International Journal of Food Science and Nutrition
www.foodsciencejournal.com
ISSN: 2455-4898
Received: 02-08-2026, Accepted: 02-09-2026, Published: 17-09-2026
Volume 11, Issue 3, 2026, Page No. 322-327

Efficacy of probiotics in enhancing the shelf life of chilli fruits

Rosemary Baiju[1*], Ajithkumar K[2], Savitha A S[1], Yenjerappa S T[3] and Mathad P F[4]
[1] Department of Plant Pathology, College of Agriculture, Raichur, University of Agricultural Sciences, Raichur, Karnataka, India
[2] ICAR-AICRP on Linseed, MARS, Raichur, University of Agricultural Sciences, Raichur, Karnataka, India
[3] College of Agriculture, Gangavathi, University of Agricultural Sciences, Raichur, Karnataka, India
[4] AICRP on PHET, College of Agricultural Engineering, Raichur, University of Agricultural Sciences, Raichur, Karnataka, India
Corresponding Author: Rosemary Baiju
DOI: https://doi.org/10.66856/ijfsn.2026.11.3.11167

Abstract
Chilli (*Capsicum annuum* L.) is an economically important spice and vegetable crop whose post-harvest quality is adversely affected by fungal deterioration, particularly *Aspergillus flavus*. The present study evaluated the efficacy of selected potential probiotics in maintaining the physical and physicochemical quality of chilli fruits during storage following *A. flavus* inoculation. Chilli fruits were inoculated with *A.* flavus and subsequently treated with potential probiotics namely Darolac, Fourrts or *Pichia kudriavzevii*, while untreated and *A. flavus* inoculated fruits served as controls. Fruit quality was assessed at 7, 14, 21, 28 and 35 days after treatment (DAT) and observed for firmness, colour (*L**, *a** and *b**), pH and bulk density. Firmness declined progressively during storage in all the treatments, but Darolac consistently maintained the maximum firmness among the probiotic treatments, recording 374.63 g at 35 DAT compared with 219.97 g in *A. flavus* inoculated fruits. Storage resulted in an increase in *L** and *b** values and a decline in *a** value, with the greatest deterioration occurring in *A. flavus* inoculated fruits. Darolac treated fruits showed comparatively better retention of colour characteristics. The pH declined from 5.31 to 4.87 in Darolac treated fruits, whereas *A. flavus* inoculated fruits declined from 5.11 to 4.22. Similarly, bulk density at 35 DAT was maximum in untreated fruits (162.33 kg m^{-3}), followed by Darolac (143.77 kg m^{-3}), while *A. flavus* inoculated fruits recorded only 94.67 kg m^{-3}. Overall, Darolac showed the best performance among the evaluated probiotics in maintaining the fruit firmness and physicochemical quality during storage, indicating its potential as sustainable post-harvest management of *A. flavus* associated deterioration in chilli.

Keywords: *A. flavus*, bulk density, colour, Darolac, firmness, pH.

Introduction
Chilli (*Capsicum annuum* L.) is one of the most economically and nutritionally important spice crop as well as vegetable crop globally, cultivated and consumed for its pungency, color and antioxidant properties. Chilli is one of the India's major exported spices, contributing to about 27 per cent of the total spice export. India exported 17.34 lakh tonnes of spices and spice products worth ₹ 39,140.11 crore, with chilli remaining the largest individual contributor whereas imports were only 4,913 tonnes, indicating that India is a major net exporter of chilli (Anon., 2025). However, its post-harvest quality is significantly threatened by fungal contamination, particularly by *Aspergillus flavus*, a potential aflatoxin producing pathogen (Ajithkumar and Naik, 2006) [2].

A. flavus is a ubiquitous and cosmopolitan filamentous fungus capable of proliferating under a wide range of environmental conditions (Thathana *et al*., 2017) [13]. Mycotoxins are the toxic secondary metabolites produced by fungi belonging to the genera *Aspergillus*, *Penicillium* and *Fusarium*, including aflatoxin, ochratoxin, citrinin, fumonisin, ergot alkaloids, patulin, trichothecenes, zearalenone and deoxynivalenol (Ajithkumar *et al*., 2024) [3]. Thus, mitigating aflatoxin contamination has become an urgent goal both to safeguard public health and to enhance market competitiveness for aflatoxin prone crops in countries like India (Swapna *et al*., 2026) [12].

