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Farmers' willingness to adopt daylily forage technology in Northern Shanxi of China

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Introduction: The transformation of the food structure is accelerating in China, and the shortage of feed grains is the main limiting factor. Traditional feed production and feeding modes no longer meet the requirements for high-quality livestock and poultry breeding. Therefore, China's forage industry must fully utilize its resource endowment advantages. This study explores two aspects: first, the research on the impact of personal, family, planting, and other characteristics on farmers' willingness to adopt the forage utilization technology of stems and leaves of *Hemerocallis citrina* Baroni (Hc-FUT); and second, the influence of behavioral attitudes, subjective norms, and perceived behavioral control on farmers' willingness to adopt Hc-FUT, based on the Theory of Planned Behavior (TPB).

Methods: Data were obtained from 225 farmers in the Yunzhou District, Datong City, Shanxi Province, China. A logistic regression model was used to examine the impact of the four characteristics on farmers' willingness to adopt Hc-FUT, and a structural equation model was used to examine farmers' willingness to use Hc-FUT based on TPB. SPSS 27 and AMOS 26were used for analysis.

Results: The results show that farmers who used Hc stems and leaves to feed livestock were more willing to adopt Hc-FUT. Greater government support and increased usage of the technology positively correlated with a higher willingness among farmers to adopt it. Both subjective norms and perceived behavioral control had a significant positive impact on adoption intention, whereas subjective norms also positively impacted behavioral attitudes.

KEYWORDS

daylily, forage utilization, willingness to adopt, TPB theory, SEM model

1 Introduction

Food security is crucial for human survival, yet global food security remains a critical and complex challenge, with one-third of the population experiencing severe food insecurity (World Health Organization, 2022), contributing to the third global food crisis in 50 years (Clapp, 2023).

China has prioritized grain security as a strategic cornerstone since the founding of the People's Republic, achieving basic self-sufficiency through decades of targeted policies (Wu, 2023). However, the nation now faces unique challenges in reconciling its historical achievements with emerging socioeconomic demands. As socialism with Chinese characteristics enters a new era, shifting consumption patterns—marked by declining staple grain intake and rising meat demand—have exposed structural contradictions in the agricultural system. This transition has intensified the "human-livestock grain competition" dilemma (Hazra, 2014), particularly under resource constraints: China is still in the primary stage of developing its forage industry, and the severe shortage of land and water resources is seriously affecting its development (Hou, 2022). The main issue in grain security in China is the security of feed grains (Zhang, 2023; Wu, 2024), and the country faces a 50-million-ton deficit in high-quality forage (Chen et al., 2023). The "greater food concept" proposed by the Party Central Committee leverages China's resource endowment through innovative approaches: integrating crop-livestock systems, promoting circular agriculture, and advancing biotechnology for alternative protein sources. This pathway aligns with both ecological civilization objectives and the population's evolving dietary demands, demonstrating how China's unique developmental stage creates laboratory conditions for redefining global food security paradigms. Current research indicates that China's agricultural by-products (e.g., crop straw, vegetable residues, and soybean dregs) demonstrate significant potential for feed utilization. Taking corn straw in Shanxi Province as an example, elevating the feed conversion rate to above 50% could generate economic benefits exceeding 18 billion yuan. However, prevalent technical challenges—including high conversion costs, insufficient industrial chain integration, and lack of large-scale application mechanisms—remain core bottlenecks restricting the efficient utilization of these agricultural by-products (Yin and Yang, 2025; Cai et al., 2011; Tang, 2024; Qi and Zhou, 2023).

Hemerocallis citrina Baroni (Hc) is native to central-northern China and has become a raw material for food and medicine because of its high nutritional value (Guo et al., 2022; Sun et al., 2024). Hc is distributed in various regions south of the Qinling Mountains, as well as in the Hebei, Shandong, and Shanxi provinces. In 2021, the Hc planting area in Datong City, Shanxi Province reached 17,667 hm^2, the total output value of the entire Hc industry chain reached 4.2 billion yuan RMB. Hc is accompanied by a large number of stems and leaves after harvesting, and due to the lack of scientifically effective and economically viable processing and utilization technologies, most of the stems and leaves are treated as trash to casually discard or burned or easily used, resulting in wastage of resources and environmental pollution (Zhao et al., 2021). Reusing the stems and leaves of Hc as forage can not only alleviate the shortage of forage but also promote the healthy development of the Hc industry, protecting the ecological environment of agricultural and rural areas. Although the nutritional components of *Hemerocallis citrina* are predominantly concentrated in its flowers, the stems and leaves also contain abundant flavonoid metabolites. Notably, the leaves exhibit particularly diverse compositions and significant functional properties, demonstrating potential applications in antioxidant, anti-inflammatory, and antibacterial activities. (Shiao et al., 1962; Rodriguez-Enriquez and Grant-Downton, 2013; Karak, 2019; Lv and Guo, 2023). The utilization of Hc stems and leaves as forage is mainly based on their biological characteristics and product functions through a series of technological treatments and other forage combinations. Transforming them into forage resources that can be safely consumed and have high nutritional value is meaningful for livestock. This technology has achieved notable progress, demonstrating significant applicability in ruminant (beef cattle and Tan sheep) farming when co-ensiled with silage corn. Studies confirm that feed incorporating daylily stems and leaves complies with forage standards. Through optimized blending at a 2:3 ratio, it effectively reduces fiber components by 18–23% while improving palatability and digestibility. The formulation enhances lactic acid accumulation, suppresses proliferation of harmful microorganisms like *Clostridium butyricum*, and maintains stable pH levels within the ideal 4.13–4.51 range throughout the preservation period (Mei et al., 2021; Zhang et al., 2023; Zheng et al., 2024). The Shanxi Province's forage industry technology team has accumulated certain technological expertise in the field of Hc stem and leaf forage utilization, aiming to turn the waste of Hc into treasured and recycled resources. Although the technology has good prospects, there is still a significant gap in terms of promotion and application.

The Theory of Planned Behavior (TPB), proposed by Ajzen (1991), is one of the most representative and widely applied theories for studying farmers' technology adoption behavior and intention. In practical applications, TPB has been used to study the intention of college students to consume green food (He and Sui, 2024) and to explore the impact of digital literacy on farmers' pro-environmental behavior (Lu et al., 2024). Scholars have also used TPB to study farmers' adoption behavior regarding agricultural technology, such as water-saving technology, green manure technology, green control technology, and sustainable agriculture technology, etc. (Adnan et al., 2019; Xiang and Guo, 2023; Sarkar et al., 2022). It is a powerful tool for predicting behavior and intention (Rahmaninkoshkaki and Zarei, 2018). Thus, it is also an advantageous tool for analyzing farmers' intention to adopt Hc-FUT.

