

# Antibacterial activity of Monascus-fermented sorghum extracts against *Staphylococcus* *aureus* and *Escherichia coli*

*by* Ignatius Srinta

---

**Submission date:** 08-Jul-2025 06:38AM (UTC+0700)

**Submission ID:** 2711645842

**File name:** Antibacterial.pdf (381.41K)

**Word count:** 4901

**Character count:** 25518

**Antibacterial activity of *Monascus*-fermented sorghum extracts against *Staphylococcus aureus* and *Escherichia coli***

\*Srianta, I., Sutedja, A.M. and Nugerahani, I.

Department of Food Technology, Faculty of Agricultural Technology, Widya Mandala Catholic University  
Surabaya, Jalan Dinoyo 42-44 Surabaya, Indonesia 60265**Article history:**

Received: 13 December 2023

Received in revised form: 18

April 2024

Accepted: 20 May 2024

Available Online: 7 August  
2024**Keywords:***Monascus*,  
Sorghum,  
Extract,  
Various solvents,  
Antibacterial,  
MIC**DOI:**[https://doi.org/10.26656/fr.2017.8\(4\).409](https://doi.org/10.26656/fr.2017.8(4).409)**Abstract**

*Monascus purpureus* is one of the few types of edible fungi known for their abundant bioactivity. This research was aimed to investigate the antibacterial activity of *Monascus*-fermented sorghum extract (MFSE). Three different solvents were used for extraction: ethyl acetate, ethanol, and water. Antibacterial activity was assessed by determining minimum inhibitory concentration (MIC). The broth microdilution method was used to determine the MIC of the extract against *Staphylococcus aureus* and *Escherichia coli*. Additionally, moisture content, color, and biomass of *Monascus*-fermented sorghum (MFS) were analyzed, along with the pigment and total phenolic content of MFSE. All obtained data were calculated for the mean. Antibacterial activity was observed in MFSE extracted with all three solvents, displaying MIC values of 0.018, 0.216, and 0.794 mg/L against *S. aureus* and 0.996, 1.205, and 1.138 mg/L against *E. coli* for ethyl acetate, ethanol, and water extract, respectively. The MFSE extracted with ethyl acetate exhibited the lowest MIC, indicating the highest antibacterial activity.

**1. Introduction**

In recent years, there has been a growing preference for the development and utilization of natural compounds over synthetic ones (Gökmen *et al.*, 2021). *Monascus purpureus* is one of the few types of edible fungi. Through solid-state fermentation, *M. purpureus* produces pigments and compounds known for their abundant bioactivity, such as antioxidants, anti-inflammation, anticancer, antidiabetic, antiobesity, and antimicrobial (Kim *et al.*, 2006; Kim *et al.*, 2007; Hong *et al.*, 2008; Kim *et al.*, 2010; Lee *et al.*, 2011; Hsu and Pan, 2012; Srianta *et al.*, 2017; Feng *et al.*, 2019; Choe *et al.*, 2020; Gökmen *et al.*, 2021; Ding *et al.*, 2022). Commonly, rice is used to produce red-yeast rice (angkak), which has been used as a natural food colorant, preservative, food supplement and traditional medicine in Asia. However, any other cereal grains containing sufficient fermentable carbohydrates for *M. purpureus* can also be considered suitable substrates.

Sorghum (*Sorghum bicolor* (L.) Moench) is the fifth most important cereal globally, following maize, rice, wheat, and barley. It requires less water and shows higher resilience to significant shifts in climate compared to other cereals (Balakrishna *et al.*, 2019). In spite of that, sorghum is still underutilized. Sorghum has a composition similar to multiple cereal grains. For every

100 g, sorghum, rice, and maize contain carbohydrates at 73 g, 79 g, and 72 g respectively, protein at 11 g, 7 g, and 9 g, fat at 3.3 g, 0.7 g, and 4.5 g, fiber at 2.3 g, 1.0 g, and 2.7 g, calcium at 28 mg, 6 mg, and 9 mg, phosphorus at 287 mg, 147 mg, and 380 mg, and iron at 4.4 mg, 0.8 mg, and 4.6 mg (Sirappa, 2003). Srianta and Harijono (2015) had successfully fermented sorghum using *M. purpureus*. The fermentation process yielded yellow, orange and red pigments at concentrations of 61.00, 29.10, 35.60 AU/g respectively, for ethanol extract and 16.30, 12.40, 13.30 AU/g for water extract.

