 ºC	Warry and Weerts, 1992; Katole et al, 2017.
Humidity	55-83 %.	Lumpkin and Bartholomew, 1986.
Light	100–50 % sunlight	Kathirvelan, 2015.
PH	3.5-10	Serag et al. (2000)
Phosphorous	0.5 to 1.0 kg P/ha/week	Lumpkin et al, 1985)
Macronutrients	potassium (K+), calcium (Ca2+) and magnesium (Mg2+)	Serag et al. (2000)

Based on this table the two important factors that are not totally controllable are the humidity and the temperature, so to find the places where azolla can be cultivated among Lebanon its essential to compare the temperature and the humidity needed by azolla to that in Lebanon.

Average annual temperature and humidity in lebanon

Region	Temperature	Humidity
Beirut	23.16 ºC	66 %

South governates	20.3 ºC	63 %
Tripoli	23.44 ºC	64.91 %
Baalbeck	16.22 ºC	62.0 %
Beqaa	17.62 ºC	58.93 %
Mount lebanon	21.21 ºC	56 %
Nabatieh	20.3 ºC	59 %

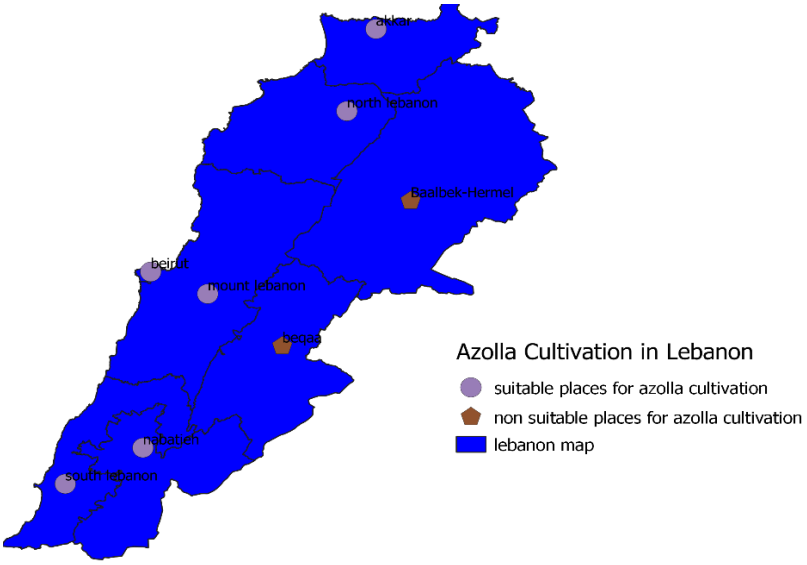

Fig 1: suitable regions for azolla cultivation among Lebanon

Based on the map that studies the regions where azolla can be cultivated based on data collected from weather and climate website (tcktcktck.org, n.d.) azolla can be cultivated in all regions in

mount Lebanon, Beirut, North Lebanon, Akkar, south Lebanon and Nabatieh, where all of these regions with their villages and cities show an optimum temperature (between 20-25) and humidity (between 56-66), however, based on the map azolla cannot be cultivated in Baalbek and Beqaa, although they have optimum average annual humidity(62 % and 58.93 % respectively) it is unsuitable to plant azolla among them because the average annual temperature are below the limit but not so much(16.22 ºC and 17.62 °C respectively). However, according to Mohammad Haj Ali, personal communication, February 19, 2022, that he was able to plant azolla in Beqaa when he offers the optimum temperature using green house, and during the interview he said that because of greenhouse system he is able to cultivate azolla over the year because it can provide the optimum temperature during the winter, also he added that the most common type of azolla used is azolla pinnata. Thus, temperature is not a major problem that can hinder azolla cultivation in Lebanon and azolla can be cultivated over Lebanon if the suitable requirements for controlling temperature are available.