Probiotics are beneficial living microorganisms which when consumed in adequate quantities, provide health benefits to the host (FAO/WHO). These are the beneficial microorganisms that support the gut health of humans. Probiotic microorganisms, particularly lactic acid bacteria and beneficial yeasts, can suppress undesirable fungi through the production of organic acids and antimicrobial metabolites and may also interact with mycotoxins through adsorption or biodegradation (Abdolmaleki *et al*., 2022) [1].

In the present study, the potential probiotic formulations *viz*., Darolac, Fourrts and *Pichia kudriavzevii* were evaluated against *A. flavus* associated with chilli fruits. Their efficacy under challenge conditions and their ability to maintain fruit quality during storage were assessed based on firmness, colour (*L**, *a** and *b**), pH and bulk density, with the aim of identifying an effective treatment for reducing fungal deterioration and extending the post-harvest quality and shelf life of chilli.

Material and Methods
Experimental details
A shelf-life experiment was conducted to evaluate the efficacy of potential probiotic as post-harvest treatments in maintaining the quality of chilli fruits inoculated with *Aspergillus flavus* during storage. Five treatments comprising untreated chilli fruits (T_1), *A. flavus* inoculated fruits followed by Darolac treatment (T_2), *A. flavus*

inoculated fruits followed by Fourrts treatment (T_3), *A. flavus* inoculated fruits followed by *Pichia kudriavzevii* treatment (T_4) and *A. flavus* inoculated fruits without probiotic treatment (T_5) were taken. Observations were recorded at 7, 14, 21, 28 and 35 days after treatment (DAT). Changes in post-harvest quality parameters, including firmness, colour (*L**, *a** and *b**), pH and bulk density, were recorded at each observation interval to assess the progression of deterioration and the effectiveness of the probiotic treatments in maintaining chilli fruit quality.

Firmness assessment

The textural properties of dried chilli were evaluated using a texture analyzer (TA). Dried red chilli fruit samples were subjected to a double compression cycle using a 2 mm diameter cylindrical probe. The analysis parameters were set to a pretest speed of 2.5 mm/sec, a 12 mm compression distance and a 15 g trigger force. All the measurements were performed in triplicate (Faliarizao *et al*., 2025) [10].

Colour assessment

Hunter's lab colorimeter was used to measure the colour of chilli fruits. It provided reading in terms of *L**, *a** and *b**, where luminance (*L**) forms the vertical axis that indicates whiteness (+) to darkness (-). In the same way, *a** indicates redness (+) to greenness (-) and *b** indicates yellowness (+) to blueness (-). The instrument was calibrated before placing the sample by placing calibration plates provided with the instrument. Once the instrument was calibrated, measurement of colour is done. All the measurements were replicated thrice and the average values were recorded.

Bulk density

Approximately 100 mg sample of dried red chilli fruit were transferred to a 10 ml graduated cylinder and its volume was recorded before and after compaction.

pH

The pH value of dried red chilli powder samples was determined using a pH meter. For sample preparation, 0.25 g of the dried chilli fruit powder was weighed and dissolved in 25 ml of distilled water. Prior to measuring the pH, the pH meter should be calibrated with different pH buffers according to the manufacturer's instructions. The pH value of the prepared samples was recorded once the reading stabilized.

Statistical analysis

The experimental data were analysed statistically as reported in the study. Standard error of mean (S. Em. ±) and critical difference (C. D.) at 1 per cent were used for interpretation of treatment differences.

Results and Discussion

Firmness of chilli fruits

Firmness declined progressively during storage in all the treatments, but the magnitude of decline differed markedly among treatments (Table 1). At 7 DAT, untreated fruits recorded the maximum firmness (1147.73 g), followed by Darolac (974.47 g), Fourrts (933.50 g) and *P. kudriavzevii* (913.27 g), while *A. flavus* inoculated fruits recorded the minimum (666.10 g). At 14 DAT, untreated fruits retained firmness of about 1139.83 g, whereas Darolac and Fourrts recorded 920.93 and 913.57 g, respectively. At 21 DAT, Darolac recorded firmness of about 682.83 g and was significantly superior among the probiotic treatments. The same trend continued at 28 and 35 DAT, when Darolac recorded 516.43 and 374.63 g, respectively, compared with 219.97 g in *A. flavus* inoculated fruits. Thus, Darolac consistently provided the best retention of firmness among the probiotic treatments. The firmness retained by the probiotic treated chilli fruits during storage might be due to the suppression of *A. flavus* growth by antifungal metabolites produced by the probiotic microorganisms (Brummell, 2006) [8]. In contrast, fruits inoculated with *A. flavus* alone consistently recorded the minimum texture analyzer readings, which can be attributed to extensive degradation of pectin and cellulose during fungal colonization, resulting in rapid tissue softening and loss of firmness (Vicente *et al*., 2007) [14].

