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Optimizing animal care through compound feed management in Saudi Arabia

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Proper animal feeding practices play a fundamental role in enhancing livestock health and maximizing output. Given the governmental restrictions on green fodder cultivation in Saudi Arabia (SA) due to water conservation efforts, the use of compound feed could serve as a viable alternative for livestock farmers. This study aimed to investigate livestock farmers' farming objectives, their feeding management strategies, and the uptake of compound feed in the country. Data from 650 randomly selected livestock farmers were collected through an online survey with the assistance of the Ministry of Environment, Water and Agriculture. The findings showed that most farmers raised sheep and goats for trade purposes using specialized farms and desert grazing. Alfalfa hay was widely used as a fodder along with barley grain. While approximately 47% of the farmers did not utilize compound feed, 44% reported its usage. Binary logistic regression analysis indicated that formal education, farming experience, and income level significantly influenced the adoption of compound feed among livestock farmers. These results underscore the critical role of education and financial resources in promoting the use of compound feed among livestock farmers in SA. It is recommended that government institutions should develop initiatives to educate farmers on proper animal nutrition practices and provide financial support to make compound feed more affordable for low-income farmers. The widespread use of compound feed has the potential to enhance livestock health and productivity, thereby positively contributing to the food security of SA.

KEYWORDS

compound feed, animal nutrition, green fodder, Saudi Arabia, livestock

1 Introduction

The livestock sector plays a pivotal role in global food security and livelihood generation. It provides a diverse range of nutritious food products that are essential for improved human health and nutrition (Appleby and Mitchell, 2018; Godde et al., 2021; FAO, 2023). Nearly 40% of the value-added agricultural products are derived from livestock production. Around the globe, over one billion people depend on livestock productions systems for their livelihood, with the majority being small-scale livestock farmers (FAO, 2023; FAO et al., 2023). Moreover, sustainable livestock production systems are also vital to the achievement of several Sustainable Development Goals (SDGs) of the United Nations (UN), which focus on hunger reduction, income generation, and

environmental stewardship (Alonso et al., 2019; Varijakshapanicker et al., 2019; Molina-Flores et al., 2020; Schneider and Tarawali, 2021; FAO, 2023; FAO et al., 2023).

The livestock sector is a cornerstone of Saudi Arabia's economy, accounting for 46% of the national Gross Domestic Product (GDP), with an approximate monetary worth of 24.7$ billion (FAO, 2021). It has played an important role in achieving self-sufficiency in several livestock-derived products and therefore has a positive impact on the national food security. The country predominantly relies on locally produced meat, with an annual output of approximately 292,000 tons, and has a substantial production of dairy products, approximately 29.16 million tons (FAO, 2021). Remarkably, Saudi Arabia exceeds self-sufficiency in dairy and egg production, with rates of 121% and 112%, respectively. The self-sufficiency rates for red meat, poultry, and fish stand at 43%, 66%, and 40%, respectively (Ministry of Environment, 2022). According to the FAO's (2021) annual statistical report, 43% of the total agricultural imports of the country are grain crops, whereas dairy products and table eggs constitute about 24% of the total agricultural exports.

As the global population continues to grow and living standards improve due to higher incomes, a corresponding increase in the demand for animal-based products is also expected. This has led to an expansion in ruminant livestock production, consequently increasing the consumption of feeds like cereal grains and soybean meals—resources that could otherwise be used for human consumption. This development has sparked concerns about competition for already scarce arable land dedicated to cereal crop production, highlighting the need for sustainable agricultural practices (Wilkinson and Lee, 2018). Fodder is a critical ingredient of animal feed and is essential for meeting livestock' nutritional requirements. Insufficient availability of both fresh and processed fodder can lead to a decline in livestock population, and therefore adversely affects dairy and meat production (Hailesilassie, 2016; Ahamed et al., 2023). To address rising fodder demands, many farmers in Saudi Arabia (SA) expanded cultivation, which in turn resulted in increased utilization of the country's limited water resource. According to Ministry of Environment, Water and Agriculture, SA, fodder crops alone consume about 79% of the amount of water used for agricultural purposes in SA. Given the current rates of water consumption, some regions in the Kingdom may face reserve stock depletion during the next decade (Ghanem et al., 2021). Moreover, amid the ongoing threat of climate change that is anticipated to have negative impacts on the agricultural productivity and water resources in SA (Al Zawad and Aksakal, 2010; DeNicola et al., 2015; Haque and Khan, 2022), it is a serious challenge to grow more fodder to meet livestock feed requirements. To optimize the use of limited water resources, the country has prepared a comprehensive "National Water Strategy 2030," which aims to improve water resource management in the country by reducing the cultivation of water-intensive fodder crops (Ghanem et al., 2021). In this context, there is an urgent need to employ advanced feed approaches to enhance the production, profitability, and sustainability of animal-based products in the country.

