

USDA-ARS | U.S. Wheat and Barley Scab Initiative  
**FY21 FINAL Performance Progress Report**

**Due date:** July 26, 2023

[Cover Page](#)

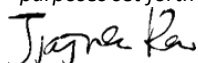
<b>USDA-ARS Agreement ID:</b>	59-0206-0-130
<b>USDA-ARS Agreement Title:</b>	Essential Oil Nanoemulsion to Control of Mycotoxin Production in Cereals
<b>Principle Investigator (PI):</b>	Jaijai Rao
<b>Institution:</b>	North Dakota State University
<b>Institution UEI:</b>	EZ4WPGRE1RD5
<b>Fiscal Year:</b>	2021
<b>FY21 USDA-ARS Award Amount:</b>	\$58,749
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<b>Period of Performance:</b>	6/1/21 - 5/31/23
<b>Reporting Period End Date:</b>	5/31/2023

[USWBSI Individual Project\(s\)](#)

USWBSI Research Category*	Project Title	ARS Award Amount
FST-R	Essential Oil Nanoemulsion to Control of Mycotoxin Production in Cereals	\$58,749
<b>FY21 Total ARS Award Amount</b>		<b>\$58,749</b>

I am submitting this report as a:  FINAL Report

*I certify to the best of my knowledge and belief that this report is correct and complete for performance of activities for the purposes set forth in the award documents.*



Principal Investigator Signature

05/23/2023

Date Report Submitted

† BAR-CP – Barley Coordinated Project  
 DUR-CP – Durum Coordinated Project  
 EC-HQ – Executive Committee-Headquarters  
 FST-R – Food Safety & Toxicology (Research)  
 FST-S – Food Safety & Toxicology (Service)  
 GDER – Gene Discovery & Engineering Resistance  
 HWW-CP – Hard Winter Wheat Coordinated Project

MGMT – FHB Management  
 MGMT-IM – FHB Management – Integrated Management Coordinated Project  
 PBG – Pathogen Biology & Genetics  
 TSCI – Transformational Science  
 VDHR – Variety Development & Uniform Nurseries  
 NWW – Northern Soft Winter Wheat Region  
 SPR – Spring Wheat Region  
 SWW – Southern Soft Red Winter Wheat Region

**Project 1:** Essential Oil Nanoemulsion to Control of Mycotoxin Production in Cereals

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**1. What are the major goals and objectives of the research project?**

**Goal one:** Preparation, Characterization of essential oil nanoemulsions and their major chemical compounds nanoemulsions.

**Goal two:** Antifungal and antimycotoxigenic mechanisms of action (MOA) of essential oil nanoemulsions.

**Goal three:** Application of essential oil nanoemulsions for reducing Fusarium Infection and DON production during micro malting processing.

**2. What was accomplished under these goals or objectives? (For each major goal/objective, address these three items below.)**

**a) What were the major activities?**

**Majority activities in goal one:**

- The chemical composition of essential oils (thyme oil, clove leaf, bud and hop oil) and their fractions (volatile and nonvolatile fraction of thyme oil, clove oil) have been characterized using Gas chromatography–mass spectrometry (GC-MS).
- A number of physically stable 5 wt% of essential oil-in-water nanoemulsions including thyme oil, thyme oil fractions and their constituents, clove leaf, clove bud, and clove oil constituents, hop essential oil have been fabricated using high energy method.
- The physiochemical properties of nanoemulsions have been characterized including particle size, particle size distribution and long term stability of nanoemulsion.

**Majority activities in goal two:**

- The antifungal activity of essential oil-in-water nanoemulsions have been evaluated.
- in terms of inhibition of mycelial growth and spore germination
- The influence of essential oil nanoemulsions on outer cell membrane compositions (total lipid content, chitin content) and permeability and integrity of cytoplasmic membrane were evaluated using fluorescence-based assay (confocal laser scanning microscopy).
- The mycotoxin inhibitory activity of essential oil-in-water nanoemulsions have been evaluated in rice culture.
- The method for evaluating mycotoxin inhibitory activity of essential oil-in-water nanoemulsions in Trichothecene biosynthesis induction (TBI) medium has been established.