*Monascus* pigments have been reported to possess antibacterial properties (Kim *et al.*, 2006; Feng *et al.*, 2019; Gökmen *et al.*, 2021). *Monascus purpureus* produces 6 pigments, classified into three groups: orange pigments [monascorubrin ( $C_{23}H_{26}O_5$ ) and rubropunctanin ( $C_{21}H_{22}O_5$ )], yellow pigments [ankaflavin ( $C_{23}H_{30}O_5$ ) and monascin ( $C_{21}H_{26}O_5$ )], and red pigments [monascorubramin ( $C_{23}H_{27}NO_4$ ) and rubropunctamine ( $C_{21}H_{23}NO_4$ )] (Feng *et al.*, 2012). Antibacterial activity was observed in *Monascus* red pigment (Gökmen *et al.*, 2021), orange pigment (Feng *et al.*, 2019), and amino acid derivatives of *Monascus* pigment (Kim *et al.*, 2006). Antibacterial activity was investigated against Gram-positive bacteria *Staphylococcus aureus* and Gram-negative bacteria *E. coli*. *Staphylococcus aureus* and *E.*

\*Corresponding author.

Email: [srianta@ukwms.ac.id](mailto:srianta@ukwms.ac.id)

*coli* were pathogens causing various human infections and foodborne diseases (Tong et al., 2015; Bintsis, 2017; Braz et al., 2020)

This research aimed to investigate the antibacterial activity of MFSE against *S. aureus* and *E. coli*. It is the first to examine the antibacterial activity of a *Monascus*-fermented product that utilizes sorghum as a substrate.

## 12 2. Materials and methods

### 2.1 Microorganism, substrate, and chemical

*Monascus purpureus* M9 culture was used for solid-state fermentation of sorghum. It was isolated from commercial *Monascus*-fermented rice in Surabaya, Indonesia and identified as *M. purpureus* M9 (NCBI Accession Number: HM188425.1). *Staphylococcus aureus* ATCC 25920 and *Escherichia coli* ATCC 25927 were used for antibacterial assay. The bacteria were suspended in DMSO 20%. The sorghum used was commercial dehulled sorghum. It was vacuum-packed until used. All chemical and media used in the analysis was analytical grade.

### 2.2 Starter culture preparation

*Monascus purpureus* M9 was monthly cultured on a potato dextrose agar (PDA) slant. The starter culture was prepared with inoculating 8 loops of the culture (8 pieces of colony) scrubbed from the PDA slant, then incubated at 30°C for 7 days. Before use, the culture was suspended in 10 mL of sterile distilled water for 1 hr and homogenized with a vortex.

### 2.3 Sorghum solid-state fermentation

The fermentation process was carried out according to Srianta et al. (2016) with modification to the dehulled sorghum pre-treatment. Dehulled sorghum was washed and steamed first at 90°C for 60 mins. Fifty g of steamed sorghum was weighed and put inside an Erlenmeyer flask, then sterilized at 121°C for 20 mins. Solid-state fermentation was carried out by inoculating 5 mL of *M. purpureus* M9 starter culture that was adjusted using a haemocytometer and containing  $5 \times 10^5$  spores/mL into each flask containing sterilized substrate. It was then incubated at 30°C for 14 days with daily shaking of the flask to ensure thorough fermentation. The fermented material was then dried in an oven at 45°C for 24 hrs, ground into powder, and sieved (size 45 mesh). The MFS powder was analyzed for moisture content, color and biomass.

### 2.4 Moisture content, color and biomass analysis of *Monascus*-fermented sorghum

The moisture content of MFS was analyzed using oven drying method (Association of the Official Analytical Collaboration (AOAC) International, 2005). The sample underwent drying at 105°C for 3 hrs and followed by weighing every 30 min until a constant weight was obtained. The loss in weight due to moisture evaporation was then used to calculate the moisture content of the sample. The color of MFS was measured using color reader (Konica Minolta, 2015). The MFS was packed inside a transparent plastic and measured for L\*, a\*, b\*, C, and °h values. These measurements were repeated in triplicate.

Biomass analysis was conducted according to Srianta et al. (2016). The fungal biomass was estimated by determining the amount of N-acetyl glucosamine released through the acid hydrolysis of chitin, a component within the cell wall of the mycelia (Babitha et al., 2006). Chitin hydrolysis was carried out by using 10 M HCl and autoclaving at 130°C for 2 hrs. The hydrolysate was neutralized to pH 7.0, mixed with acetylacetone reagent and followed by Ehrlich reagent. Optical density was measured at 530 nm against the reagent blank. N-acetyl glucosamine (Sigma Aldrich Co. LLC) was used as a standard.