Traditional livestock feeding methods, which are characterized by the lack of nutritional balance and sufficient fodder, are significant contributors to low livestock productivity (Manoj, 2015). Studies show that heavy reliance on livestock grazing is tied to inadequate knowledge about the importance of feed quality and its impacts on livestock productivity, scarcity of land for cultivating high-quality fodder as lands are used for other crops, diminishing soil fertility, and unfavorable climatic conditions like reduced rainfall and prolonged dry seasons. Additionally, farmers have limited understanding of how to grow forage, which exacerbates the forage deficit that negatively affects livestock production, particularly in dry seasons (Shrinivasa and Mathur, 2020).

Optimal animal nutrition is indispensable for the health and welfare of animals as well as for the production of safe, high-quality animal-derived products (van der Linde et al., 2001; Yosef et al., 2022). Rising demands for proteins of animal origin have intensified animal production systems, making them heavily reliant on industrial compound feed (Moorby and Fraser, 2021). Compound feed offers key advantages over traditional feed. It is not only a nutritionally balanced diet, but it is also convenient to use, and leads to improved yields (Okewole and Igbeka, 2016; Balehegn et al., 2020). Additionally, it helps reduce forage waste and enhances nutrient availability (Garg et al., 2013). Compound feeds are complex and comprise over 20 carefully chosen ingredients, which are selected on the stringent criteria of nutritional quality, safety, price, and availability (van der Aar et al., 2016). Three main criteria determine the composition, including cost, nutritional profile, and animal characteristics. Moreover, the nutritional composition of compound feed varies as per the type of livestock to be fed and its stages of growth (Zahari and Alimon, 2005).

Livestock farmers' adoption and use of compound feed can be influenced by different personal, socio-economic, and several other factors. Personal factors include age, gender, level of formal education, farm size, size of herd, and livestock farming experience. Economic factors include level of farm income, off-farm income, and cost of compound feed. Other factors that may also influence livestock farmers' adoption decisions include level of knowledge about compound feed and its potential benefits for maximizing livestock productivity, purpose of livestock farming, access to grazing resources, access to credit services, access to extension and advisory services, farmers' sources of information about livestock nutrition, memberships of farmer-based livestock organizations, availability of alternative feed sources, availability of compound feed and market access, and market prices of animal-based products. All these factors can shape livestock farmers' decisions about adoption of compound feed for feeding livestock (Baba et al., 2019; Dhraief et al., 2019; Lima et al., 2023; Ngeno, 2024).

Inadequate livestock diets can result in significant economic losses through poor animal health, inefficient feed conversion, and reduced output of animal-derived products (Gizzi and Givens, 2004; Han and Dingemanse, 2015; Makkar, 2018). Encouraging livestock farmers to adopt compound feed for boosting livestock productivity and meeting the demand for animal-derived products poses a substantial challenge for agricultural policy makers. A recent study Al-Mutairi et al. (2023) assessed livestock farmers' on-farm adoption of feed-safety standard practices in the Riyadh region. However, there are no studies that attempted to explore livestock farmers' adoption of compound feeding practices. This study is designed to fill this gap and intends to analyze livestock farmer's adoption of compound feeding practices at the farm level

and determine the impact of different socio-economic factors that affect their adoption decisions.

2 Materials and methods

2.1 Research design, population and sampling

A cross-sectional survey was used as a research design for the present study. Information about livestock farmers of Saudi Arabia was obtained from the Ministry of Environment, Water and Agriculture (MEWA), which has developed a database of the registered livestock farmers in Saudi Arabia. As of December 2021, the total number of registered livestock farmers with the ministry were 108,901 (Ministry of Environment, 2021). Around 650 livestock farmers were randomly selected for data collection. Data were collected with the help of the MEWA using an online survey. The survey was started in May 2023 and took 4 months for its completion. About 538 livestock farmers provided data for the study that was used in the final analysis.

2.2 Research instrument

In order to facilitate understanding and ensure clarity, the survey questionnaire was structured into several sections, each focusing on a specific theme. The opening section contained questions related to livestock farmers' demographic and socio-economic attributes, including gender, nationality, education, level of income, livestock farming experience, main occupation besides livestock farming, types of livestock, and area of residence. The second section included questions about the purpose of livestock farming. The third section asked the livestock farmers how they raise their livestock. In the fourth section, there were questions regarding the management and supervision of livestock farming activities. The fifth section consisted of questions about livestock farmers' herd feeding practices, including different types of green fodder, concentrated feed, and type of grains. The last section of the survey questionnaire contained questions regarding their knowledge about compound livestock feed. The questionnaire was evaluated by the researchers and experts from the King Saud University.