Scientifically and effectively exploring the rational utilization and promotion of Hc stems and leaves will contribute to expanding income channels in the Hc industry, realizing a low-carbon green cycle, and supporting the country in achieving the "dual carbon" goal. This is a new proposition for promoting farmer income growth and rural ecological revitalization, especially for the Hc-planting areas in Datong City, Shanxi Province, and throughout the country. To further promote the use of Hc-FUT, we conducted field research to investigate the willingness of 225 households in Datong City to adopt Hc-FUT and the core factors affecting farmers' willingness to adopt it. Finally, policy recommendations were proposed based on the problems encountered during the promotion process. This study aims to promote the sustainable development of the Hc industry along a "green, efficient, and circular" path, increase the supply of forage, and protect China's food safety in multiple ways.

2 Theoretical introduction and research hypotheses

2.1 Theoretical introduction

TPB states that an individual's behavior (B) is largely influenced by their intention (I) to perform the behavior, which, in turn, is influenced by their behavioral attitude (BA), subjective norms (SN), and perceived behavioral control (PBC). Among these, behavioral attitude refers to the degree to which an individual likes or dislikes the execution of the behavior; Subjective norms refer to the social pressure that individuals feel when performing the behavior, manifested specifically as the influence of others or groups on decision-makers; Perceived behavioral control refers to the degree of difficulty an individual feels when performing a certain behavior, reflecting both their prior experience and anticipated difficulties. TPB also posits that subjective norms shape behavioral attitudes through the internalization of social pressures or group values (Ajzen, 1991; Pan and Wang, 2018). Conner and Armitage (1998) further extended this framework by proposing that perceived behavioral control (PBC) not only directly influences behavioral intentions but also reinforces positive evaluations of behavioral outcomes (attitudes) through enhanced behavioral confidence. This theory primarily considers both internal and external factors, examining the connections between individuals, society, and the environment, and analyzing the transformation process of ideological concepts and behaviors in the actual decision-making process of individuals. This helps us understand how people change their behavior patterns (Daxini et al., 2019; Hyland et al., 2018; Senger et al., 2017).

2.2 Research hypotheses

Based on the analysis of TPB, farmers' intention to adopt Hc-FUT is affected by their attitude, subjective norms, and perceived behavioral control, subjective norms and perceived behavioral control can positively influence behavioral attitudes. According to the survey results of farmers in Yunzhou District, Datong City (Table 1), only 36.4% of farmers had heard of Hc-FUT, and most farmers were unfamiliar with this technology, so farmers' attitudes toward agricultural technologies are likely shaped by a combination of external and internal factors, including government policies, social advocacy, self-efficacy, and resource availability. Empirical studies corroborate this multidimensional influence: Pan and Wang (2018) demonstrated in eco-tourism research that subjective norms indirectly enhance environmental behavioral intentions through their effect on specific environmental attitudes. Similarly, Wang et al. (2023) revealed in a study on farmers' biopesticide adoption that both subjective norms and perceived behavioral control (e.g., perceived efficacy and ease of implementation) exert significant positive impacts on behavioral attitudes. Therefore, we can reasonably infer that the attitude toward adopting this technology will be influenced by one's cognition, conditions, and the surrounding environment. Thus, behavioral attitudes may be affected by subjective norms and perceived behavioral control. Based on this, we propose the following hypotheses:

> *H1*: Behavioral attitude has a significantly positive impact on farmers' intention to adopt Hc-FUT.
>
> *H2*: Subjective norms have a significantly positive impact on farmers' intention to adopt Hc-FUT.
>
> *H3*: Perceived behavioral control has a significant positive impact on farmers' intention to adopt Hc-FUT.
>
> *H4*: Perceived behavioral control has a significant positive impact on behavioral attitude.
>
> *H5*: Subjective norms have a significant positive impact on behavioral attitude.

Based on these hypotheses, a model was constructed, as shown in Figure 1.

3 Materials and methods

3.1 Data source

3.1.1 Study area

Shanxi Province is located in the middle of the Yellow River Basin, with a total area of 156,700 square kilometers, accounting for 1.6% of the total area of the country. Shanxi Province has a large population and limited land resources, leading to shortages of land and water resources (Zhang et al., 2024). This study used a stratified random sampling method. A total of five townships, namely Dangliuzhuang Township, Jijia Township, Jule Township, Xiping Town, and Xubao Township in Yunzhou District, Datong City, Shanxi Province, were selected as the research areas. The research team conducted on-site household surveys in the research area in April 2024.

3.1.2 Survey overview

Before conducting the formal research, a pre-survey was conducted by randomly selecting 10 farmers within the research area. The questionnaire was revised and improved based on the survey results. After these modifications, formal research began. A total of 235 questionnaires were distributed during the formal survey; after removing 10 invalid questionnaires, 225 valid questionnaires were collected, with an effective recovery rate of 95.74%. The distribution of the number of surveyed farmers is shown in Table 2. This study investigated farmers' awareness of and willingness to adopt Hc-FUT. Overall, farmers had a certain level of understanding regarding the utilization of Hc stems and leaves; however, their degree of understanding of Hc-FUT was relatively low. Of the farmers surveyed, 52.4% believed that Hc stems and leaves could be utilized as forage, 36.4% had heard of Hc-FUT, and 44.4% were willing to try it. The specific views and opinions of the farmers are shown in Table 1.

3.2 Variable and model selection

3.2.1 Variable and model

The variables are selected in two parts. The first part includes the four main characteristics. In terms of research on farmers' willingness to adopt technology, scholars have categorized the factors influencing farmers' willingness to adopt agricultural technology into personal characteristics, family characteristics, planting characteristics, and other characteristics. Personal characteristics mainly include gender, age, education level, etc. (Burton, 2014; Giua et al., 2022; Serebrennikov et al., 2020); family characteristics mainly include the labor force, income, expenditure, etc. (Cui et al., 2022; Sardianou and Genoudi, 2013); planting characteristics mainly include planting area (Mi et al., 2021), and whether the farm has suffered from natural disasters (Khodadad et al., 2022), etc.; other characteristics include financial support (Zhou et al., 2022), technological innovation (Khan et al., 2022), etc. In this section, we use a logistic regression model to analyze the data.

The second part is based on the TPB. According to the TPB, we selected four latent variables and set the corresponding observation

TABLE 1 Farmers' views and opinions of the Hc-FUT.