### 2.5 *Monascus*-fermented sorghum extraction

The MFS was extracted with three different solvents: ethyl acetate, ethanol, and water. One gram of the powder was weighed and extracted with ethyl acetate/ethanol/water with ratios of 1:50 (w/v) (1 g in 50 mL solvent) with Soxhlet apparatus at 80°C for 2 hrs. The extract obtained was evaporated at 200 mbar, 50 rpm for 30 mins using a rotary evaporator, producing a concentrated extract. The MFSE was analyzed for antibacterial activity assay, pigment and total phenolic contents.

### 2.6 Antibacterial activity assay

Broth microdilution test was carried out according to Klančnik et al. (2010). Approximately 50 µL of *S. aureus* and *E. coli* suspension in Mueller Hinton Broth (MHB) medium was added to the wells of a sterile 96-well microtitre plate containing 50 µL of two-fold serially diluted MFSE or amoxicillin. The final volume in each well was 100 µL. Control wells were prepared with culture medium, bacterial suspension only, MFSE only and DMSO 20% in amounts corresponding to the highest quantity present. The contents of each well were mixed on a microplate shaker at 900 rpm for 1 min prior to 24 hrs incubation. The MIC was the lowest concentration where no viability was observed after 24 hrs on the basis of metabolic activity (Mourey and Canillac, 2002). Viability could be indicated by the

presence of respiratory and ATP activity. To indicate respiratory activity, the presence of color was determined after adding 10  $\mu\text{L}$ /well of TTC (2,3,5-triphenyltetrazoliumchloride) dissolved in water (TTC 20 mg/mL). The microplate was then incubated under appropriate cultivation conditions for 30 mins in the dark (Eloff, 1998). To determine the ATP activity, the bioluminescence signal was measured by a microplate reader after adding 100  $\mu\text{L}$ /well of BacTiter-Glo™ reagent and after 5 min incubation in the dark (Klančnik et al., 2009). Positive controls were wells with a bacterial suspension in MHB and a bacterial suspension in MHB with DMSO 20% in amounts corresponding to the highest quantity present in the broth microdilution assay. Negative controls were wells with MHB and MFSE or amoxicillin. All measurements of MIC values were repeated in triplicate.

### 2.7 Pigment content analysis

The pigment content of MFSE analysis was carried out according to Srianta et al. (2016). The MFSE was dissolved in respective solvent and the absorbance was measured with UV-vis spectrophotometer at  $\lambda$  400 nm, 470 nm, and 500 nm for yellow, orange, and red pigment, respectively. The pigment content was expressed as absorbance (nm) at the wavelength per gram of dry matter (AU/g).

### 2.8 Total phenolic content

The total phenolic content of MFSE was analyzed according to Srianta et al. (2014). Folin-Ciocalteu was used as a reagent and Gallic acid was used as a standard. A total of 0.1 mL of extract was put into a 10 mL volumetric flask and 0.5 mL of Folin-Ciocalteu reagent was added. The samples were left at room temperature for 5 min then added with 1.5 mL 20% (w/v)  $\text{Na}_2\text{CO}_3$ . The mixture was added with distilled water until the volume reached 10 mL. After 30 mins at room temperature, absorbance was measured at a wavelength of 765 nm versus blank using a spectrophotometer (Shimadzu UV 1800, Japan). Total phenolic content was expressed in mg GAE/g.

## 3. Results and discussion

### 3.1 Moisture content, color and biomass content of *Monascus*-fermented sorghum

The MFS powder had a moisture content of 8.72% (Table 1). The moisture content of food powder below 10% has a high stability for storage (Zambrano et al., 2019). The lightness ( $L^*$ ), redness ( $a^*$ ), yellowness ( $b^*$ ), chroma ( $C$ ), and hue ( $^{\circ}\text{h}$ ) values of the MFS powder are presented in Table 1. The positive  $a^*$  and  $b^*$  values of all the fermented products reflected that the powder color is

a combination of red and yellow. Hue indicates a red color and chroma value indicates a dull-brownish red color.  $L^*$  value below 50 indicates low lightness, resulting in a dark red color.

Fungal biomass, branched fibrous mycelium of *Monascus*, was formed during the fermentation. Generally, biomass comprises protein, lipids, polysaccharides, chitin (or chitosan), and various inorganic salts in different proportions (Isaza-Pérez et al., 2020). The biomass yield of MFS was recorded at 825.786 mg/g or 0.825 g/mL. It was higher than the biomass obtained from *M. purpureus* fermentation on potato waste, which ranged from 0.046 to 0.262 g/mL (inoculum concentration  $7 \times 10^5$  spores/mL) (Abdel-Raheem et al., 2022). High biomass implies that sorghum was a suitable substrate for *M. purpureus* fermentation. Additionally, the high biomass could have resulted from the assistance of the steaming process (90°C for 60 mins), which helped soften the sorghum and facilitated easier utilization for the growth of *M. purpureus* (Zhao et al., 2018). Based on our previous research (Srianta and Harijono, 2015), the biomass of unsteamed dehulled sorghum only ranged from 26.64 to 36.70 mg/g (inoculum concentration  $5 \times 10^5$  spores/mL).