2.3 Data analysis

Descriptive statistics such as frequency distributions and percentages were used to summarize demographic and socio-economic characteristics of the livestock farmers. Moreover, descriptive statistics were also used to show the results related to different livestock management practices of the farmers on their farms. Based on their use of compound feed, the livestock farmers were categorized into two groups: non-adopters and adopters. Binary Logistic Regression model was used to analyze the impact of various socio-economic variables on the adoption of compound feeding practices. The significance level (α) was set at 5% in order to decide the overall statistical significance of the regression model as well as for each independent variable in the model. Statistical Package for Social Sciences (SPSS v28) was used for data analysis. The regression model takes the following form:

The logistic regression model can be formulated as follows in Equations 1–4:

$$y = \begin{cases} 1 \text{ represents adoption} \\ 0 \text{ no adoption} \end{cases} \quad (1)$$

$$y \sim Bernoulli(\pi)$$

Where: Y is the dependent variable and takes two values: 0 is no adoption and 1 represents adoption.
let $x_1, x_2, ..., x_7$ to denote p independent variables that can be affect the dependent variable, then the distribution of $y = \{1, 0\}$ given explanatory variables is Bernoulli with parameter π, and given by:

$$\begin{aligned} \pi &= pr(y = 1|x_1, x_2, ..., x_p) \\ &= \frac{\exp(\beta_0 + \beta_1 + \beta_2 + \beta_3 + \beta_4 + \beta_5 + \beta_6 + \beta_7)}{1 + \exp(\beta_0 + \beta_1 + \beta_2 + \beta_3 + \beta_4 + \beta_5 + \beta_6 + \beta_7)} \end{aligned} \quad (2)$$

and

$$\begin{aligned} 1 - \pi &= pr(y = 0|x_1, x_2, ..., x_p) \\ &= \frac{1}{1 + \exp(\beta_0 + \beta_1 + \beta_2 + \beta_3 + \beta_4 + \beta_5 + \beta_6 + \beta_7)} \end{aligned} \quad (3)$$

where exp refers to exponential function, $(\beta_0, \beta_1, ..., \beta_7)$ are logistic coefficients which show the effects of explanatory or independent variables on the probability that the Responsive livestock breeder belong to represents adoption π or no adoption $(1 - \pi)$.

The logit model, $Log_e\left(\pi/(1-\pi)\right)$, denoted as follow (Gujarati, 2021):

$$Log_e\left(\frac{\pi}{1-\pi}\right) = \beta_0 + \beta_1 + \beta_2 + \beta_3 + \beta_4 + \beta_5 + \beta_6 + \beta_7 \quad (4)$$

$\beta_0, \beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7$ are the parameters that will be estimated.

X_1 = Education level
X_2 = Monthly income
X_3 = Farming experience
X_4 = Occupation besides livestock farming
X_5 = Geographical location
X_6 = Membership of livestock associations
X_7 = Knowledge about compound feed.

3 Results

3.1 Livestock farmers' demographic and socioeconomic attributes

Table 1 presents the results of the livestock farmers' demographic and socioeconomic attributes. An overwhelming

majority (98%) of the farmers were males; females constituted only 2% of the livestock farmers. Saudi nationals also dominate the livestock profession as almost 99% of the livestock farmers were Saudi citizens. About 57% of the farmers were below 40 years of age. Nearly two-fifth (39%) of the farmers were between 41 to 60 years of age. The farmers who were over 60 years formed only a small percentage (4%) of the sample. About three-fifth (59%) of the livestock farmers had college-level education, whereas 34% of them only attended secondary school education or below. The farmers who had university-level qualifications were around 7%. About 46% of the farmers had maximum monthly income of 10,000 Saudi Riyals (SR) or below than it. The farmers whose monthly income ranges between 11,000 to 15,000 SR were around 22%. Nearly 19% of the farmers reported their monthly income over 15,000 SR. However, about 13% of the livestock farmers preferred not to disclose their monthly income.

Over half (55%) of the farmers possessed <10 years of livestock farming experience, while about 29% of them reported between 10 to 20 years of experience. The farmers who had more than 20 years of livestock farming experience were around 16%. Half (51%) of the livestock farmers were working in the public sector, whereas 16% of them were private sector employees. Just over one-fourth (22%) of the farmers indicated that livestock farming was their sole profession. Most of the farmers had sheep (82%) and goats (56%) on their farms. Only a small percentage (4%) of the farmers had cows for milk production purposes. In terms of regional distribution of the livestock farmers, over half (48%) of them were located in the central regions of Saudi Arabia, followed by 20% of the farmers in the western regions and 15% of them in the northern regions of Saudi Arabia. Only 6% of the farmers were members of the livestock associations operating in the country; a vast majority of them (94%) had no formal memberships. Internet (39%) was the main source of information about livestock nutrition. About 16% of the livestock farmers used agricultural extension wing of the MEWA for getting information about livestock nutrition.