The results are in consistent with Garcia *et al.* (2021) [11], they evaluated the effect of chitosan (CS), propolis (P), chitosan nanoparticles (CNPs) and propolis nanoparticles (PNPs), individually and in combination, against *A. flavus* in fig fruits. At 12 days of storage, the untreated control recorded firmness of about 4.9 N, while firmness was 5.1 N in CS + PNPs, 4.5 N in CS + CSNPs, 2.8 N in CS + P, 6.0 N in CS + CSNPs + PNPs, 5.6 N in CS + PNPs + CSNPs + P, 4.4 N in CS + PNPs + P, 5.6 N in CS + CSNPs + P, and 4.1 N in CS alone. The better retention of firmness in some treatments was associated with reduced *A. flavus* development and maintenance of fruit quality.

Changes in fruit colour

Storage caused a gradual increase in *L** and *b** values and a progressive decrease in *a** value. *A. flavus* inoculated fruits consistently recorded the maximum *L** values, increasing from 24.37 at 7 DAT to 25.72 at 35 DAT, whereas untreated fruits showed the minimum *L** values, from 23.32 to 24.64 (Table 2). In contrast, redness was best retained by untreated fruits, with *a** values of 12.96 and 12.62 at 7 and 35 DAT, respectively. *A. flavus* inoculated fruits recorded the minimum *a** values, declining from 9.88 to 6.71. The *b** value increased from 11.57 to 11.69 in untreated fruits and from 12.86 to 13.16 in *A. flavus* inoculated fruits. Among the probiotic treatments, Darolac generally retained better redness and showed comparatively lower changes in *b** value than *P. kudriavzevii*. The greater changes in infected fruits indicate more pronounced pigment and tissue deterioration during storage. The present outcome is in accordance with Balasubramaniyan *et al*. (2026), they reported that healthy chilli fruits exhibited *L**, *a** and *b** values of 41.69, 37.62 and 42.74, respectively, whereas *A. flavus* infected chilli fruits showed values of 48.98, 19.63 and 40.64, respectively. The results of the study aligned with that of Chen *et al*. (2022), who observed that the *L** value increased from approximately 52 to 62, the *a** value decreased from approximately 35 to 20 and the *b** value increased from approximately 36 to 42 over six months of storage in the different packaging treatments.

pH changes during storage

The pH of chilli fruits declined progressively from 7 to 35 DAT (Table 3). Untreated fruits maintained the maximum pH throughout storage, decreasing from 5.39 to 5.10. Among the probiotic treatments, Darolac showed the best pH retention, with values decreasing from 5.31 to 4.87, followed by Fourrts (5.23 to 4.75) and *P. kudriavzevii* (5.22

to 4.67). *A. flavus* inoculated fruits showed the greatest decline, from 5.11 at 7 DAT to 4.22 at 35 DAT. Lower pH generally inhibits many bacteria, while acid tolerant microbes can still continue to grow (Alegbeleye *et al*., 2022) [4]. The maximum reduction in pH in fruits inoculated with *A. flavus* (T_5), might be due to active metabolism of the pathogen. *A. flavus* utilizes carbohydrates as an energy source and produces low molecular weight organic acids that lower the pH of the surrounding tissues (Yang *et al*., 2017) [15]. The comparatively smaller pH decline in Darolac treated fruits suggests slower deterioration and reduced microbial activity associated with fungal colonization.