### 3.2 Antibacterial activity

MIC value is defined as the lowest concentration of the assayed antimicrobial agent that inhibits the visible growth of the microorganism tested (Balouiri et al., 2016). A low MIC value indicates a high antibacterial activity. The MIC values of MFSE against *S. aureus* and *E. coli* are presented in Table 2. The extraction using ethyl acetate produced MFSE with the lowest MIC, indicating that ethyl acetate-extracted MFSE exhibited the highest antibacterial activity against both *S. aureus* and *E. coli*. Meanwhile, ethanol and water-extracted MFSE showed lower antibacterial activity, with water-extracted displaying the lowest. Most *Monascus* pigments are slightly polar, making them more soluble in organic solvents like ethanol than in water (Carvalho et al., 2007; Qian and Wu, 2010; Bai et al., 2022). As a result, the amount of *Monascus* pigments that are extracted by ethyl acetate and ethanol is larger (Table 3). This larger quantity of extracted pigments is responsible for the observed antibacterial activity, thus making ethyl acetate and ethanol-extracted MFSE have lower MIC than water-extracted MFSE.

In addition to *Monascus* pigments, *Monascus*-fermented products are known to contain significant amounts of phenolic compounds (Srianta et al., 2013; Razak et al., 2015). Ethanol-extracted MFSE contains the highest total phenolic content (Table 3). As per Haminiuk et al. (2014), phenolic compounds also exhibit



Table 1. Moisture content, color and biomass content of MFS.

Moisture content (%)	Color					Biomass (mg/g)
	L* value	a* value	b*value	C	°h	
8.72	46.5	23.6	13.8	27.4	3.3	825.786

Table 2. MIC of amoxicillin and MFSE against *S. aureus* and *E. coli*.

Bacteria	Amoxicillin (µg/mL)	Ethyl acetate extract (mg/mL)	Ethanol extract (mg/mL)	Water extract (mg/mL)
<i>Staphylococcus aureus</i> ATCC 25920	3.125	3.125	12.5	100
<i>Escherichia coli</i> ATCC 25927	12.5	6.25	50	200

higher solubility in organic solvents that are less polar than water. Razak *et al.* (2015) found that phenolic acid present in *Monascus*-fermented rice bran extract is p-coumaric, ferulic, sinapic, vanillic, caffeic, and syringic acid. All of those phenolic acids exhibited antimicrobial properties (Liu *et al.*, 2020). Amoxicillin, a common antibiotic medication against Gram-positive and Gram-negative bacteria, was used as a reference. The MIC values of all three MFSEs remain higher than amoxicillin which exhibited a MIC value of 3.125 µg/mL against *S. aureus* and 12.5 µg/mL against *E. coli*.

Several studies have explored the antibacterial properties of red, orange, and yellow *Monascus* pigment. Gökmen *et al.* (2021) discovered that *Monascus* red pigments had a MIC value of 128 mg/mL against *S. aureus* and >128 mg/mL against *E. coli*. They observed that the effect was stronger compared to using a commercial red pigment which had a MIC value of 256 mg/mL against *S. aureus* and >256 mg/mL against *E. coli*. Feng *et al.* (2019) that found orange pigments demonstrated antibacterial activity against *S. aureus*, displaying inhibition zone diameters ranging from 5-34 mm for orange pigment concentrations ranging from 0-10 mg/mL. Kim *et al.* (2006) discovered that amino acid derivatives of *Monascus* pigment showed a high antimicrobial activity. Derivatives containing L-Phe, D-Phe, L-Asp, D-Asp, L-Tyr, D-Tyr, L-Cys, and Nisin exhibited high activities against *S. aureus* (Gram-positive bacteria) with MIC values ranging from 8-16 µg/mL, while the control red pigment showed a MIC value of 64 µg/mL. For *E. coli* (Gram-negative bacteria), the same derivatives exhibited lower activities with MIC values ranging from 8-64 µg/mL, and the control red pigment with MIC value of >128 µg/mL. Kim and Ku (2018) reviewed several studies regarding the antimicrobial effects of *Monascus* pigments and concluded that Gram-positive bacteria were more prone to inhibition compared to Gram-negative bacteria.