TABLE 1 Livestock farmers' demographic profile.

Variable	Groups	Frequency	Percent
Gender	Male	527	98.0
	Female	11	2.0
Nationality	Saudi national	530	98.5
	Resident	8	1.5
Age (years)	Below 40	307	57.0
	41–60	212	39.4
	Above 60	19	3.5
Education	Primary	38	7.1
	Secondary	146	27.1
	College	319	59.3
	Higher education	35	6.5
Monthly income (SR)	Below 5,000	138	25.7
	>5,000–<10,000	111	20.6
	>10,000–<15,000	118	21.9
	Above 15,000	102	19.0
	I prefer not to disclose	69	12.8
Livestock farming experience (years)	Below 10	295	54.8
	11—20	156	29.0
	Above 20	87	16.2
Occupation besides livestock farming	Livestock farming only	120	22.3
	Public sector employee	274	50.9
	Private sector employee	86	16.0
	Retired	58	10.8
Type of livestock*	Camels	104	19.3
	Sheep	439	81.6
	Goats	301	55.9
	Cattle	23	4.3
Geographical location	Central region	259	48.1
	Northern region	80	14.9
	Eastern region	44	8.2
	Western region	108	20.1
	Southern region	47	8.7
Membership of livestock associations	No	505	93.9
	Yes	33	6.1
Sources of information about livestock nutrition	Agric ext wing of MEWA**	87	16.2
	Saudi food and drug authority	11	2.0
	Internet	209	38.8
	Others	116	21.6

*Percentages do not add up to 100. **Ministry of Environment, Water and Agriculture, KSA.

3.2 Livestock management and feeding practices

The findings about farmers' livestock management and herd feeding practices are shown in Table 2. Most of the livestock farmers raised livestock for reproduction (43%) and trade purposes (41%). About 28% of them also raised livestock as a hobby. Relatively less farmers were involved in livestock farming specifically for milk (6%) and meat (18%) production. Most of the livestock farmers (76%) had workers for the care and feeding of their livestock under their supervision. Approximately 13% of the farmers indicated that they personally managed their livestock without any outside help. There was a small percentage (2%) of the farmers who were not involved in the supervision of raising livestock and all activities were managed by the workers without their supervision. Most of the (40%) farmers raised the livestock at special farms, followed by grazing in desert (34%). The farmers who used sheds outside cities were about 30%. The majority (67%) of the livestock farmers were feeding different animals of their herd with same fodder. The most commonly used green fodder was Alfalfa (68%), followed by

the Rhodes herb (31%) and wet clover (23%). The least used green fodder crops were Blue Bionic (9%) and Bonicam (10%). In terms of grain feeding, barely is the most commonly used grain (84%) by the farmers, followed by Bran (11%) and Maize (9%). Over two-fifth (44%) of the farmers indicated that they used concentrated feed cubes for feeding their livestock. Soybean powder as a feed was used by only few farmers (2%). However, about 47% of the farmers did not use any concentrated feed for their livestock.

3.3 Feed procurement practices and knowledge about compound feed

Table 3 presents the findings pertaining to farmers' feed procurement practices and their level of understanding regarding compound feed. The majority (63%) of the farmers procured livestock feed from designated feed markets. Additionally, approximately 30% of them purchased feed from mobile vehicles engaged in the sale of fodder outside of feed markets. A significant proportion of the farmers (34%) made livestock feed purchases on a monthly basis, while around 16% reported weekly purchases. Farmers who purchased livestock feed more than once a week accounted for approximately 6% of the total. Regarding feed storage practices, over half (58%) of the livestock farmers stored feed under shaded areas on their farms. A relatively small percentage (9%) of the farmers utilized dedicated warehouses equipped with appropriate temperature and humidity control systems for the storage of livestock feed. The most prominent factor influencing farmers' decisions about livestock feed was the quality of the feed in relation to enhancing livestock production (43%). Price (20%) and ease of availability (18%) were two other factors that played a role in farmers' decision-making processes regarding feed selection. When queried about their level of knowledge regarding compound livestock feed, nearly half (47%) of the farmers reported possessing a moderate level of understanding. Approximately one-fifth (22%) of the farmers indicated a low level of knowledge, while livestock farmers who claimed to possess a high level of knowledge regarding compound livestock feed accounted for approximately 17% of the total.

3.4 Relationship of socioeconomic factors with adoption of compound livestock feed

Table 4 presents the findings of a binary logistic regression analysis conducted to assess how livestock farmers' socioeconomic variables influence their decision to adopt compound feed. We employed regression analysis to examine whether socioeconomic factors helped us explain differences in adoption of compound feeding practices. The regression model was statistically significant ($\chi^2 = 258.38$; $df = 19$; p-value ≤ 0.001) and correctly predicted the adoption of compound feed for 76% of the livestock farmers. The analysis of Hosmer and Lemeshow test ($\chi^2 = 4.627$; $df = 8$; p-value $= 0.797$) indicated that the model has appropriate goodness of fit. Moreover, the value of Nagelkerke R^2 (0.588) suggests that approximately 58% of the variability in adoption of compound livestock feed is due to the model, which suggests a

TABLE 2 Livestock management and feeding practices of the livestock farmers.