Daily nutrients requirements for cow

All cattle need five nutrients keys nutrients: energy, protein, minerals, vitamins, and water (Baker,n.d.). according to national research council, 2001, which specifies the daily nutrients of dairy cattle. In this book the daily requirements for dairy cattle were summarized with different weights and cases.

BW kg	ADG kg/d	DMI kg/d	TDN %	NEm Mcal/d	NE_G Mcal/d	ME Mcal/d	RDP g/d	RUP g/d	RDP %	RUP %	CP[a] %	Ca g/d	P g/d
240 days pregnant (Conceptus weight of 39 kg and ADG of 0.4 kg/day)													
300	0.3 (0.7)[b]	7.7	56.5	5.42	0.96	15.7	663	291	8.6	3.8	12.4	36	19
	0.4 (0.8)	7.7	58.6	5.42	1.32	16.4	693	310	9.0	4.0	13.0	39	20
	0.5 (0.9)	7.7	60.8	5.42	1.68	17.0	721	329	9.3	4.2	13.5	41	21
	0.6 (1.0)	7.7	63.1	5.42	2.06	17.7	748	346	9.7	4.5	14.1	44	22
	0.7 (1.1)	7.7	65.5	5.42	2.44	18.3	774	364	10.0	4.7	14.7	47	23
	0.8 (1.2)	7.7	68.1	5.42	2.82	18.9	798	380	10.4	5.0	15.4	49	24
	0.9 (1.3)	7.6	70.9	5.42	3.21	19.4	822	395	10.8	5.2	16.1	52	24
350	0.3 (0.7)	8.6	56.2	6.18	1.10	17.5	739	282	8.6	3.3	11.9	38	20
	0.4 (0.8)	8.7	58.3	6.18	1.50	18.3	773	299	8.9	3.4	12.4	40	21
	0.5 (0.9)	8.7	60.5	6.18	1.92	19.0	805	315	9.3	3.6	12.9	43	22
	0.6 (1.0)	8.7	62.8	6.18	2.35	19.8	836	330	9.6	3.8	13.4	46	23
	0.7 (1.1)	8.7	65.3	6.18	2.78	20.4	865	345	10.0	4.0	14.0	48	24
	0.8 (1.2)	8.6	67.8	6.18	3.22	21.1	893	358	10.4	4.2	14.5	51	25
	0.9 (1.3)	8.5	70.6	6.18	3.66	21.8	921	371	10.8	4.3	15.1	53	25
400	0.3 (0.7)	9.5	56.0	6.91	1.23	19.2	813	275	8.6	2.9	11.5	40	21
	0.4 (0.8)	9.6	58.1	6.91	1.68	20.1	851	291	8.9	3.0	11.9	42	22
	0.5 (0.9)	9.6	60.3	6.91	2.15	21.0	887	305	9.2	3.2	12.4	45	23
	0.6 (1.0)	9.6	62.6	6.91	2.62	21.8	921	319	9.6	3.3	12.9	47	24
	0.7 (1.1)	9.6	65.0	6.91	3.11	22.5	953	331	9.9	3.5	13.4	50	25
	0.8 (1.2)	9.5	67.6	6.91	3.60	23.3	985	342	10.3	3.6	13.9	52	26
	0.9 (1.3)	9.4	70.3	6.91	4.09	24.0	1015	352	10.8	3.7	14.5	55	26
450	0.3 (0.7)	10.4	55.8	7.62	1.35	20.9	884	273	8.5	2.6	11.2	41	22
	0.4 (0.8)	10.5	57.9	7.62	1.85	21.9	926	288	8.9	2.8	11.6	44	23
	0.5 (0.9)	10.5	60.1	7.62	2.37	22.8	965	301	9.2	2.9	12.1	46	24
	0.6 (1.0)	10.5	62.4	7.62	2.89	23.7	1003	313	9.5	3.0	12.5	49	25
	0.7 (1.1)	10.5	64.8	7.62	3.42	24.5	1038	324	9.9	3.1	13.0	51	26
	0.8 (1.2)	10.4	67.4	7.62	3.96	25.4	1073	333	10.3	3.2	13.5	54	27
	0.9 (1.3)	10.3	70.1	7.62	4.51	26.1	1106	341	10.7	3.3	14.0	56	28

Fig 2: nutritional needs for cattle

National Research Council. (2001). *Nutrient requirements of dairy cattle: 2001*. National Academies Press.