Bulk density

Bulk density declined progressively during storage. At 7 DAT, untreated fruits recorded the maximum value (177.10 kg m^{-3}), while *A. flavus* inoculated fruits recorded the minimum value (153.73 kg m^{-3}). At 35 DAT, untreated fruits recorded bulk density of about 162.33 kg m^{-3}, followed by Darolac (143.77 kg m^{-3}), Fourrts (131.93 kg m^{-3}) and *P. kudriavzevii* (117.77 kg m^{-3}), whereas *A. flavus* inoculated fruits recorded only 94.67 kg m^{-3} (Table 4). The higher bulk density in probiotic treated fruits, particularly Darolac, indicates comparatively better preservation of structural quality. The marked reduction under *A. flavus* infection may be related to tissue degradation and development of a more porous material after deterioration and drying. The study is in accordance with Balasubramaniyan *et al*. (2026), he reported that the bulk density of *A. flavus* infected chilli fruits (98.77 kg m^{-3}) was lower than that of healthy fruits (127.31 kg m^{-3}), indicating tissue degradation and reduced structural integrity. Aoun *et al*. (2020) reported that aflatoxin levels were negatively correlated with kernel bulk density in maize. High aflatoxin kernels had significantly minimum density (0.90 g cm^{-3}) than low aflatoxin kernels (0.96 g cm^{-3}).

Chilli (*Capsicum annuum* L.) is one of the most economically and nutritionally important spice crop as well as vegetable crop globally, cultivated and consumed for its pungency, color and antioxidant properties. Chilli is one of the India's major exported spices, contributing to about 27 per cent of the total spice export. India exported 17.34 lakh tonnes of spices and spice products worth ₹ 39,140.11 crore, with chilli remaining the largest individual contributor whereas imports were only 4,913 tonnes, indicating that India is a major net exporter of chilli (Anon., 2025). However, its post-harvest quality is significantly threatened by fungal contamination, particularly by *Aspergillus flavus*, a potential aflatoxin producing pathogen (Ajithkumar and Naik, 2006) [2].

A. flavus is a ubiquitous and cosmopolitan filamentous fungus capable of proliferating under a wide range of environmental conditions (Thathana *et al*., 2017) [13]. Mycotoxins are the toxic secondary metabolites produced by fungi belonging to the genera *Aspergillus*, *Penicillium* and *Fusarium*, including aflatoxin, ochratoxin, citrinin, fumonisin, ergot alkaloids, patulin, trichothecenes, zearalenone and deoxynivalenol (Ajithkumar *et al*., 2024) [3]. Thus, mitigating aflatoxin contamination has become an urgent goal both to safeguard public health and to enhance market competitiveness for aflatoxin prone crops in countries like India (Swapna *et al*., 2026) [12].

Probiotics are beneficial living microorganisms which when consumed in adequate quantities, provide health benefits to the host (FAO/WHO). These are the beneficial microorganisms that support the gut health of humans. Probiotic microorganisms, particularly lactic acid bacteria and beneficial yeasts, can suppress undesirable fungi through the production of organic acids and antimicrobial metabolites and may also interact with mycotoxins through adsorption or biodegradation (Abdolmaleki *et al*., 2022) [1].

In the present study, the potential probiotic formulations *viz*., Darolac, Fourrts and *Pichia kudriavzevii* were evaluated against *A. flavus* associated with chilli fruits. Their efficacy under challenge conditions and their ability to maintain fruit quality during storage were assessed based on firmness, colour (*L**, *a** and *b**), pH and bulk density, with the aim of identifying an effective treatment for reducing fungal deterioration and extending the post-harvest quality and shelf life of chilli.

Material and Methods

Experimental details

A shelf-life experiment was conducted to evaluate the efficacy of potential probiotic as post-harvest treatments in maintaining the quality of chilli fruits inoculated with *Aspergillus flavus* during storage. Five treatments comprising untreated chilli fruits (T_1), *A. flavus* inoculated fruits followed by Darolac treatment (T_2), *A. flavus* inoculated fruits followed by Fourrts treatment (T_3), *A. flavus* inoculated fruits followed by *Pichia kudriavzevii* treatment (T_4) and *A. flavus* inoculated fruits without probiotic treatment (T_5) were taken. Observations were recorded at 7, 14, 21, 28 and 35 days after treatment (DAT). Changes in post-harvest quality parameters, including firmness, colour (*L**, *a** and *b**), pH and bulk density, were recorded at each observation interval to assess the progression of deterioration and the effectiveness of the probiotic treatments in maintaining chilli fruit quality.

Firmness assessment

The textural properties of dried chilli were evaluated using a texture analyzer (TA). Dried red chilli fruit samples were subjected to a double compression cycle using a 2 mm diameter cylindrical probe. The analysis parameters were set to a pretest speed of 2.5 mm/sec, a 12 mm compression distance and a 15 g trigger force. All the measurements were performed in triplicate (Faliarizao *et al*., 2025) [10].