Livestock management practices	Percent
Purpose of livestock farming*	
Milk production	6.3
Meat production	18.0
Trade purposes	41.3
Animals for reproduction	42.9
Beauty competitions	5.0
As a hobby	27.5
Management and supervision of the herd	
Personally	13.6
A family member or relative or friend under my supervision	2.0
A family member or relative or friend without my supervision	0.7
Worker under my supervision	76.0
Worker without my supervision	1.9
Livestock farming approach*	
Grazing in desert	34.4
Special farm	40.1
A stall in the market	2.4
Sheds outside cities	29.9
Specialized animal production projects	0.6
Others	4.3
Diversity of livestock nutrition	
Feeding different animals with the same fodder	66.7
Feeding different animals with different types of fodder	27.5
Type of green fodder*	
Alfalfa hay	67.7
Wet clover	23.0
Rhodes herb	30.7
Sudan weed	1.1
Blue bionic	9.1
Bonicam	9.5
Type of grains*	
Barley	83.5
Maize	9.3
Sorghum	2.8
Wheat	2.4
Bran	11.0
Other pills	16.0
Type of concentrated feed	
Soybean powder	2.4
Concentrated or complete feed cubes	43.9
No use of concentrated feed	46.8

*Percentages do not add up to 100.

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TABLE 3 Livestock farmers' feed procurement practices.

Feed procurement practices	Percent
Feed procurement*	
Barely filling stations	2.6
Feed markets	63.2
Vehicles selling fodder outside feed markets	29.7
Directly from feed factories	1.5
Directly from farms	4.8
Feed purchasing frequency	
No specified period	14.7
Every month	33.8
Fortnightly	12.1
Weekly	16.0
More than once in a week	6.1
Feed storage practices	
An open place	16.2
Under shade	57.6
A dedicated warehouse with temperature and humidity control	8.9
Major factors behind feed selection	
Price	20.4
Quality for enhancing production	42.6
Ease of availability	17.7
Personal desire	8.9
Other	4.6
Self-perceived level of knowledge about compound feed	
Low	21.6
Moderate	46.7
High	17.1

*Percentages do not add up to 100.

significant improvement over the null model. The model estimates revealed that education level, monthly income, and farming experience had a significant relationship with the adoption of compound feed.

The odds of adoption of compound feed by livestock farmers having college-level qualifications were approximately 34 times higher than those who had primary-level education. Similarly, the odds of adoption of the farmers having university-level qualifications were approximately 161 times higher than those with primary education. Livestock producers with a monthly income ranging from 6,000 to 10,000 SR were about eight times more inclined to embrace compound feed compared to those earning <5,000 SR per month. Additionally, livestock farmers earning over 15,000 SR on a monthly basis were roughly fifteen times more likely to adopt compound feed than those earning below 5,000 SR each month. Regarding livestock farming experience, individuals with over two decades of experience were approximately eight times more disposed toward adopting compound feeding methods when compared to those with <10 years of experience.

4 Discussion and implications

This research aims to investigate how livestock farmers in Saudi Arabia manage and feed their animals. It also examines their feed procurement practices and perceived knowledge about compound feed. Additionally, we evaluate how different socio-economic factors influence their decisions to use compound feed. The findings of the research indicate that animal husbandry is primarily a male-dominated occupation in Saudi Arabia. This could be attributed to the longstanding tradition of men being engaged in livestock rearing, as well as the physical demands and labor-intensive nature of this field which are often associated with masculinity. However, given advancements in farming practices and evolving societal attitudes, there is a potential for women to play an active role in this industry and excel in the field of livestock farming (Narmatha et al., 2015; Quisumbing and Doss, 2021). The majority of individuals working in the livestock industry in Saudi Arabia are Saudi citizens, with only a small number of residents owning farms. This imbalance may result from their inclination toward other industrial sectors or challenges in hiring affordable labor from abroad rather than employing local workers. Nevertheless, foreign workers form the major part of the workforce involved in managing and carrying out day-to-day operations on livestock farms under the supervision of Saudi owners in the country.