Investigate question	"Yes"		"No"		Reason, number, and proportion of "No"		
	Number of people	Proportion	Number of people	Proportion	Reason	Number of people	Proportion
Can the stems and leaves of Hc be utilized as forage?	118	52.4%	107	47.6%	They do not raise livestock, so they are unclear	57	53.3%
					Hc stems and leaves lack nutrients	16	14.0%
					Burning is more convenient and can reduce pests and diseases	11	10.3%
					Harvesting the stems and leaves of Hc is troublesome and has little value	18	16.8%
					There is enough forage for livestock	6	5.6%
Whether you have heard of the Hc-FUT?	82	36.4%	143	63.6%			
Whether you are willing to try the Hc-FUT?	100	44.4%	125	55.6%	It has a high cutting cost	7	6.7%
					Hc stems and leaves have no market	12	11.4%
					There is a lack of understanding of Hc-FUT	39	37.1%
					Lack of cutting funds	39	37.1%
					Lack of labor power	52	49.5%
					Not planting Hc	20	19.0%
					Worried about affecting the yield of Hc	11	10.5%
					There is enough forage for livestock	10	9.5%
When do you think cutting the stems and leaves of Hc will not affect its yield in the following year?					1–2 months after picking Hc flowers.	65	28.9%
					After 1/3 of the Hc stems and leaves withered	82	36.4%
					The end of October to the end of November	78	34.7%

variables, each of which is reflected by multiple observed variables. We consider adoption intention as the dependent variable, while behavioral attitude, subjective norms, and perceived behavioral control are the independent variables. Structural Equation Modeling (SEM) is a data analysis method that allows the detection of relationships between multiple variables in the model (Khoshmaram et al., 2020). Therefore, we used SEM to analyze the data in this section.

3.2.2 Variable statistics of logistic regression model

In the logistic regression model, the dependent variable is "whether the farmer is willing to adopt Hc-FUT." "Y = 0" represents that the farmer is unwilling, while "Y = 1" represents that the farmer is willing. The independent variables include personal, family, planting, and other characteristics, with a total of 18 indices. The specific variables and measures are shown in Table 3.

3.2.3 Variable statistics of SEM

There were four latent variables (behavioral intention, attitude toward behavior, subjective norms, and perceived behavioral control), and each latent variable had multiple corresponding observed variables. A 5-level Likert scale was adopted to measure the observed variables, with values ranging from 1 to 5 representing "completely disagree" to "completely agree," respectively. The selection of observation variables and data statistics are shown in Table 4.

In SPSS, principal component analysis was applied to the above variables for factor dimensionality reduction, and the rotated factor loadings were calculated to validate the scale's rationality. The results are shown in Tables 5, 6. The factor dimensionality reduction results indicated that three factors could be extracted from the above variables. The rotated factor loadings showed that the coefficients for the observed variables of each

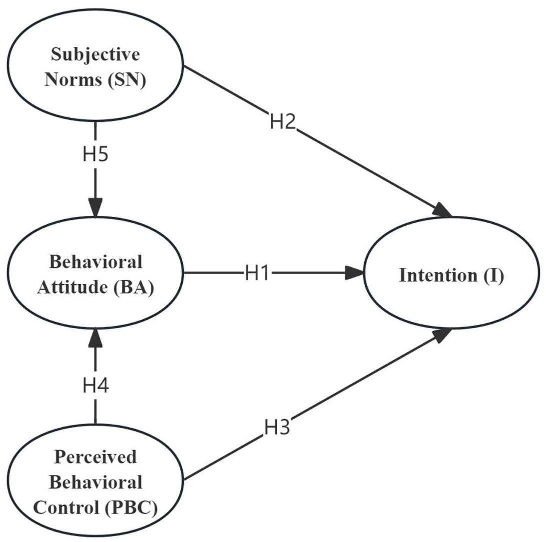

FIGURE 1
Hypothesis model.

TABLE 2 Distribution of farmers investigation.

City investigation	Townships (towns) investigation	The number of samples
Yunzhou District of Datong City	Dangliuzhuang Township	28
	Jijia Township	24
	Jule Township	58
	Xiping Town	85
	Xubao Township	36
Total	5	225

latent variable were all greater than 0.5. Notably, the observed variables for Intention and Subjective Norm belonged to the same component, suggesting a strong connection between Intention and Subjective Norm.

3.3 Model building

3.3.1 Logistic regression model

The logistic regression model is an effective tool for studying the factors that influence farmers' adoption intention. Given independent variables $X = (x_1, x_2, \ldots, x_n)$ and parameters $\beta = (\beta_0, \beta_1, \ldots, \beta_n)$, the linear combination is Equation 1:

$$z = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n \quad (1)$$

In Equation 2: The linear output z is transformed into a probability $P(Y = 1|X)$ via the Sigmoid function:

$$P(Y = 1|X) = \sigma(z) = \frac{1}{1+e^{-z}} \quad (2)$$

The linear component of binary logistic regression corresponds to the log-odds of the event probability:

$$\ln\left(\frac{P(Y=1|X)}{1-P(Y=1|X)}\right) = \beta_0 + \beta_1 x_1 + \cdots \beta_n x_n \quad (3)$$

In Equation 3, dependent variable Y is a binary variable (0 or 1) representing the classification outcome, independent variables X is Continuous or discrete feature variables, parameters β is estimated via maximum likelihood estimation (MLE), indicating the direction and magnitude of each variable's contribution to the probability, and the role of sigmoid function is maps the linear output z to the interval (0, 1), enabling probabilistic interpretation.

3.3.2 Structural equation modeling

Structural Equation Modeling (SEM) is a data analysis method that allows the detection of relationships between multiple variables in a model (Khoshmaram et al., 2020). This method also considers measurement errors, allowing the investigator to report the data analysis while accounting for these errors (Hair et al., 2017). The specific forms of SEM are as follows:

$$\eta = B\eta + \Gamma\xi + \varsigma \quad (4)$$

$$X = \Lambda x \xi + \delta \quad (5)$$

$$Y = \Lambda y \eta + \varepsilon \quad (6)$$

In Equation 4: B represents the relationship between endogenous variables, Γ represents the impact of ξ (external latent variable) on η (internal latent variable). ζ represents the vector of residual terms of the structural model, reflecting the part of η that could not be explained in the structural model. In Equations 5, 6, X and Y represent the exogenous dominant variables, Λx and Λy represent the factor load of X and Y, respectively; ξ and η represent the exogenous latent variables and endogenous latent variables, respectively; δ and ε represent the measurement errors of X and Y, respectively, where ε is not correlated with η, ξ, and δ, and δ is not correlated with ξ, η, and ε.

4 Results

4.1 Logistic regression results

4.1.1 Multicollinearity test and regression results

Multicollinearity is a statistical phenomenon that affects the results of logistic regression models. The Variance Inflation Factor (VIF) indicates whether a variable has a strong linear relationship with other variable: a VIF higher than 10 or tolerance (1/VIF) less than 0.1 both indicate that multicollinearity causes bias in the model. Therefore, this study first used SPSS (version 26.0) to test the multicollinearity between the variables, as shown in Table 7.