Colour assessment

Hunter's lab colorimeter was used to measure the colour of chilli fruits. It provided reading in terms of *L**, *a** and *b**, where luminance (*L**) forms the vertical axis that indicates whiteness (+) to darkness (-). In the same way, *a** indicates redness (+) to greenness (-) and *b** indicates yellowness (+) to blueness (-). The instrument was calibrated before placing the sample by placing calibration plates provided with the instrument. Once the instrument was calibrated, measurement of colour is done. All the measurements were replicated thrice and the average values were recorded.

Bulk density

Approximately 100 mg sample of dried red chilli fruit were transferred to a 10 ml graduated cylinder and its volume was recorded before and after compaction.

pH

The pH value of dried red chilli powder samples was determined using a pH meter. For sample preparation, 0.25

g of the dried chilli fruit powder was weighed and dissolved in 25 ml of distilled water. Prior to measuring the pH, the pH meter should be calibrated with different pH buffers according to the manufacturer's instructions. The pH value of the prepared samples was recorded once the reading stabilized.

Statistical analysis

The experimental data were analysed statistically as reported in the study. Standard error of mean (S. Em. ±) and critical difference (C. D.) at 1 per cent were used for interpretation of treatment differences.

Results and Discussion

Firmness of chilli fruits

Firmness declined progressively during storage in all the treatments, but the magnitude of decline differed markedly among treatments (Table 1). At 7 DAT, untreated fruits recorded the maximum firmness (1147.73 g), followed by Darolac (974.47 g), Fourrts (933.50 g) and *P. kudriavzevii* (913.27 g), while *A. flavus* inoculated fruits recorded the minimum (666.10 g). At 14 DAT, untreated fruits retained firmness of about 1139.83 g, whereas Darolac and Fourrts recorded 920.93 and 913.57 g, respectively. At 21 DAT, Darolac recorded firmness of about 682.83 g and was significantly superior among the probiotic treatments. The same trend continued at 28 and 35 DAT, when Darolac recorded 516.43 and 374.63 g, respectively, compared with 219.97 g in *A. flavus* inoculated fruits. Thus, Darolac consistently provided the best retention of firmness among the probiotic treatments. The firmness retained by the probiotic treated chilli fruits during storage might be due to the suppression of *A. flavus* growth by antifungal metabolites produced by the probiotic microorganisms (Brummell, 2006) [8]. In contrast, fruits inoculated with *A. flavus* alone consistently recorded the minimum texture analyzer readings, which can be attributed to extensive degradation of pectin and cellulose during fungal colonization, resulting in rapid tissue softening and loss of firmness (Vicente *et al*., 2007) [14].

The results are in consistent with Garcia *et al.* (2021) [11], they evaluated the effect of chitosan (CS), propolis (P), chitosan nanoparticles (CNPs) and propolis nanoparticles (PNPs), individually and in combination, against *A. flavus* in fig fruits. At 12 days of storage, the untreated control recorded firmness of about 4.9 N, while firmness was 5.1 N in CS + PNPs, 4.5 N in CS + CSNPs, 2.8 N in CS + P, 6.0 N in CS + CSNPs + PNPs, 5.6 N in CS + PNPs + CSNPs + P, 4.4 N in CS + PNPs + P, 5.6 N in CS + CSNPs + P, and 4.1 N in CS alone. The better retention of firmness in some treatments was associated with reduced *A. flavus* development and maintenance of fruit quality.

Changes in fruit colour

Storage caused a gradual increase in *L** and *b** values and a progressive decrease in *a** value. *A. flavus* inoculated fruits consistently recorded the maximum *L** values, increasing from 24.37 at 7 DAT to 25.72 at 35 DAT, whereas untreated fruits showed the minimum *L** values, from 23.32 to 24.64 (Table 2). In contrast, redness was best retained by untreated fruits, with *a** values of 12.96 and 12.62 at 7 and 35 DAT, respectively. *A. flavus* inoculated fruits recorded the minimum *a** values, declining from 9.88 to 6.71. The *b** value increased from 11.57 to 11.69 in untreated fruits and from 12.86 to 13.16 in *A. flavus* inoculated fruits. Among the probiotic treatments, Darolac generally retained better redness and showed comparatively lower changes in *b** value than *P. kudriavzevii*. The greater changes in infected fruits indicate more pronounced pigment and tissue deterioration during storage. The present outcome is in accordance with Balasubramaniyan *et al*. (2026), they reported that healthy chilli fruits exhibited *L**, *a** and *b** values of 41.69, 37.62 and 42.74, respectively, whereas *A. flavus* infected chilli fruits showed values of 48.98, 19.63 and 40.64, respectively. The results of the study aligned with that of Chen *et al*. (2022), who observed that the *L** value increased from approximately 52 to 62, the *a** value decreased from approximately 35 to 20 and the *b** value increased from approximately 36 to 42 over six months of storage in the different packaging treatments.