Most farmers primarily rear their livestock for commercial purposes and breeding. In Saudi Arabia, this is a profitable practice due to substantial market demand for meat. Livestock are sold in the open market and ultimately used for meat consumption by local residents, which is why sheep and goats are the predominant choices for many farmers. However, only a small proportion of farmers operate their own meat supply outlets to directly cater to consumers. On the other hand, the production of milk is largely controlled by big dairy companies such as Almarai, Nadec, Alsafi, and Nada in Saudi Arabia, making it less common for farmers to raise livestock specifically for milk production. These companies manage large-scale dairy farms equipped with advanced infrastructure and technology for milk production processing. Cattle farming for milk production is comparatively more costly than sheep and goat farming. It involves additional expenses for constructing suitable infrastructure for cows, as well as the challenge of managing them, particularly in desert environments. This also explains why only a few farmers raise cattle and do not engage in milk production.

Farmers in Saudi Arabia employ various techniques to maximize livestock productivity and overcome challenges. The most common method is raising animals on specialized farms, which involves creating tailored facilities such as barns and feeding systems. This approach has been encouraged by the increasing local demand for meat products, particularly lambs and goats. Specialized farms allow for improved management operations, leading to enhanced production efficiency and profitability while also offering better waste management opportunities that can reduce the environmental impact of livestock (Kamphuis et al., 2015; Martin et al., 2020; Wang'ombe, 2023). Additionally, many farmers still utilize traditional methods like grazing in designated desert areas

TABLE 4 Relationship of socioeconomic variables with the adoption of compound feed.

Independent variables	β	S.E.	Wald's χ^2	df	Sig.	Odds ratio (OR)	95% CI for OR	
							Lower	Higher
Education level			49.445	3	<0.001*			
Primary	Reference case							
Secondary	0.783	1.202	0.424	1	0.515	2.188	0.207	23.062
College	3.528	1.153	9.364	1	0.002	34.064	3.555	326.372
Higher education	5.083	1.334	14.516	1	<0.001	161.334	11.803	2,205.223
Monthly income (SR)			51.510	4	<0.001*			
Below 5,000	Reference case							
6,000–10,000	0.194	0.564	0.118	1	0.731	1.214	0.402	3.665
11,000–15,000	2.087	0.527	15.704	1	<0.001	8.057	2.871	22.614
Above 15,000	2.745	0.523	27.498	1	<0.001	15.562	5.578	43.412
Prefer not to disclose	2.266	0.518	19.150	1	<0.001	9.642	3.494	26.603
Farming experience (Years)			29.930	2	<0.001*			
Below 10	Reference case							
11−20	0.883	0.310	8.130	1	0.004	2.418	1.318	4.435
Above 20	2.097	0.393	28.426	1	<0.001	8.144	3.767	17.605
Occupation besides livestock farming			5.333	3	0.149			
Livestock farming only	Reference case							
Govt. sector employee	−0.984	0.428	5.292	1	0.021	0.374	0.162	0.864
Private sector employee	−0.720	0.500	2.072	1	0.150	0.487	0.182	1.297
Retired	−0.801	0.543	2.178	1	0.140	0.449	0.155	1.301
Geographical location			3.229	4	0.520			
Central	Reference case							
Northern	−0.211	0.431	0.239	1	0.625	0.810	0.348	1.885
Eastern	−0.520	0.472	1.217	1	0.270	0.594	0.236	1.498
Western	0.352	0.360	0.952	1	0.329	1.421	0.701	2.880
Southern	−0.035	0.512	0.005	1	0.945	0.965	0.354	2.635
Membership of livestock associations								
No	Reference case							
Yes	0.680	0.525	1.677	1	0.195	1.973	0.705	5.521
Knowledge about compound feed			0.029	2	0.985			
Low	Reference case							
Moderate	0.014	0.337	0.002	1	0.966	1.014	0.524	1.965
High	−0.044	0.398	0.012	1	0.912	0.957	0.439	2.088
Constant	−5.100	1.219	17.508	1	<0.001	0.006		

Dependent variable is adoption of compound feed (0 = No adoption; 1 = adoption). Model $\chi^2 = 258.38$ ($df = 19$; p-value ≤ 0.001). Nagelkerke $R^2 = 0.588$. Hosmer and Lemeshow $\chi^2 = 4.627$ ($df = 8$; p-value = 0.797). *Statistically significant at the 0.01 level.

where natural vegetation is available for the animals to feed on freely. While this method requires less infrastructure and is cost-effective, it presents challenges in ensuring consistent nutrition and animal welfare (Monteiro et al., 2017; Wróbel et al., 2023).