Some studies suggested that the mechanism might involve the interaction of *Monascus* pigment with enzymes in the germinated spores and vegetative cells, restricting the use of iron and affecting cell membrane permeability. This could result in reduced transportation of nutrients, oxygen and metabolites (Kim *et al.*, 2006; Xu, 2011). Feng *et al.* (2019) also observed that orange pigment causes *S. aureus* cells to wrinkle, damaging the membrane and causing protein leakage of bacteria cells. Meanwhile, amino acid derivatives of *Monascus* pigment depend on the hydrophobicity of the pigment and the amount of pigment adsorbed to the cell surface. The more hydrophobic, the higher the adsorption, which leads to limitation of oxygen uptake (Kim *et al.*, 2006).

#### 4. Conclusion

Sorghum is a suitable substrate to produce *Monascus*-fermented products whose extract has antibacterial activity. Ethyl acetate, ethanol, and water-extracted MFSE demonstrated antibacterial activity against *S. aureus* and *E. coli*. Ethyl acetate exhibited the highest activity, followed by ethanol and water extracts. All of the MFSE exhibited stronger activity on Gram-positive bacteria.

#### Conflict of interest

The authors declare no conflict of interest.

#### Acknowledgements

Thanks to Widya Mandala Surabaya Catholic University for financial support through Penelitian Internal UKWMS.

Table 3. Pigment and total phenolic contents of MFSE.

Solvent	Pigment content (AU/g)			Total phenolic content (mg/mL)
	Yellow	Orange	Red	
Ethyl acetate	177.3378	64.7206	52.4588	1.6974
Ethanol	153.8563	59.0424	66.1631	9.8037
Water	47.4565	24.5389	20.1564	2.3995

## References

- Abdel-Raheem, H.E.F., Alrumman, S.A., Gadow, S.I., El-Sayed, M.H., Hikal, D.M., Hesham, A.E. and Ali, M.M.A. (2022). Optimization of *Monascus purpureus* for Natural Food Pigments Production on Potato Wastes and Their Application in Ice Lolly. *Frontiers in Microbiology*, 13, 862080. <https://doi.org/10.3389/fmicb.2022.862080>
- Association of the Official Analytical Collaboration (AOAC) International. (2005). Official Methods of Analysis. 18<sup>th</sup> ed. Maryland, USA: AOAC International.
- Babitha, S., Soccol, C.R. and Pandey, A. (2006). Jackfruit seed - a novel substrate for the production of *Monascus* pigments through solid state fermentation. *Food Technology and Biotechnology*, 44(4), 465-471.
- Bai, J., Gong, Z., Shu, M., Zhao, H., Ye, F., Tang, C., Zhang, S., Zhou, B., Lu, D., Zhou, X., Lin, Q. and Liu, J. (2022). Increased Water-Soluble Yellow *Monascus* Pigment Productivity via Dual Mutagenesis and Submerged Repeated-Batch Fermentation of *Monascus purpureus*. *Frontiers in Microbiology*, 13, 914828. <https://doi.org/10.3389/fmicb.2022.914828>
- Balakrishna, D., Vinodh, R., Madhu, P., Avinash, S., Rajappa, P.V. and Bhat, B.V. (2019). Tissue Culture and Genetic Transformation in *Sorghum bicolor*. In Aruna, C., Visarada, K.B.R.S., Venkatesh Bhat, B., Tonapi, V.A. (Eds.) Breeding Sorghum for Diverse End Uses, p. 115-130. UK: Woodhead Publishing Service. <https://doi.org/10.1016/B978-0-08-101879-8.00007-3>