pH changes during storage

The pH of chilli fruits declined progressively from 7 to 35 DAT (Table 3). Untreated fruits maintained the maximum pH throughout storage, decreasing from 5.39 to 5.10. Among the probiotic treatments, Darolac showed the best pH retention, with values decreasing from 5.31 to 4.87, followed by Fourrts (5.23 to 4.75) and *P. kudriavzevii* (5.22 to 4.67). *A. flavus* inoculated fruits showed the greatest decline, from 5.11 at 7 DAT to 4.22 at 35 DAT. Lower pH generally inhibits many bacteria, while acid tolerant microbes can still continue to grow (Alegbeleye *et al*., 2022) [4]. The maximum reduction in pH in fruits inoculated with *A. flavus* (T_5), might be due to active metabolism of the pathogen. *A. flavus* utilizes carbohydrates as an energy source and produces low molecular weight organic acids that lower the pH of the surrounding tissues (Yang *et al*., 2017) [15]. The comparatively smaller pH decline in Darolac treated fruits suggests slower deterioration and reduced microbial activity associated with fungal colonization.

Bulk density

Bulk density declined progressively during storage. At 7 DAT, untreated fruits recorded the maximum value (177.10 kg m^{-3}), while *A. flavus* inoculated fruits recorded the minimum value (153.73 kg m^{-3}). At 35 DAT, untreated fruits recorded bulk density of about 162.33 kg m^{-3}, followed by Darolac (143.77 kg m^{-3}), Fourrts (131.93 kg m^{-3}) and *P. kudriavzevii* (117.77 kg m^{-3}), whereas *A. flavus* inoculated fruits recorded only 94.67 kg m^{-3} (Table 4). The higher bulk density in probiotic treated fruits, particularly Darolac, indicates comparatively better preservation of structural quality. The marked reduction under *A. flavus* infection may be related to tissue degradation and development of a more porous material after deterioration and drying. The study is in accordance with Balasubramaniyan *et al*. (2026), he reported that the bulk density of *A. flavus* infected chilli fruits (98.77 kg m^{-3}) was lower than that of healthy fruits (127.31 kg m^{-3}), indicating tissue degradation and reduced structural integrity. Aoun *et al*. (2020) reported that aflatoxin levels were negatively correlated with kernel bulk density in maize. High aflatoxin kernels had significantly minimum density (0.90 g cm^{-3}) than low aflatoxin kernels (0.96 g cm^{-3}).

Table 1: Efficacy of potential probiotics on the firmness of chilli fruits at various intervals during storage

Treatment number	Treatment detail	Firmness of chilli fruits (g)				
		7 DAT*	14 DAT	21 DAT	28 DAT	35 DAT
T_1	Untreated chilli fruits	1147.73	1139.83	1140.23	1138.53	1087.50
T_2	Chilli fruits inoculated with *A. flavus* followed by Darolac	974.47	920.93	682.83	516.43	374.63
T_3	Chilli fruits inoculated with *A. flavus* followed by Fourrts	933.50	913.57	540.03	396.07	286.70
T_4	Chilli fruits inoculated with *A. flavus* followed by *Pichia kudriavzevii*	913.27	821.63	520.70	373.23	269.93
T_5	Chilli fruits inoculated with *A. flavus*	666.10	640.27	472.47	314.13	219.97
S. Em. ±		12.69	11.17	12.00	11.90	10.55
C. D. at 1%		40.50	35.65	38.32	37.97	33.67

*DAT - Days after treatment

Table 2: Efficacy of potential probiotics on the colour of chilli fruits at various intervals during storage