Livestock nutrition is heavily reliant on green fodder, which provides essential nutrients and fiber necessary for growth and overall health. Different varieties of green fodder are used depending on availability, nutritional content, and animal-specific requirements. In Saudi Arabia, alfalfa is a popular choice among

livestock producers due to its high protein content and ability to thrive in warm and dry climatic conditions. Rhodes grass and wet clover are also commonly used by farmers. Barley is the primary grain for feeding livestock. However, a government-imposed ban on green fodder cultivation has posed significant challenges for the country's livestock industry by impacting water use in agriculture. The agricultural sector accounts for approximately 67% of domestic water usage with around 80% of the water extracted from deep non-renewable groundwater aquifers as well as renewable shallow alluvial aquifers (Ministry of Environment, 2022). Fodder production has the largest share, accounting for 67% of the agricultural water consumption (Ghanem et al., 2021). Over-extraction of groundwater resources has led to the depletion of limited groundwater resources (Awadh et al., 2021; Alotaibi et al., 2023). During the 1980s, the government initiated massive agricultural subsidies for installing deep wells to promote agricultural production in Saudi Arabia. However, in the long run, these practices have proved unsustainable for the country (FAO, 2018; Touidjeni et al., 2022). Since 2019, there has been a decline in the consumption of water by the agricultural sector due to strict governmental policies regarding agricultural water use (Odnoletkova and Patzek, 2023). Moreover, a ban on green fodder cultivation has resulted in a decrease in the area under fodder crops (Ministry of Environment, 2019).

The prohibition of green fodder cultivation has effectively reduced agricultural water usage, but it has also heightened livestock farmers' dependence on imported fodder from other nations. Saudi Arabia now ranks fifth globally as a major importer of forage crops (OEC, 2023a). In 2022, the country was ranked as the second largest importer of Lucerne (alfalfa) meals and pellets (OEC, 2023b). The import value of alfalfa meals rose from $31.3 million in 2018 to $65.5 million in 2021. With the livestock industry expanding, future fodder imports are expected to increase further. Relying heavily on imported fodder presents various challenges such as increased costs for livestock farmers and susceptibility to supply chain disruptions. This underscores the necessity for Saudi Arabia to consider alternative approaches like investing in sustainable fodder production technologies to ensure long-term food and feed security for its livestock sector.

The utilization of compound feed is positioned to address the challenges arising from the ban on green fodder cultivation and heavy dependence on imported fodder in Saudi Arabia. Despite a significant number of farmers still relying on traditional grazing and green fodder, a notable proportion has shifted toward using compound feed for their livestock. The demand for compound feed has led to steady growth in Saudi Arabia's animal feed market, with its value reaching 2.41$ billion in 2020 and projected to rise to 3.46$ billion by the end of 2027, driven by the rapidly expanding livestock industry (KSI, 2023). Limited domestic production capacity necessitates substantial imports of animal feed into the country from other nations. Additionally, government support and subsidies have been provided to importers with an aim to enhance availability and affordability of compound feed for livestock farmers; however, recent subsidy-restructuring initiatives seek more sustainable practices within the sector while reducing budget strain (Ghazaly et al., 2020).

Compound feed provides numerous advantages over green fodder, particularly in terms of convenience, nutritional content, and cost-effectiveness. Its ready-to-use nature eliminates the need for labor-intensive processes such as planting, harvesting, and processing green fodder. Additionally, it is designed to offer balanced nutrition for livestock that ensures their optimal growth, development, and overall well-being (McDonald et al., 2011; Okewole and Igbeka, 2016; Balehegn et al., 2020; Shrinivasa and Mathur, 2020). Moreover, compound feed addresses the risk of nutrient deficiencies associated with green fodder by carefully meeting the specific nutritional needs of various livestock species. Furthermore, compared to green fodder, compound feed has a longer shelf life which reduces spoilage and wastage risk (McDonald et al., 2011). Overall, the adoption of compound feed can lead to increased efficiency in livestock production, improved animal health and welfare, and reduced costs for farmers.

Several studies (Mondal, 2009; Drannikov et al., 2022; Li et al., 2022; Marynich et al., 2022; Ndudzo et al., 2023) suggest that use of compound feed improves growth and overall productivity of sheep and goats, mainly through improved nutritional profile, digestibility, feed conversion efficiency and reduced costs. Unlike pasture grazing, compound feeds ensure a balanced supply of proteins, fats, carbohydrates, minerals, and vitamins, which is essential during crucial stages of growth and development like lactation and reproduction. Moreover, compound feed ingredients like legumes and grains are more digestible than roughages and help sheep and goats to extract nutrients easily from feed. This in turn results in increased body weight, milk production and improved meat quality, helping livestock farmers to maximize economic returns. Although compound feed is generally more expensive than fodder, however it has high economic feasibility due to its significant role in increasing overall productivity and profitability by improving livestock health, reproductive performance, survival rates, and reduced labor costs, especially where farm labor is expensive (Altynbayeva and Baimukhanova, 2021). In certain areas where most of the ingredients of compound feed are locally produced and processed, its price might also be low. In Saudi Arabia, much of the ingredients of compound feed are imported from other countries due to lack of local production. However, currently the government is offering subsidies to procure compound feed for the farmers at affordable prices as the government has placed a ban on fodder production as well as on wheat production in Saudi Arabia to preserve rapidly depleting groundwater resources.