The tolerances of the selected independent variables are all greater than 0.1 and the VIFs are all less than 10, indicating that there is no multicollinearity among the variables. A binary logistic regression analysis was conducted using SPSS 26.0 software. This study has

TABLE 3 Variable meanings and descriptive statistics.

Variable	Definition and measurement	Expected sign
Planting intention (Y)	1 = Willing; 0 = Unwilling	
Gender (X1)	1 = Male; 0 = Female	+/−
Is he/she the head of the household? (X2)	1 = Yes; 0 = No	+/−
Age (X3)	Assign values based on the actual situation	+/−
Degree of education (X4)	1 = Lower than junior middle school; 2 = Junior middle school; 3 = High school; 4 = University and above	+
Health condition (X5)	1 = Very bad; 2 = Bad; 3 = Common; 4 = Good; 5 = Very good	+
Attitude toward risk (X6)	1 = Conservative; 2 = Steadiness; 3 = Adventurous	+
Actual number of agricultural labor force in the family (X7)	Assign values based on actual situation	+
Occupational status (X8)	1 = Farmer; 2 = Farming and working part-time; 3 = Worker;	−
Whether to raise livestock or not (X9)	1 = Yes; 0 = No	+
Land area (hm^2) (X10)	Assign values based on actual situation	+
Is the land contiguous? (X11)	1 = Yes; 0 = No	+
Whether to rent land or not? (X12)	1 = Yes; 0 = No	+/−
Fertility level of land (X13)	1 = Very fertile; 2 = Fertile; 3 = Common; 4 = Barren; 5 = Very barren	−
Irrigation conditions (X14)	1 = Very bad; 2 = Bad; 3 = Common; 4 = Good; 5 = Very good	+
Planting area of Hc (hm^2) (X15)	Assign values based on actual situation	+
Have natural disasters occurred in agricultural production in recent years? (X16)	1 = Yes; 0 = No	−
Do you think the stems and leaves of yellow flowers can be used as feed through processing or other methods? (X17)	1 = Yes; 0 = No	+
Have you ever fed livestock with yellow flower stems and leaves? (X18)	1 = Yes; 0 = No	+
Government support intensity (X19)	1 = Very unsupported; 2 = Unsupported; 3 = Common; 4 = Support; 5 = Very support	+
The number of people planting yellow flowers around (X20)	1 = Very little; 2 = Little; 3 = Common; 4 = Many; 5 = A lot	+

passed the mixed test of model coefficients, logarithmic test of maximum likelihood squared, and Hosmer Lemeshow test, confirming that the model fits the data well. The chi-square value of the model is 119.563, with a p-value of 0.000, which is less than 0.001, indicating that at least one variable coefficient among the independent variables is non-zero.

4.1.2 Results of logistic regression analysis

The significance of each variable is shown in Table 8. Based on the above results, we further analyze the degree and direction of influence of each independent variable on the dependent variable. The specific findings are as follows:

The research has found that X18 has a significantly positive influence on adoption intentions. Analyzing the reasons based on actual research results, farmers who have used Hc stems and leaves to feed livestock have a deeper understanding of the feeding characteristics of Hc stems and leaves, resulting in a higher willingness to adopt this technology. Moreover, X19 also significantly positively influences adoption intention, mainly because the promotion of agricultural technology needs strong support from the government; the greater the government support, the higher the willingness of farmers to adopt it. Additionally, owing to geographical and kinship factors, farmers often communicate and learn agricultural techniques among themselves. The suggestions of their neighbors are frequently considered by farmers, improving their decisions. Thus, the neighborhood effect can positively influence farmers' intentions to adopt the technology.

4.1.3 Robust test

To verify the regression results, this study employs a method of removing certain independent variables and conducting a series of robustness tests. As shown in Table 6, Model 2 presents the regression results after removing "gender" from personal characteristics, while Model 3 shows the regression results after excluding "whether to raise livestock or not" from family characteristics. In both cases, the three factors— "X18," "X19," and "X20"—continue to significantly positively influence adoption intention, and the direction of influence remains unchanged. Thus, the analysis results demonstrate robustness.

4.2 Structural equation modeling

4.2.1 Reliability and validity testing

Because this study drew on well-established scales, confirmatory factor analysis was used in this study to test the reliability and effectiveness of the model.

TABLE 4 Variable selection and data statistic.

Latent variable	Measurement questions	Dimension	Source	Mean value	Standard deviation
Intention (I)	You are willing to adopt the Hc-FUT (I1)	Behavioral tendency	Xiao (2016) and Ahmmadi et al. (2021)	2.83	1.34
	You plan to adopt the Hc-FUT next year (I2)	Future commitment		2.32	1.16
Attitude (A)	The Hc-FUT can help livestock grow better (A1)	Production	Ahmmadi et al. (2021) and Holland and Hill (2007)	3.28	0.98
	The Hc-FUT can generate more income (A2)	Economy		3.45	0.93
	The Hc-FUT is beneficial to the environment (A3)	Environment		3.64	0.93
Subjective norms (SN)	Government supports the Hc-FUT (SN1)	Governmental guidance	Roh et al. (2022)	2.95	0.99
	Many people adopt the Hc-FUT (SN2)	Community pressure		2.23	0.90
	If someone recommends the Hc-FUT to you, would you be willing to try it? (SN3)	Compliance propensity		2.92	1.33
Perceived behavioral control (PBC)	Your mechanical conditions are not suitable for the Hc-FUT (PBC1)	Mechanical conditions	Shi et al. (2017)	3.43	0.95
	Your labor force is insufficient for the Hc-FUT (PBC2)	Labor force		3.52	1.00
	You have not mastered the knowledge and techniques required for the Hc-FUT (PBC3)	Knowledge		3.83	1.00

TABLE 5 Total variance explained.

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.778	52.526	52.526	5.778	52.526	52.526	4.032	36.654	36.654
2	1.524	13.851	66.377	1.524	13.851	66.377	2.393	21.756	58.410
3	1.149	10.447	76.824	1.149	10.447	76.824	2.025	18.413	76.824
4	0.565	5.140	81.964						
5	0.507	4.609	86.572						

Cronbach's alpha and composite reliability (CR) were used to test the internal consistency of each latent variable. Convergent validity refers to the theoretical correlation between two or more items, measured by the path loading coefficient and average variance extraction (AVE). Differential validity refers to the degree to which two or more latent variables are uncorrelated with other latent variables, as measured by comparing the square root of the AVE values of each latent variable with the correlation coefficients of other latent variables. All indicators of the model were verified, and the table displays the values of each indicator (See Appendix). The Cronbach's alpha coefficient and combination reliability (CR) both exceeded the minimum value of 0.7 (Hair et al., 2017). The factor loading coefficients were close to or greater than the threshold value of 0.7, and all AVE values were greater than 0.5. Furthermore, most of the square roots of the latent variables' AVE values were greater than the correlation coefficients between those latent variables and other latent variables. These results indicate that the model performed well in terms of structural reliability, convergent validity, and discriminant validity.