- Balouiri, M., Sadiki, M. and Ibensouda, S.K. (2016). Methods for *in vitro* evaluating antimicrobial activity: A review. *Journal of Pharmaceutical Analysis*, 6(2), 71-79. <https://doi.org/10.1016/j.jpha.2015.11.005>
- Bintsis T. (2017). Foodborne pathogens. *AIMS Microbiology*, 3(3), 529-563. <https://doi.org/10.3934/microbiol.2017.3.529>
- Braz, V.S., Melchior, K. and Moreira, C.G. (2020). *Escherichia coli* as a Multifaceted Pathogenic and Versatile Bacterium. *Frontiers in Cellular and Infection Microbiology*, 10, 548492. <https://doi.org/10.3389/fcimb.2020.548492>
- Carvalho, J.C., Oishi, B.O., Woiciechowski, A.L., Pandey, A., Babitha, S. and Soccol, C.R. (2007). Effect of substrates on the production of *Monascus* biopigments by solid-state fermentation and pigment extraction using different solvents. *Indian Journal of Biotechnology*, 6, 194-199.
- Choe, D., Song, S.M., Shin, C.S., Johnston, T.V., Ahn, H.J., Kim, D. and Ku, S. (2020). Production and Characterization of Anti-Inflammatory *Monascus* Pigment Derivatives. *Foods*, 9(7), 858. <https://doi.org/10.3390/foods9070858>
- Ding, Y.Z., Kong, L.C., Zhang, Y.C. and Jiang, D.H. (2022). Antioxidation and inhibition of  $\alpha$ -glucosidase activity of secondary metabolites of *Monascus purpureus* Mp-21. *Acta Microbiologica Sinica*, 62(1), 103-118. <https://doi.org/10.13343/j.cnki.wsxb.20210120>
- Eloff, J.N. (1998). A sensitive and quick microplate method to determine the minimal inhibitory concentration of plant extracts for bacteria. *Planta Medica*, 64(8), 711-713. <https://doi.org/10.1055/s-2006-957563>
- Feng, L.H., Li, Y.Q., Sun, G.J. and Zhao, X.Z. (2019). Antibacterial effect of orange *Monascus* pigment against *Staphylococcus aureus*. *Acta Alimentaria*, 48(2), 169-176. <https://doi.org/10.1556/066.2019.48.2.4>
- Feng, Y., Shao, Y. and Chen, F. (2012). *Monascus* pigments. *Applied Microbiology and Biotechnology*, 96(6), 1421-1440. <https://doi.org/10.1007/s00253-012-4504-3>
- Gökmen, G.G., Silbir, M.S., Goksungur, Y. and Kisla, D. (2021). Antimicrobial activity of red pigments derived from *Monascus purpureus*: a comparison to industrial red pigments. *Journal of the Science of Food and Agriculture Reports*, 1(1), 5-10. <https://doi.org/10.1002/jsf2.20>
- Haminiuk, C.W., Plata-Oviedo, M.S., de Mattos, G., Carpes, S.T. and Branco, I.G. (2014). Extraction and quantification of phenolic acids and flavonols from *Eugenia pyriformis* using different solvents. *Journal of Food Science and Technology*, 51(10), 2862-2866. <https://doi.org/10.1007/s13197-012-0759-z>
- Hong, M.Y., Seeram, N.P., Zhang, Y. and Heber, D. (2008). Anticancer effects of Chinese red yeast rice versus monacolin K alone on colon cancer cells. *The Journal of Nutritional Biochemistry*, 19(7), 448-458. <https://doi.org/10.1016/j.jnutbio.2007.05.012>
- Hsu, W.H. and Pan, T.M. (2012). *Monascus purpureus*-fermented products and oral cancer: a review. *Applied Microbiology and Biotechnology*, 93(5), 1831-1842. <https://doi.org/10.1007/s00253-012-3891-9>
- Isaza-Pérez, F., Ramírez-Carmona, M., Rendón-Castrillón, L. and Ocampo-López, C. (2020). Potential of residual fungal biomass: a review. *Environmental Science and Pollution*