Using food waste as an alternative source of livestock feed could also be a viable option in the context of Saudi Arabia. Historically, feeding livestock with food waste has been practiced in many parts of the world and livestock animals acted as bio-processors for converting food waste materials into quality products like milk, meat, and eggs. However, intensive and precision animal feeding approaches has become more common focusing on maximum productivity to meet food requirements of the rapidly growing population (Dou et al., 2018). But greater vigilance about environmental sustainability and conservation of resources has renewed interest in reinvigorating this age-old practice. Saudi Arabia is one of those countries that has high food waste at consumer level. The estimates showed that about

40–50% of food goes to waste in the country (UNDP, 2022). Utilizing a considerable proportion of this waste after processing for livestock feed offers several benefits for the country. Firstly, it can reduce waste disposal problems and burden on landfills and therefore contributes to sustainable waste management (Nath et al., 2023). Secondly, it can reduce pressure on natural resources by minimizing the use of land, water, energy, and other resources to produce animal feed. It would also help reduce feed exports from other countries and would serve as a cost-effective feed source for livestock farmers (Dou et al., 2022; Lalramhlimi et al., 2022; Rasool et al., 2023). Lastly, it would contribute toward climate change mitigation and achievement of sustainable development goals by reducing greenhouse gas emissions and transforming food production into a more sustainable food system and would help the country transition toward circular bioeconomy (Dou et al., 2018; Nath et al., 2023). However, development of efficient systems for converting food waste into livestock feed is a serious challenge and requires collaboration and coordination of various stakeholders for its effective implementation. Moreover, strict regulatory measures that ensure safety of animal feed would also be necessary for safeguarding animal and human health (Ominski et al., 2022).

The results indicate that specific socioeconomic attributes of livestock farmers are linked to their choices regarding using compound feed. Formal education, farming experience, and income significantly impact the adoption of compound feed. Livestock farmers with higher formal education, more farming experience, and higher income levels tend to adopt compound feed for their animals compared to those with lower education, less experience in farming, and lower incomes. Higher formal education allows farmers to better understand the benefits of using compound feed in enhancing animal health and overall productivity, while farming experience provides them with knowledge and confidence to implement new practices on their farms. Moreover, higher incomes enable investment in purchasing compound feed for livestock. These factors play a critical role in shaping farmers' decisions and underscore the significance of education, experience, and financial resources in promoting the use of compound feed in livestock farming. This also suggests that making compound feed more affordable and accessible for low-income farmers could potentially raise adoption rates leading to improved livestock productivity and profitability. Hence policymakers should prioritize providing educational opportunities, particularly those with limited formal education and should implement targeted interventions to improve the financial access of low-income farmers to compound feed in order to promote its adoption and enhance livestock productivity and profitability.

5 Conclusion

Based on the results, it is evident most of the livestock farmers in Saudi Arabia are engaged in raising sheep and goats for commercial purposes, catering to local meat consumption. The majority of the farmers feed their livestock with alfalfa hay and barley grain. The prohibition on local green fodder production has led to an increase in the importation of these crops over recent years to satisfy domestic demand. To address the scarcity of green fodder, farmers have also started using compound feed. The widespread adoption of compound feed presents a strategic solution for sustainable livestock production in KSA by potentially improving productivity, sustainability, and profitability within the industry. This transition could facilitate more efficient use of the nation's limited arable land and water resources by significantly reducing water consumption, thereby allowing the cultivation of other high-value crops. To decrease reliance on imports for animal feed, it is recommended that Saudi Arabia invests in developing less water-intensive and salt-tolerant green fodder crops as increased reliance on imports makes the country more vulnerable to fluctuations in global feed markets and potential supply disruptions. As income level of the livestock farmers is a significant determinant of compound feed adoption, potential subsidies by the government should particularly be targeted toward small-scale low-income farmers. Additionally, the agricultural extension wing of the Ministry of Environment, Water and Agriculture (MEWA) needs to be actively involved in educating livestock farmers about the potential benefits of compound feed as well as feed safety practices and relevant institutions should implement these practices along the feed supply chain in order to ensure a healthy food system. Ensuring a stable supply of quality fodder and compound feed for livestock producers would help Saudi Arabia achieve its vision of a thriving livestock industry, capable of meeting the growing demand for high-quality animal-based products.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by IBR, King Saud University, Saudi Arabia. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

MA: Formal analysis, Project administration, Visualization, Writing – review & editing. BA: Data curation, Investigation, Methodology, Supervision, Writing – original draft. NA: Conceptualization, Data curation, Formal analysis, Writing – original draft. MI: Data curation, Investigation, Writing – review & editing, Conceptualization, Software, Writing – original draft. MM: Data curation, Investigation, Writing – review & editing, Methodology, Project administration.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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