The chi-square value divided by degrees of freedom (CMIN\DF), root mean square error of approximation (RMSEA), comparative fit index (CFI), goodness-of-fit index (GFI), adjusted goodness-of-fit index (AGFI), and normed fit index (NFI) were selected to measure the structural validity of the structural equation modeling. After analysis with Amos 26.0, the results are as follows: chi-square/degree of freedom = 3.953; RMSEA = 0.115; CFI = 0.925; GFI = 0.890; AGFI = 0.821; NFI = 0.903. The measured indicators suggest that the structural validity of the structural equation model is acceptable.

4.2.2 Results of SEM analysis

The path coefficient estimation results obtained by running the research model using Amos 26.0 software are listed in Table 9. As shown in the table, three hypotheses are supported, while two others are not. Specifically, hypotheses H2, H5, and H3 are significant at the 0.001, 0.001, and 0.05 levels, respectively, whereas H1 and H4 are not significant.

4.2.2.1 Concretely

1. Hypotheses H2 and H5 had correlation coefficients of 0.982 and 0.383, respectively, and were significant at the 0.001 level. In the study, subjective norms include three questions: "Government supports the utilization of Hc stems and leaves as forage," "Many people adopt the utilization of Hc stems and leaves as forage," and "If someone recommends this

TABLE 6 Rotated component matrix.

Variable	Component		
	1	2	3
I1	0.857		
I2	0.857		
A1		0.770	
A2		0.820	
A3		0.876	
SN1	0.808		
SN2	0.827		
SN3	0.847		
PBC1			0.878
PBC2			0.836
PBC3			0.537

TABLE 7 Collinearity test.

Variable	Collinearity statistics
	VIF
Gender (X1)	2.152
Is he/she the head of household (X2)	2.048
Age (X3)	1.313
Degree of education (X4)	1.193
Health condition (X5)	1.288
Attitude toward risk (X6)	1.191
Actual number of agricultural labor force in the family (X7)	1.249
Occupational status (X8)	1.095
Whether to raise livestock or not (X9)	1.163
Land area (mu) (X10)	1.232
Is the land contiguous? (X11)	1.208
Whether to rent land or not? (X12)	1.155
Fertility level of land (X13)	1.675
Irrigation conditions (X14)	1.658
Planting area of Hc (mu) (X15)	1.275
Have natural disasters occurred in agricultural production in recent years? (X16)	1.144
Do you think the stems and leaves of yellow flowers can be used as feed through processing or other methods? (X17)	1.48
Have you ever fed livestock with yellow flower stems and leaves? (X18)	1.295
Government support intensity (X19)	2.264
The number of people planting yellow flowers around (X20)	2.255

technology to you, would you be willing to try it?" This shows that the more the government supports this technology, the higher the willingness of farmers to adopt it, and the more positive attitude toward the technology. The more people around farmers adopt this technology, the higher the willingness of farmers to adopt it, and the more positive attitude toward the technology. Moreover, the more recommendations farmers receive about this technology, the higher the willingness of farmers to adopt it, and the more positive attitude toward the technology. Therefore, in the future process of technology promotion, giving full play to the organizational and driving roles of the government and others is an important direction.

2. Hypothesis H3: The correlation coefficient is −0.217, $p = 0.019$, and there is a significant negative correlation at the 5% level. In this study, perceived behavioral control included three aspects: mechanical conditions, labor force, and mastery of relevant technologies, showing that the better the corresponding mechanical conditions, the more abundant the labor force, and the more familiar the technology, the higher the willingness to adopt it. In the future promotion of this technology, attention should be paid to the improvement of related supporting facilities, alleviating the problem of labor shortage, and more publicity and guidance should be provided at the same time.
3. Hypotheses H1 and H4 did not pass the significance level test for two possible reasons: first, farmers who use this technology and have relevant knowledge are few. Thus, farmers judge whether to adopt technology based on their perception of their surroundings and the difficulty of implementation. Second, relevant technologies were introduced and promoted during the research period, thereby weakening farmers' awareness of restrictive conditions.

5 Discussion

By integrating logistic regression with Structural Equation Modeling (SEM), this study systematically elucidates the multifaceted mechanisms influencing farmers' adoption intention of Hc-FUT. The logistic regression model identified three significant drivers: farmers' prior experience of feeding livestock with *Hemerocallis citrina* stems and leaves (X18, $\beta = 2.00$, $p < 0.001$), government support intensity (X19, $\beta = 0.84$, $p < 0.01$), and neighborhood adoption rate (X20, $\beta = 1.13$, $p < 0.001$). SEM path analysis further validated the psychological mechanisms underlying behavioral decisions, revealing that subjective norms exerted a significant positive influence on adoption intention ($\beta = 0.982$, $p < 0.001$), consistent with findings from Pan and Wang's (2018) ecotourism research and Chen and Jiang's (2013) ecological construction willingness study, indicating external pressures (government/neighborhood influence) dominated adoption decisions. Subjective norms also positively affected behavioral attitudes ($\beta = 0.383$, $p < 0.001$), aligning with Wang et al.'s (2023) findings. Perceived behavioral control demonstrated a positive impact on adoption intention ($\beta = -0.217$, $p = 0.019$), congruent with Nhuong and Truong (2024) and Zheng et al. (2024). Notably, the attitude-intention decoupling contrasted with Adnan et al.'s (2019) findings where attitudes strongly predicted green fertilizer adoption, and perceived behavioral control showed no significant effect on attitudes. Hypotheses H2, H3, and H5 were validated, whereas H1 and H4 were rejected.

TABLE 8 Results of the logistic regression model.

Variable	Model 1		Model 2		Model 3	
	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
Have you ever fed livestock with yellow flower stems and leaves? (X18)	1.954****	0.501	1.939****	0.498	1.97****	0.495
Government support intensity (X19)	0.845***	0.288	0.863***	0.285	0.84***	0.286
The number of people planting yellow flowers around (X20)	1.126****	0.35	1.118****	0.349	1.128****	0.35
constant	−4.882*	2.52	−5.351***	2.233	−4.784*	2.484

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$, ****$p < 0.001$.

TABLE 9 Results of heterogeneity analysis.

Hypotheses		Estimate	S. E.	p-value	Whether the hypothesis is supported or not
H1	A - > I	−0.039	0.072	0.586	No support
H2	SN - > I	0.982***	0.063	<0.001	Support
H3	PBC - > I	−0.217*	0.092	0.019	Support
H4	PBC - > A	−0.027	0.112	0.808	No support
H5	SN - > A	0.383***	0.062	<0.001	Support

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$, ****$p < 0.001$.