In this table the daily requirements for dairy cow weighing in range from 300 kg to 450 kg were summarized with different digestibility. Assuming that the study is based on 450 kg cow with % of total digestible nutrient digestibility= 64.8 % (TDN= 64.8 %). According to Sprinkle (1996), the energy needed for 453 kg ≈ 450 kg non lactating cow is 18 Mcal. However, for a lactating cow produces milk at a range of 4.5 kg/d then the required energy equal 23,000,000 calories or 23 Mcal per day, since for each 0.45 kg of milk the needed energy increases by 0.48 Mcal. Regarding the percentage of dry matter that should be taken by 450 kg cow must equal to 2.3 % of its body weight which should be equal to 10.35/d, also the cow can eat in range between 2 to 2.5. Based on table 4, the crude protein (CP) percentage per dry matter for 450 kg with

digestibility of 64.8 % is equal to 13 % of DM= 0.13*10.35 kg=1.3455 kg of CP per day, regarding minerals the required amounts of calcium and phosphorus are 51 g/d (0.5 %) and 24 g/d (0.25) respectively. Also, the needed percentage of magnesium per diet 0.35 % (Linn, A. J. (n.d.). By assuming that the commercial feed can provide 100 % of the cow nutritional needs, so in every 1 kg of commercial feed it should contain 130 g of protein, 3472 M Cal of energy (% TDN=64.4), 5 g of calcium, 2.5 g of phosphorus and 3.5 g of magnesium.

Nutritional composition of azolla

nutrients	%DM
Crude protein	21.4
Crude fiber	12.7
Ether extracts	2.7
Ash	16.2
NFE	47.0
Cell wall fraction	
NDF	36.88
ADF	47.08
Magnesium	0.35
Trace minerals ppm DM	
Manganese	174.42
Zinc	87.59
Copper	16.74

Iron	755.73
sodium	23.79

Table 2: nutritional composition of azolla

Alalade, O. A., Iyayi, E. A., & Alalade, T. O. (2007). The nutritive value of Azolla (Azolla pinnata) meal in diets for growing pullets and subsequent effect on laying performance. *The Journal of Poultry Science*, *44*(3), 273-277.

Also, according to Kathirvelan et al., (2015) that the percentages of calcium and phosphorus in azolla dry matter are 1.67 % and 0.46% and according to Ashraf et al., (2018) the gross energy of azolla is 3988.7 M Cal/Kg. Based on this information, azolla contains higher nutritional (protein, energy, calcium, and phosphorus) value per dry matter than daily cow nutritional needs, where in every 1kg of dry weight of azolla there are: 214 g of protein, 3988 M Cal of energy, 16.7 g of calcium, 4.6 g of phosphorus while in 1Kg of commercial feed there are 130 g of protein, 3472 M Cal of energy (% TDN=64.4), 5 g of calcium, 2.5 g of phosphorus and 3.5 g of magnesium.

Mixing azolla with commercial feed

Azolla is high in proteins, vital amino acids, vitamins (vitamin A, B12, and Beta-Carotene), growth promoter intermediates, and minerals such as calcium, magnesium, phosphorus, iron copper and variety of other elements. Also, it can be easily digested by livestock because it contains low lignin and high protein, its nutritional composition makes it highly useful and efficient feed for cattle. Also, Livestock can be given azolla without extra concentrate after a fortnight of feeding azolla mixed with concentrate (Pillai et al,2005).

Then azolla can totally replace the commercial feed.