- Research International, 27(12), 13019-13031. <https://doi.org/10.1007/s11356-020-08193-6>
- Kim, C., Jung, H., Kim, Y.O. and Shin, C.S. (2006). Antimicrobial activities of amino acid derivatives of *Monascus* pigments. *Federation of European Microbiological Societies Microbiology Letters*, 264 (1), 117-124. <https://doi.org/10.1111/j.1574-6968.2006.00451.x>
- Kim, D. and Ku, S. (2018). Beneficial Effects of *Monascus* sp. KCCM 10093 Pigments and Derivatives: A Mini Review. *Molecules*, 23(1), 98. <https://doi.org/10.3390/molecules23010098>
- Kim, J.H., Kim, H.J., Park, H.W., Youn, S.H., Choi, D.Y. and Shin, C.S. (2007). Development of inhibitors against lipase and alpha-glucosidase from derivatives of *Monascus* pigment. *Federation of European Microbiological Societies Microbiology Letters*, 276(1), 93-98. <https://doi.org/10.1111/j.1574-6968.2007.00917.x>
- Kim, J.H., Kim, Y.O., Jeun, J., Choi, D.Y. and Shin, C.S. (2010). L-Trp and L-Leu-OEt derivatives of the *Monascus* pigment exert high anti-obesity effects on mice. *Bioscience, Biotechnology, and Biochemistry*, 74(2), 304-308. <https://doi.org/10.1271/bbb.90620>
- Klančnik, A., Guzej, B., Kolar, M.H., Abramovic, H. and Mozina, S.S. (2009). In vitro antimicrobial and antioxidant activity of commercial rosemary extract formulations. *Journal of Food Protection*, 72(8), 1744-1752. <https://doi.org/10.4315/0362-028x-72.8.1744>
- Klančnik, A., Piskernik, S., Jersek, B. and Mozina, S.S. (2010). Evaluation of diffusion and dilution methods to determine the antibacterial activity of plant extracts. *Journal of Microbiological Methods*, 81(2), 121-126. <https://doi.org/10.1016/j.mimet.2010.02.004>
- Konica Minolta. (2015). Color Reader CR-20 Instruction Manual. Retrieved on December 12, 2023 from Konica Minolta Website: [https://www.konicaminolta.com/instruments/download/instruction\\_manual/color/pdf/cr-20\\_instruction\\_eng.pdf](https://www.konicaminolta.com/instruments/download/instruction_manual/color/pdf/cr-20_instruction_eng.pdf)
- Lee, B.H., Hsu, W.H., Liao, T.H. and Pan, T.M. (2011). The *Monascus* metabolite monascin against TNF- $\alpha$ -induced insulin resistance via suppressing PPAR- $\gamma$  phosphorylation in C2C12 myotubes. *Food and Chemical Toxicology*, 49(10), 2609-2617. <https://doi.org/10.1016/j.fct.2011.07.005>
- Liu, J., Du, C., Beaman, H.T. and Monroe, M.B.B. (2020). Characterization of Phenolic Acid Antimicrobial and Antioxidant Structure-Property Relationships. *Pharmaceutics*, 12(5), 419. <https://doi.org/10.3390/pharmaceutics12050419>
- Mourey, A. and Canillac, N. (2002). Anti-*Listeria monocytogenes* activity of essential oils components of conifers. *Food Control*, 13(4-5), 289-292. [https://doi.org/10.1016/S0956-7135\(02\)00026-9](https://doi.org/10.1016/S0956-7135(02)00026-9)
- Qian, J. and Wu, Q. (2010). Improving water solubility of *Monascus* pigment. *Journal of Chinese Cereals and Oils Association*, 4, 77-79.
- Razak, D.L., Abd Rashid, N.Y., Jamaluddin, A., Sharifudin, S.A. and Long, K. (2015). Enhancement of phenolic acid content and antioxidant activity of rice bran fermented with *Rhizopus oligosporus* and *Monascus purpureus*. *Biocatalysis and Agricultural Biotechnology*, 4(1), 33-38. <https://doi.org/10.1016/j.BCAB.2014.11.003>
- Sirappa, M.P. (2003). Prospek Pengembangan Sorgum di Indonesia Sebagai Komoditas Alternatif untuk Pangan, Pakan, dan Industri. *Jurnal Litbang Pertanian*, 22(4), 133-140. [In Bahasa Indonesia].
- Srianta, I. and Harijono. (2015). *Monascus*-fermented sorghum: pigments and monacolin K produced by *Monascus purpureus* on whole grain, dehulled grain and bran substrates. *International Food Research Journal*, 22(1), 377-382.
- Srianta, I., Kusumawati, N., Nugerahani, I., Artanti, N. and Xu, G.R. (2013). In Vitro  $\alpha$ -glucosidase Inhibitory Activity of *Monascus*-Fermented Durian Seed Extracts. *International Food Research Journal*, 20(2), 533-536.
- Srianta, I., Nugerahani, I., Kusumawati, N., Suryatanijaya, E. and Subianto, C. (2014). Therapeutic antioxidant activity of *Monascus*-fermented durian seed: a potential functional food ingredient. *International Journal of Food, Nutrition and Public Health*, 7(1), 53-59. <https://doi.org/10.47556/IJFNPH.7.1.2014.5>
- Srianta, I., Zubaidah, E., Estiasih, T., Iuchi, Y., Harijono and Yamada, M. (2017). Antioxidant activity of pigments derived from *Monascus purpureus*-fermented rice, corn, and sorghum. *International Food Research Journal*, 24(3), 1186-1191.
- Srianta, I., Zubaidah, E., Estiasih, T., Yamada, M. and Harijono. (2016). Comparison of *Monascus purpureus* growth, pigment production and composition on different cereal substrates with solid state fermentation. *Biocatalysis and Agricultural Biotechnology*, 7, 181-186. <https://doi.org/10.1016/j.bcab.2016.05.011>
- Tong, S.Y., Davis, J.S., Eichenberger, E., Holland, T.L. and Fowler, V.G., Jr (2015). *Staphylococcus aureus* infections: epidemiology, pathophysiology, clinical