The significant effects of X19 and X20 in logistic regression reinforce the crucial role of subjective norms in farmers' technology adoption intention. Farmers' prior experience of feeding livestock with *Hemerocallis citrina* stems and leaves exhibited stronger Hc-FUT adoption willingness, suggesting experiential learning fostered positive attitudes. However, behavioral attitudes failed to significantly influence adoption intention in SEM analysis, potentially attributable to limited technology familiarity - only 36.4% of respondents reported awareness of Hc-FUT, with merely 24% possessing relevant feeding experience (Table 1). This knowledge deficit likely hindered attitude-to-intention conversion, consistent with findings from low-diffusion agricultural innovation studies (Sarkar et al., 2022). Furthermore, the omission of risk perception variables (e.g., cost–benefit concerns), established as critical moderators in technology adoption literature (Mi et al., 2021; Giua et al., 2022), might explain the unvalidated PBC → A pathway, as risk perceptions could counteract perceived behavioral control's positive effects.

Suboptimal SEM fit indices (RMSEA = 0.115, the ideal value should be ≤0.08; GFI = 0.890, the ideal value should be ≥0.90.) indicate systematic deviations between the Theory of Planned Behavior framework and empirical data. While TPB presupposes rational individual assessments, the collectivist context of rural Shanxi, where community norms (kinship networks, neighborhood exemplars) supersede personal attitudes, may distort theoretical intention formation pathways. Sample heterogeneity further complicates model fit - the inclusion of both livestock farmers (18%) and non-farmers introduces group disparities in resource endowment and technological needs.

This research reveals TPB's distinctive manifestation in collectivist agricultural systems: Hc-FUT adoption decisions predominantly hinge on subjective norms. The non-significant attitude-intention relationship challenges TPB's universal assumption about attitude centrality, highlighting cultural context's moderating role and providing empirical evidence for TPB's cross-cultural adaptation. Methodologically, the integrated logistic regression-SEM framework incorporating personal characteristics, household attributes, cultivation features, and psychological cognition enhances explanatory power in agricultural technology adoption research. These findings contribute to Hc-FUT dissemination strategies and China's ongoing efforts to alleviate feed shortages through technological innovation.

6 Recommendation

Through data analysis of this survey, subjective norms had the most significant impact on farmers' willingness to adopt yellow flower stem and leaf forage technology, followed by perceived behavioral control. Although there was no significant correlation between behavioral attitude and willingness to adopt the technology, most farmers had a positive attitude toward the technology. Therefore, theoretically implementing this technology is feasible. However, in practice, the following points need to be noted.

First, government support is an important means of effectively promoting Hc-FUT. We suggest increasing government attention and elevating the utilization of Hc stems and leaves as forage for the strategic integrated development of the yellow flower industry in counties and cities. Corresponding subsidy policies should be issued by the government as soon as possible, and the range of subsidies should include Hc stem, leaf forage, and related machinery. The government has taken the lead in formulating quality standards for HC stem and leaf forage. Supervise the entire production, processing, and sales of Hc stems and leaf forage by establishing a quality inspection system. Forage-processing enterprises should be encouraged to develop diversified Hc stem and leaf forage products to meet different breeding needs and enhance the added value and market competitiveness of Hc stem and leaf forage. Organize relevant technical personnel to regularly conduct technical training and hold exhibitions and promotion events to enhance the renown and influence of the Datong City Hc stem and leaf forage products, thereby attracting more attention and use from breeding enterprises.

Second, perceived behavioral control has a significant positive impact on farmers' willingness to adopt yellow flower stem and leaf forage technology. Therefore, effective measures should be taken to solve the problems of insufficient machinery, labor, and knowledge regarding the use of yellow flower stem and leaf forage. Relevant scientific research institutions and enterprises should coordinate to strengthen cooperation and develop and promote suitable machinery for Hc stem and leaf forage, addressing the problem of labor shortage among farmers by leveraging the coordination of professional cooperatives.

Third, there is a need to continue to strengthen research and innovation in Hc stem and leaf forage utilization technologies. We suggest setting up special funds for innovative research and promoting the utilization of Hc stems and leaves for forage to strengthen the scientific and technological support foundation for extending the yellow flower industry chain. For example, research and development of forage-cutting machinery, nutrient composition testing of different varieties of forage grass with different proportions and combinations, testing the feeding effect on cattle and sheep, experiments on optimal cutting time, and optimal acquisition methods. Develop technical regulations and product standards for the utilization of Hc stem and leaf forage through an agricultural technology promotion service system and popularize these technologies to a vast number of farmers. Additionally, enterprises should be guided and supported in establishing Hc stem and leaf forage collection, storage, and sales systems. They should be equipped with corresponding equipment, facilities, and markets to achieve centralized collection, storage, processing, distribution, and sales of yellow flower stems and leaf forage.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the [patients/ participants OR patients/participants legal guardian/next of kin] was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

XiangjH: Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Software, Validation, Writing – original draft. QL: Data curation, Formal analysis, Investigation, Software, Validation, Writing – original draft. QJ: Data curation, Formal analysis, Investigation, Software, Writing – review & editing. MZ: Investigation, Writing – review & editing. ChL: Data curation, Investigation, Writing – review & editing. YY: Data curation, Investigation, Writing – review & editing. CG: Data curation, Investigation, Methodology, Writing – review & editing. CuL: Investigation, Writing – review & editing. XiangyH: Funding acquisition, Resources, Supervision, Writing – review & editing.

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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.

Generative AI statement

The authors declare that no Gen AI was used in the creation of this manuscript.

Publisher's note

References

Adnan, N., Nordin, S. M., Bahruddin, M. A., and Tareq, A. H. (2019). A state-of-the-art review on facilitating sustainable agriculture through green fertilizer technology adoption: assessing farmers behavior. *Trends Food Sci. Technol.* 86, 439–452. doi: 10.1016/j.tifs.2019.02.040

Ahmmadi, P., Rahimian, M., and Movahed, R. G. (2021). Theory of planned behavior to predict consumer behavior in using products irrigated with purified wastewater in Iran consumer. *J. Clean. Prod.* 296:126359. doi: 10.1016/j.jclepro.2021.126359

Ajzen, I. (1991). The theory of planned behavior. *Organ. Behav. Hum. Decis. Process.* 50, 179–211. doi: 10.1016/0749-5978(91)90020-T

Burton, R. J. F. (2014). The influence of farmer demographic characteristics on environmental behavior: a review. *J. Environ. Manag.* 135, 19–26. doi: 10.1016/j.jenvman.2013.12.005

Cai, Y. Q., Chou, G. H., and Xu, Z. G. (2011). Evaluation on potentials of energy utilization of crop residual resources in different regions of China. *J. Nat. Resour.* 26, 1637–1646.