	100 % commercial feed	75 % commercial feed+25%azolla	50 % commercial feed+50%azolla	25 % commercial feed+75%azolla	100 % azolla
energy consumed	23000 Kcal/d (100 %)	23855.3 kcal/d (103.7 %)	24710.7 Kcal/d (107.4 %)	25566 kcal/d (111.15 %)	26421.3 Kcal/d (114.87 %)
protein	1.3455 kg (100 %)	1.56285 kg (116 %)	1.7802 kg (132.3 %)	1.99755 kg (148.4 %)	2.2149 kg (164.6 %)
calcium	51.75 g (100 %)	82.02 g (158.5 %)	112.29 g (217 %)	142.57 g (275.5 %)	172.845 g (334 %)
Phosphorus	25.875 g (100 %)	31.3 g (121 %)	36.74 g (142 %)	42.176 g (163 %)	47.61 g (184 %)
Magnesium	36.225 g (100 %)	36.225 g (100 %)	36.225 g (100 %)	36.225 g (100 %)	36.225 g (100 %)

In this table azolla had been mixed with commercial feed in different percentages (0 %, 25 %, 50 %, and 100 %), the commercial feed consists of 24 % wheat silage, 30 % corn 2 % salts, 12 % soybeans, 20 % hay, and 12 % cotton seeds(H.**Al khair, personal communication, February 5 ,2022**) (taking into consideration that the commercial feed can provide the daily nutrition for cow), then the nutritional values like: energy, protein, calcium, phosphorus, and magnesium had been studied based with the different cow rations, according to this table, as the % of azolla

increases in the ration the nutritional values increases,(except for magnesium because azolla and commercial feed has the same percentage of magnesium in their dry matter), Which was expected because azolla contains higher energy, protein, phosphorus and calcium than the cow daily needs. For **energy** increasing percentage of azolla from 0 % to 100 %, increases the energy consumed from 100 % to 114 %; while for **protein**, the amount of taken crude protein increases from 100 % to 164.6 % as the % of azolla increases from 0 % to 100 %. For **calcium**, the amount of taken calcium increases from 100 % to 334 % as the % of azolla in ration increases from 0 % to 100 %. For **phosphorus**, the amount of taken phosphorus increases from 100 % to 184 % as the % of azolla increases from 0 % to 100 %. Thus, mixing azolla with commercial feed provide the cow with its daily nutrient needs and exceed it. Also, if the source of feed is 100 % azolla, then to get the 100 % of needed nutrients individually: crude protein, energy, calcium, phosphorus and magnesium the amount of azolla needed are 6.28 kg, 9 kg, 3.05 kg, 5.625 kg, and 10.35 kg respectively.

Economical saving

Feed costs ranged between 20.1 to 43.4 in average 31.75 as a percent of total costs (Schmidt & Pritchard, 1987). So, the cost of cow feeding is approximately the quarter of the total cost, and it is important to find another source of feed that is cheap with acceptable nutritional value and locally available to reduce the cost of feeding. Moreover, the primary criterion for a sustainable livestock production system is that it should be based on the country's resources, preferably on the farm itself. Second, crops and livestock should be balanced for these activities to be complementary and, if possible, synergistic (Preston & Murgueitio, 1992). According to Van Hove et al, (1983) that azolla pinnata can double its biomass in 3-5 days under the suitable

conditions, so it has extremely fast biomass development that may achieve the balance between livestock and feed. Also, based on table 3 azolla has a perfect nutritional value especially the crude protein (21 %) where according to Mederos et al, (2002), that the most expensive component of the diet is protein, so that what makes azolla an especially useful replacer of feed.

according to Hamdan and houri, 2021, the amount of the harvested dry weight azolla is 50633 kg/ha in one year, then the amount of dry weight azolla that can be harvested from 5m*5m pond equal to 126.6 kg per year. Moreover , Based on an interview with Mohammad Haj Ali (0096170017650) who has an experience in azolla cultivation that the cost of 5 m*5 m azolla pond is 60 $ including repairs expenditure (addition of super phosphate, minerals,...etc), so the mean cost of 126.6 kg is 60 $, assuming that the pond will be out of service after 1 year and will be replaced by new one, then the average cost of production of 1kg of azolla will be 60 $/126.6 kg=0.474 $/kg,