Treatment number	Treatment detail	Colour of chilli fruits														
		7 DAT*			14 DAT			21 DAT			28 DAT			35 DAT		
		*L**	*a**	*b**	*L**	*a**	*b**	*L**	*a**	*b**	*L**	*a**	*b**	*L**	*a**	*b**
T_1	Untreated chilli fruits	23.32	12.96	11.57	23.50	12.74	11.58	23.81	12.73	11.60	24.27	12.67	11.64	24.64	12.62	11.69
T_2	Chilli fruits inoculated with *A. flavus* followed by Darolac	23.82	12.43	12.10	24.02	12.38	12.13	24.08	11.99	12.17	24.36	10.95	12.22	25.09	10.31	12.33
T_3	Chilli fruits inoculated with *A. flavus* followed by Fourrts	23.79	11.78	12.11	24.06	11.25	12.14	24.27	10.98	12.19	24.67	10.31	12.24	25.17	10.09	12.34
T_4	Chilli fruits inoculated with *A. flavus* followed by *Pichia kudriavzevi*	23.86	11.56	12.20	24.07	11.19	12.23	24.31	10.72	12.28	24.71	10.12	12.34	25.19	9.73	12.49
T_5	Chilli fruits inoculated with *A. flavus*	24.37	9.88	12.86	24.57	9.03	12.89	24.87	8.36	12.94	25.29	7.54	13.02	25.72	6.71	13.16
S. Em. ±		0.03	0.04	0.03	0.03	0.03	0.02	0.15	0.04	0.02	0.06	0.03	0.02	0.03	0.04	0.02
C. D. at 1%		0.10	0.13	0.08	0.11	0.08	0.08	0.49	0.12	0.07	0.19	0.11	0.06	0.11	0.13	0.08

*DAT - Days after treatment, *L** - Lightness, *a**- Greenness-redness, *b**- Blueness-yellowness

Table 3: Efficacy of potential probiotics on the pH of chilli fruits at various intervals during storage

Treatment number	Treatment detail	pH of chilli fruits				
		7 DAT*	14 DAT	21 DAT	28 DAT	35 DAT
T_1	Untreated chilli fruits	5.39	5.34	5.27	5.23	5.10
T_2	Chilli fruits inoculated with *A. flavus* followed by Darolac	5.31	5.20	5.12	5.05	4.87
T_3	Chilli fruits inoculated with *A. flavus* followed by Fourrts	5.23	5.13	5.05	4.96	4.75
T_4	Chilli fruits inoculated with *A. flavus* followed by *Pichia kudriavzevii*	5.22	5.09	4.95	4.90	4.67
T_5	Chilli fruits inoculated with *A. flavus*	5.11	4.91	4.70	4.61	4.22
S. Em. ±		0.02	0.01	0.02	0.04	0.01
C. D. at 1 %		0.05	0.04	0.05	0.14	0.05

*DAT - Days after treatment

Table 4: Efficacy of potential probiotics on the bulk density of chilli fruits at various intervals during storage

Treatment number	Treatment detail	Bulk density of chilli fruits (kg/m^3)				
		7 DAT*	14 DAT	21 DAT	28 DAT	35 DAT
T_1	Untreated chilli fruits	177.10	176.30	171.37	169.20	162.33
T_2	Chilli fruits inoculated with *A. flavus* followed by Darolac	175.43	169.60	166.73	154.77	143.77
T_3	Chilli fruits inoculated with *A. flavus* followed by Fourrts	174.47	165.77	151.87	142.47	131.93
T_4	Chilli fruits inoculated with *A. flavus* followed by *Pichia kudriavzevii*	174.07	155.43	146.53	133.60	117.77
T_5	Chilli fruits inoculated with *A. flavus*	153.73	135.57	127.40	100.80	94.67
S. Em. ±		0.62	1.69	1.24	2.46	1.15
C. D. at 1 %		1.99	5.40	3.97	7.85	3.67

* DAT – Days after treatment

Conclusion

The efficacy of the probiotic treatments in maintaining chilli fruit quality during storage was evaluated based on the firmness, colour, pH and bulk density. Firmness and bulk density of the chilli fruits were declined progressively during storage, with the greatest reduction observed in *A. flavus* treated fruits, whereas untreated fruits retained higher values throughout the storage period. Among the inoculated treatments, Darolac showed comparatively better retention of firmness and bulk density. The colour parameters also changed progressively, with an increase in *L** and *b** values whereas decrease in *a** value, indicating increased lightness and yellowness with a gradual loss of redness. These changes were most pronounced in *A. flavus* treated fruits, while probiotic treated fruits showed comparatively better colour retention. The pH of the chilli fruits decreased progressively during storage, with the maximum decline recorded in *A. flavus* treated fruits and comparatively better pH retention in Darolac treated fruits, followed by Fourrts and *P. kudriavzevii*. Among the probiotic treatments, Darolac showed comparatively better performance in reducing the deterioration and maintaining the firmness and quality attributes of chilli fruits during storage.