Chen, H. T., and Jiang, Z. D. (2013). Farmers ecological construction willingness and behavior in grain for green: data from farmer household survey in Ansai and Mizhi County. *J. China Agric. Univ.* 26, 224–231. doi: 10.11841/j.issn.1007-4333.2013.04.34

Chen, Y. Q., Liu, J. Y., Liu, W. K., and Wang, Q. (2023). Effects of red and blue light intensities on the growth, yield, and quality of perennial ryegrass. *Pratacult. Sci.* 40, 502–510. doi: 10.11829/j.issn.1001-0629.2022-0487

Clapp, J. (2023). Concentration and crises: exploring the deep roots of vulnerability in the global industrial food system. *J. Peasant Stud.* 50, 1–25. doi: 10.1080/03066150.2022.2129013

Conner, M., and Armitage, C. J. (1998). Extending the theory of planned behavior: a review and avenues for further research. *J. Appl. Soc. Psychol.* 28, 1429–1464. doi: 10.1111/j.1559-1816.1998.tb01685.x

Cui, S. L., Li, Y. J., Jiao, X. Q., and Zhang, D. (2022). Hierarchical linkage between the basic characteristics of smallholders and technology awareness determines smallholders' willingness to adopt green production technology. *Agriculture* 12:1275. doi: 10.3390/agriculture12081275

Daxini, A., Ryan, M., O'Donoghue, C., Barnes, A. P., and Buckley, C. (2019). Using a typology to understand farmers' intentions towards following a nutrient management plan. *Resour. Conserv. Recycl.* 146, 280–290. doi: 10.1016/j.resconrec.2019.03.027

Giua, C., Materia, V. C., and Camanzi, L. (2022). Smart farming technologies adoption: which factors play a role in the digital transition? *Technol. Soc.* 68:101869. doi: 10.1016/j.techsoc.2022.101869

Guo, A. H., Li, S., Yang, Y., Hou, F. F., Wu, J., Gao, Y., et al. (2022). Lecithin extraction optimisation and synthesis in *Hemerocallis citrina* Baroni. *Sci. Hortic.* 293:110682. doi: 10.1016/j.scienta.2021.110682

Hair, J. F., Hult, G. T. M., Ringle, C. M., Sarstedy, M., and Thiele, K. O. (2017). Mirror, mirror on the wall: a comparative evaluation of composite-based structural equation modeling methods. *J. Acad. Mark. Sci.* 45, 616–632. doi: 10.1007/s11747-017-0517-x

Hazra, C. R. (2014). Feed and forage resources for sustainable livestock development. *Range Range. Manag. Agrofor.* 35, 1–14.

He, J. X., and Sui, D. C. (2024). Investigating college students' green food consumption intentions in China: integrating the theory of planned behavior and norm activation theory. *Sustain. Food Syst.* 8:1404465. doi: 10.3389/fsufs.2024.1404465

Holland, C., and Hill, R. (2007). The effect of age, gender and driver status on pedestrians' intentions to cross the road in risky situations. *Accid. Anal. Prev.* 39, 224–237. doi: 10.1016/j.aap.2006.07.003

Hou, X. Y. (2022). The development of forage industry should do a good job in the "three non-competition". *Agri. Prod. Market* 13, 52–53.

Hyland, J. J., Heanue, K., McKillop, J., and Micha, E. (2018). Factors underlying farmers' intentions to adopt best practices: the case of paddock based grazing systems. *Agric. Syst.* 162, 97–106. doi: 10.1016/j.agsy.2018.01.023

Karak, P. (2019). Biological activities of flavonoids: an overview. *Int. J. Pharm. Sci. Res.* 10, 1567–1574. doi: 10.13040/IJPSR.0975-8232.10(4).1567-74

Khan, N., Ray, R. L., Kassem, H. S., and Zhang, S. M. (2022). Mobile internet technology adoption for sustainable agriculture: evidence from wheat farmers. *Appl. Sci.* 12:4902. doi: 10.3390/app12104902

Khodadad, M., Sanei, M., Narvaez-Montoya, C., and Aguilar-Barajas, I. (2022). Climatic hazards and the associated impacts on households' willingness to adopt water-saving measures: evidence from Mexico. *Sustainability* 14:5817. doi: 10.3390/su14105817

Khoshmaram, M., Shiri, N., Shinnar, R. S., and Savari, M. (2020). Environmental support and entrepreneurial behavior among Iranian farmers: the mediating roles of social and human capital. *J. Small Bus. Manage.* 58, 1064–1088. doi: 10.1111/jsbm.12501

Lu, S., Sun, Z. N., and Huang, M. (2024). The impact of digital literacy on farmers' pro-environmental behavior: an analysis with the theory of planned behavior. *Front. Sustain. Food Syst.* 8:1432184. doi: 10.3389/fsufs.2024.1432184

Lv, H., and Guo, S. (2023). Comparative analysis of flavonoid metabolites from different parts of *Hemerocallis citrina*. *BMC Plant Biol.* 23:491. doi: 10.1186/s12870-023-04510-6

Mei, N. A., Li, J. G., Xin, G. S., Liu, Z. X., Yun, H., Ding, Y. R., et al. (2021). Effects of *Hemerocallis citrina* Baroni stems and leaves silage on the production, slaughter performance, and meat quality of tan sheep. *J. Anim. Feed Sci.* 11, 29–32. doi: 10.13300/j.cnki.cn42-1648/s.2021.11.007

Mi, Q., Li, X., Li, X., Yu, G., and Gao, J. (2021). Cotton farmers' adaptation to arid climates: waiting times to adopt water-saving technology. *Agric. Water Manag.* 244:106596. doi: 10.1016/j.agwat.2020.106596

Nhuong, B. H., and Truong, D. D. (2024). Factors affecting the adoption of high technology in vegetable production in Hanoi, Vietnam. *Front. Sustain. Food Syst.* 8:1345598. doi: 10.3389/fsufs.2024.1345598

Pan, L. L., and Wang, X. Y. (2018). The factors affecting the intention to exhibit environmental behavior by tourists: a case study of Xixi National Wetland Park in Hangzhou. *Sci. Geogr. Sin.* 38, 1337–1345. doi: 10.13249/j.cnki.sgs.2018.08.016

Qi, D., and Zhou, T. (2023). Feed utilization of soybean dregs and its impact on economic benefits of breeding. *Feed Ind.* 46, 175–179. doi: 10.13557/j.cnki.issn1002-2813.2023.22.033

Rahmaninkoshkaki, M., and Zarei, Y. (2018). Designing the structural equation model of agricultural entrepreneurship development in rural areas of Iran (case study: villages of Marvdasht county). *Int. J. Agric. Sci. Res. Technol. Ext. Educ. Syst.* 8, 17–27.