	100 % commercial feed	75 % commercial feed+25%azolla	50 %commercial feed+50%azolla	25 %commercial feed+75%azolla	100 %azolla
Cost of mixed meal (azolla and	6.714459	6.26	5.8	5.35	4.89

commercial feed) ($)					
economical saving (%)	0	6.77	13.54	20.32	27.08

In this table, the cost of mixed meal (azolla with commercial feed) is taken into consideration with different percentages of dry azolla (0%, 25%, 50%,75%, and 100%), the average cost of 1kg of azolla is equal to 0.474$, while the cost of the commercial feed is 0.65$ per kg which is based on an interview with Hisham Al khair, personal communication, February 5, 2022, the manager of zain farm that is located in Halba. The cost of commercial feed is distributed in the table below

ration mix	Percentages of each concentrate	Mass of each concentrate (kg)	Cost of 1kg of each concentrate ($)	Cost of each concentrate ($)
wheat silage	24%	2.484	0.33	0.81972
corn	30%	3.105	0.85	2.63925
salts	2%	0.207	0.227	0.046989
Soybeans	12%	1.242	0.95	1.1799
Hay	20%	2.07	0.5	1.035
cotton seeds	12%	1.242	0.8	0.9936

Total	100%	10.35	3.657	6.714459

Then based on these values the economical saving percentages were calculated by dividing the daily mixed meal of cow*one hundred over the cost of daily commercial meal for cow. Moreover, for every 1 percent of azolla added and replace the commercial feed, the economical saving increase by 0.27% which is 0.018 $ The maximum economical saving can reach 27.08% if the meal is 100% azolla which is equivalent to 1.81 $ daily for every cow. In addition, if azolla pinnata is used as soybeans replacer (cheaper source of protein), then the 12 % of soybeans will be replaced by 12 % azolla pinnata. So, the cost of ration will be 6.12 $ instead of 6.71 $, and the % of economical saving will be 8.8 % which is equivalent to 0.5904 $ daily for every cow. So, azolla can save money and reduce the cost of feeding if it is used as commercial feed replacer with maximum saving 27.08 % or protein source (replacing soybeans) with maximum saving 8.8 % assuming the main source of protein come from soybeans.

Limitations

In this study only the major conditions for growing azolla have been taken into considerations to find the places where azolla can be cultivated in Lebanon, however there are parameters that can be applied to maintain the needed conditions for example applying greenhouse systems to achieve the needed temperature (20 ºC -30 ºC), especially that the regions where azolla cannot be cultivated in Lebanon have an average temperature near the needed one (Baalbek 16.22 ºC and Beqaa 17.62 C). Moreover, only the annual average temperature is taken into consideration and not the seasonal or monthly average temperature. Also, there are a few studies done regarding

the toxicity of azolla if it is applied as a feed alternative, where applying azolla for cattle in high percentages has not been tackle in other studies.

Conclusion

In summary, it has been found that azolla can be cultivated in all regions in Lebanon except in Baalbek and Beqaa where the average temperatures are below the required ones. Also, regarding the usage of azolla as an alternative feed source, the Mixing azolla with commercial feed gave satisfying results, whereas 1 % of azolla (0.01 kg) is added to the cow diet instead of commercial feed, the % of economical saving increases by 0.27 % which is equivalent to 0.018 $, and it can reach 27.08 % if azolla totally replaces the commercial feed. Also, if azolla is used as an alternative source of protein, assuming the source of protein in cow diet is soybeans, this will save 8.8 % of cow feeding. Thus, using azolla in farms as a source of feed will increase the income and reduce the cost of meat and milk productions if the needed parameters are achieved. Also, future research should study the possibility of applying azolla at high percentages for cattle and to study the psychological consequences on them.

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