- manifestations, and management. *Clinical Microbiology Reviews*, 28(3), 603-661. <https://doi.org/10.1128/CMR.00134-14>
- Xu, W.J. (2011). Study on the Liquid Fermentation to Produce *Monascus* Pigment with Corn Starch and Antibacterial. *Advanced Materials Research*, 183-185, 1336-1340. <https://doi.org/10.4028/www.scientific.net/AMR.183-185.1336>
- Zambrano, M.V., Dutta, B., Mercer, D.G., MacLean, H.L. and Touchie, M. (2019). Assessment of moisture content measurement methods of dried food products in small-scale operations in developing countries: A review. *Trends in Food Science and Technology*, 88, 484-496. <https://doi.org/10.1016/j.tifs.2019.04.006>
- Zhao, S., Li, G., Zheng, N., Wang, J. and Yu, Z. (2018). Steam explosion enhances digestibility and fermentation of corn stover by facilitating ruminal microbial colonization. *Bioresource Technology*, 253, 244-251. <https://doi.org/10.1016/j.biortech.2018.01.024>



# Antibacterial activity of Monascus-fermented sorghum extracts against Staphylococcus aureus and Escherichia coli

## ORIGINALITY REPORT

6%

SIMILARITY INDEX

2%

INTERNET SOURCES

5%

PUBLICATIONS

2%

STUDENT PAPERS

## PRIMARY SOURCES

1

Submitted to Chulalongkorn University

Student Paper

1%

2

[www.researchpublish.com](http://www.researchpublish.com)

Internet Source

1%

3

Klančnik, Anja, Sonja Smole Možina, and Qijing Zhang. "Anti-Campylobacter Activities and Resistance Mechanisms of Natural Phenolic Compounds in Campylobacter", PLoS ONE, 2012.

Publication

1%

4

Mehmet Ugur YILDIRIM, Bilge OZCAN, Nejdet SEN, Mustafa Resul DEMIRAY, Ibrahim BULDUK, Ercument Osman SARIHAN, Erdi Can AYTAZ. "Phytochemical Composition, Antioxidant Potential, and Computational Analysis of Delphinium peregrinum L.", Springer Science and Business Media LLC, 2025

Publication

<1%

5

P Jůzlová. "Secondary metabolites of the fungus Monascus: A review", Journal of Industrial Microbiology, 03/1996

Publication

<1%

Submitted to University of Nicosia

6

Student Paper

&lt;1 %

7

Marketa Husakova, Petra Patakova. " Purified Pigments: Biological Activities and Mechanisms of Action ", Journal of Natural Products, 2025

Publication

&lt;1 %

8

Submitted to American University in Cairo

Student Paper

&lt;1 %

9

Submitted to University of Zagreb - Faculty of Food Technology and Biotechnology

Student Paper

&lt;1 %

10

fatcat.wiki

Internet Source

&lt;1 %

11

Azin Khosravi, Seyed Hadi Razavi. "The role of bioconversion processes to enhance polyphenol bioaccessibility in rice bioaccessibility of polyphenols in rice", Food Bioscience, 2020

Publication

&lt;1 %

12

G. Sharmila, B. Nidhi, C. Muthukumaran. "Sequential statistical optimization of red pigment production by *Monascus purpureus* (MTCC 369) using potato powder", Industrial Crops and Products, 2013

Publication

&lt;1 %

13

Jin-Ming Gao, Sheng-Xiang Yang, Jian-Chun Qin. "Azaphilones: Chemistry and Biology", Chemical Reviews, 2013

Publication

&lt;1 %

14 Marleni Medina-Mendoza, Diner Mori-Mestanza, Roberth E. Iliquín-Fernández, Ilse S. Cayo Colca et al. "Optimizing dark chocolate production: Effect of conching time, berry by-products, and sachu inchi oil on antioxidant attributes", Journal of Agriculture and Food Research, 2025

Publication

<1 %

15 Sara El Bernoussi, Ihssan Boujemaa, Chakir El Guezzane, Youssef Bou-Ouzoukni et al. "Comparative Analysis of Nutritional Value and Antioxidant Activity in Sweet and Bitter Almonds", LWT, 2024

Publication

<1 %

16 Alaadin M. Alaadin, Ekbal Hasan Al-Khateeb, Anna K. Jäger. "Antibacterial Activity of the Iraqi . Root ", Pharmaceutical Biology, 2008

Publication

<1 %

17 Pattanagul, P.. "Mevinolin, citrinin and pigments of adlay angkak fermented by Monascus sp.", International Journal of Food Microbiology, 20080815

Publication

<1 %

Exclude quotes On

Exclude bibliography On

Exclude matches Off

# Antibacterial activity of Monascus-fermented sorghum extracts against Staphylococcus aureus and Escherichia coli

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

/100

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7