Rodriguez-Enriquez, M. J., and Grant-Downton, R. T. (2013). A new day dawning: *Hemerocallis* (daylily) as a future model organism. *AoB Plants* 5:pls055. doi: 10.1093/aobpla/pls055

Roh, T., Seok, J., and Kim, Y. (2022). Unveiling ways to reach organic purchase: green perceived value, perceived knowledge, attitude, subjective norm, and trust. *J. Retail. Consum. Serv.* 67:102988. doi: 10.1016/j.jretconser.2022.102988

Sardianou, E., and Genoudi, P. (2013). Which factors affect the willingness of consumers to adopt renewable energies? *Renew. Energ.* 57, 1–4. doi: 10.1016/j.renene.2013.01.031

Sarkar, A., Wang, H., Rahman, A., Azim, J. A., Memon, W. H., and Qian, L. (2022). Structural equation model of young farmers' intention to adopt sustainable agriculture: a case study in Bangladesh. *Renew. Agric. Food Syst.* 37, 142–154. doi: 10.1017/S1742170521000429

Senger, I., Borges, J. A. R., and Machado, J. A. D. (2017). Using the theory of planned behavior to understand the intention of small farmers in diversifying their agricultural production. *J. Rural. Stud.* 49, 32–40. doi: 10.1016/j.jrurstud.2016.10.006

Serebrennikov, D., Thorne, F., Kallas, Z., and McCarthy, S. N. (2020). Factors influencing adoption of sustainable farming practices in Europe: a systemic review of empirical literature. *Sustainability* 12:9719. doi: 10.3390/su12229719

Shi, H., Fan, J., and Zhao, D. (2017). Predicting household PM2.5-reduction behavior in Chinese urban areas: an integrative model of theory of planned behavior and norm activation theory. *J. Clean. Prod.* 145, 64–73. doi: 10.1016/j.jclepro.2016.12.169

Shiao, S. H., Shao, B. R., He, Y. X., Yang, Y. Q., Yang, H. Z., and Chang, Y. C. (1962). Studies on *Hemerocallis thunbergii* baker. II. Effectiveness of *Hemerocallis thunbergii* in oral treatment of experimental schistosomiasis in mice. *Yao Xue Xue Bao* 9, 218–224.

Sun, Z. N., Shen, H., Chen, Z. T., Ma, N., Yang, Y., Liu, H. X., et al. (2024). Physiological responses and transcriptome analysis of *Hemerocallis citrina* Baroni exposed to *Thrips palmi* feeding stress. *Front. Plant Sci.* 15:1361276. doi: 10.3389/fpls.2024.1361276

Tang, L. Z. (2024). Feed utilization of fruit and vegetable processing by-products. *Feed Ind.* 45, 129–134. doi: 10.13302/j.cnki.fi.2024.22.018

Wang, J., Liu, L. M., Zhao, K. Y., and Wen, Q. (2023). Farmers' adoption intentions of water-saving agriculture under the risks of frequent irrigation-induced landslides. *Clim. Risk Manag.* 39:100484. doi: 10.1016/j.crm.2023.100484

Wang, J. Q., Wang, N. N., Fan, Z. Z., Yuan, T. T., and Zhou, J. H. (2023). Analysis of influencing factors on green production behavior selection of fruit farmers based on 285 micro samples in Hebei province. *J. Hebei Agric. Sci.* 27, 89–93. doi: 10.12148/hbnykx.20230151

World Health Organization (2022). The state of food security and nutrition in the world 2022: Repurposing food and agricultural policies to make healthy diets more affordable. Rome: Food and Agriculture Organization.

Wu, L. P. (2023). Full understanding of China's food security from perspective of the greater food approach. *Soc. Sci. J.*, 191–200.

Wu, Z. C. (2024). Research on strategies for ensuring feed and grain supply under the background of food security. *China Feed.*, 160–163. doi: 10.15906/j.cnki.cn11-2975/s.20241040

Xiang, P. A., and Guo, J. (2023). Understanding farmers' intentions to adopt pest and disease green control techniques: comparison and integration based on multiple models. *Sustainability* 15:10822. doi: 10.3390/su151410822

Xiao, Y. (2016). Analyzing and modeling of the influence of driving distraction on traffic safety and traffic efficiency. Beijing, China: Tsinghua University.

Yin, Y. L., and Yang, Z. (2025). Development and efficient utilization of unconventional feed. *Feed Ind.* 46, 2–10. doi: 10.13302/j.cnki.fi.2025.01.001

Zhang, Y. X. (2023). Promotion strategy of feed grain safety supply undernew pattern of double circulation. *Feed Res.* 46, 187–190. doi: 10.13557/j.cnki.issn1002-2813.2023.23.036

Zhang, J. L., Ma, J. F., Ma, J. F., Zhao, Z. W., Ma, X. M., Liang, X. J., et al. (2023). Effects of yellow silage of daylily stem and leaves on fattening and serum biochemical indicators of Simmentaler hybrid cattle. *Ningxia J. Agri. Fores. Sci. Tech.* 64, 35–38. doi: 10.3969/j.issn.1002-204x.2023.02.010

Zhang, H. L., Wang, W. G., Wang, J., Zhao, X. J., Bo, Y. L., and Hou, Y. J. (2024). Analysis on evolution of ecological vulnerability of Shanxi Province based on the remote sensing and GIS technique. *Remote Sens. Technol. Appl.* 39, 478–491. doi: 10.11873/j.issn.1004-0323.2024.2.0478

Zhao, R. H., Luo, J. H., and Xu, B. J. (2024). Insights into secondary metabolites and health promoting effects of edible flower *Hemerocallis citrina* Baroni. *J. Funct. Foods* 116:106133. doi: 10.1016/j.jff.2024.106133

Zhao, Z. W., Wang, Z. L., Zhang, J. L., Yang, Y. W., Ma, J. F., Wang, X. Q., et al. (2021). Analysis of volatile fatty acid content in stem and leaf mixed storage of daylily. *Feed Res.* 44, 102–105. doi: 10.13557/j.cnki.issn1002-2813.2021.08.023

Zheng, M. N., Kang, J. H., Zou, C. Y., Hou, X. Y., Liang, X. Z., Han, Z. S., et al. (2024). Effects of ratio of daylily stem and leaf mixed with corn silage on the quality of silage and microbial diversity. *Acta Agrest. Sin.* 32, 3962–3972. doi: 10.11733/j.issn.1007-0435.2024.12.032

Zheng, Y. Y., Mei, L. F., and Chen, W. M. (2024). Does government policy matter in the digital transformation of farmers' cooperatives?—a tripartite evolutionary game analysis. *Front. Sustain. Food Syst.* 8:1398319. doi: 10.3389/fsufs.2024.1398319

Zhou, Z. Q., Zhang, Y. H., and Yan, Z. B. (2022). Will digital financial inclusion increase Chinese farmers' willingness to adopt agricultural technology? *Agriculture* 12:1514. doi: 10.3390/agriculture12101514