Acknowledgement
We would like to thank the University of Agricultural Sciences Raichur, Karnataka, India for supporting and facilitating the study.

References
1. Abdolmaleki K, Javanmardi F, Gavahian M, Phimolsiripol Y, Ruksiriwanich W, Mir SA, *et al*. Emerging technologies in combination with probiotics for aflatoxins removal: An updated review. International Journal of Food Science and Technology. 2022;57(9):5712-5721.
2. Ajithkumar K, Naik MK. Detection of aflatoxin producing *Aspergillus flavus* isolates from chilli and their management by post-harvest treatment. Journal of Food Science and Technology. 2006;43:200-204.
3. Ajithkumar K, Naik MK, Savitha AS, Mahadevakumar S, Sreenivasa MY, Rajesh NL. Mapping of endemic and risk free areas for mycotoxigenic fungi and detection of aflatoxin and fumonisin in major maize growing regions of Karnataka, India. Indian Phytopathology. 2024;77(4):955-967.
4. Alegbeleye O, Odeyemi OA, Strateva M, Stratev D. Microbial spoilage of vegetables, fruits and cereals. Applied Food Research. 2022;2(1):100122. https://doi.org/10.1016/j.afres.2022.100122
5. Spices Board. Annual Report 2024-25. Kochi: Ministry of Commerce and Industry, Government of India; 2025. Available from: www.indianspices.com.
6. Aoun M, Stafstrom W, Priest P, Fuchs J, Windham GL, Williams WP, *et al*. Low-cost grain sorting technologies to reduce mycotoxin contamination in maize and groundnut. Food Control. 2020;118:107363. https://doi.org/10.1016/j.foodcont.2020.107363
7. Balasubramaniyan M, Durga JS, Chelladurai V, Senthilkumar T, Krishnakumar T, Jeevarathinam G. Aflatoxin detection and quality assessment in dried red chilli (*Capsicum annuum* L.): A multifaceted approach using physical, microstructural and machine learning techniques. Journal of Stored Products Research. 2026;116:102973. https://doi.org/10.1016/j.jspr.2025.102973
8. Brummell DA. Cell wall disassembly in ripening fruit. Functional Plant Biology. 2006;33(2):103-119.
9. Chen Q, Qi W, Peng J, Tang R, Liu D, Guo X. The vacuum and light avoided packaging ameliorate the decline in quality of whole chilli during storage. Journal of Food Quality. 2022;45(1):5129220. https://doi.org/10.1155/2022/5129220
10. Faliarizao NT, Siddiq M, Dolan KD. Total phenolics, antioxidant and physical properties of red chilli peppers (*Capsicum annuum* L.) as affected by drying methods. International Journal of Food Properties. 2025;28(1):1094-2912.
11. Garcia PF, Aguilar RI, Garcia JC, Lopez M, Sanchez D, Pina DA, *et al*. Edible chitosan/propolis coatings and their effect on ripening, development of *Aspergillus flavus* and sensory quality in fig fruit, during controlled storage. Plants. 2021;10(1):112-124.
12. Swapna, Nidoni U, Mathad PF, Taduri M, Hiregoudar S. Enhancing safety and quality of red chilli and groundnut through ultraviolet-C (UV-C) radiation for aflatoxin and *Aspergillus flavus* reduction. Journal of Food Measurement and Characterization. 2026;20(5):8511-8518.
13. Thathana MG, Murage H, Abia ALK, Pillay M. Morphological characterization and determination of aflatoxin-production potentials of *Aspergillus flavus* isolated from maize and soil in Kenya. Agriculture. 2017;7(10):80-94.
14. Vicente AR, Saladie M, Rose JK, Labavitch JM. The linkage between cell wall metabolism and fruit softening: Looking to the future. Journal of the Science of Food and Agriculture. 2007;87(8):1435-1448.
15. Yang L, Lubeck M, Lubeck PS. *Aspergillus* as a versatile cell factory for organic acid production. Fungal Biology Reviews. 2017;31(1):33-49.