**Majority activities in goal three:**

- Application of clove oil nanoemulsions for reducing Fusarium Infection and DON production during micro malting processing using Fusarium-infected barley (Variety: Stellar- ND) at the North Dakota State University trial.
- Application of hop oil nanoemulsion for reducing Fusarium Infection and DON production during micro malting processing using naturally fusarium infected six row barley (Variety: Pinnacle).

**b) What were the significant results?**

- By blending 30 wt% of essential oil with 70 wt% of corn oil in oil phase (5 wt%), clove thyme oil-in-water nanoemulsion, bud oil (CBO)-in-water nanoemulsion, clove leaf oil (CLO)-in-water nanoemulsion and hop oil-in-water nanoemulsion showed highly physical stable with the mean particle size < 200 nm.
- The concentration of major chemical constituents in essential oil such as eugenol and caryophyllene in nanoemulsion maintained constant during storage time.
- The antifungal activities of essential oil nanoemulsions against two *Fusarium graminearum* isolates were strongly dependent on the essential oil concentrations. In general, the order of antifungal activity from the strongest to weakest is thyme oil, clove leaf oil, clove bud oil and hop oil.
- The antifungal activity of essential oils has been elucidated including alternating the total lipid content in outer cell membrane, decreasing chitin in outer cell membrane and damaging the cytoplasmic membrane as evidenced by confocal laser scanning microscopy (CLSM).
- In terms of antimycotoxigenic mechanisms of action (MOA) of thyme oil, thyme oil significantly ( $p < 0.05$ ) up-regulated the expression of the most genes studied (Tri3, Tri4, and Tri5) in two isolates, while thymol that is the major chemical constitutes in thyme oil did not up-regulate any gene expression.

**c) List key outcomes or other achievements.**

- Xiaoxi Qi, Bingcan Chen, **Jiajia Rao\***. Natural compounds of plant origin in the control of fungi and mycotoxins in foods. *Current Opinion in Food Science*. 2023 (accepted).
- Haiyang Jiang, Xiaoxi Qi, Shaobin Zhong, Paul Schwarz, Bingcan Chen, **Jiajia Rao\***. Effect of treatment of *Fusarium* head blight infected barley grains with hop essential oil nanoemulsion on the quality and safety of malted barley. *Food chemistry*, 2023, 421, 136172.
- Xiaoxi Qi, Shaobin Zhong, Paul Schwarz, Bingcan Chen, **Jiajia Rao\***. Mechanisms of antifungal and mycotoxin inhibitory properties of *Thymus vulgaris L.* essential oil and their major chemical constituents in emulsion-based delivery system. *Industrial Crops and Products*, 2023, 197, 116575.
- Haiyang Jiang, Shaobin Zhong, Paul Schwarz, Bingcan Chen, **Jiajia Rao\***. Antifungal activity, mycotoxin inhibitory efficacy, and mode of action of hop essential oil nanoemulsion against *Fusarium graminearum*. *Food chemistry*, 2023, 400, 134016.
- Haiyang Jiang, Shaobin Zhong, Paul Schwarz, Bingcan Chen, **Jiajia Rao\***. Chemical composition of essential oils from leaf and bud of clove and their impact on the antifungal and mycotoxin inhibitory activities of clove oil-in-water nanoemulsions. *Industrial Crops and Products*, 2022, 187 (part B), 115479.

**3. What opportunities for training and professional development has the project provided?**

- Trained one PhD student (Haiyang Jiang) under this project graduated in 2022 and one part-time researcher have been trained by this project.

#### 4. How have the results been disseminated to communities of interest?

A number of talks or poster presentation have been given in different conferences that are listed below:

- Haiyang Jiang, Xiaoxi Qi, Paul Schwarz, **Jiajia Rao\***. (2022) Impact of hop essential oil-in-water nanoemulsion treatment to control the safety of malting barley using naturally Fusarium Head Blight (FHB)-infected barley grains. *Proceedings of the 2022 National Fusarium Head Blight Forum*; Tampa, FL. December 4-6, 2022. Retrieved from: <https://scabusa.org/forum/2022/2022NFHBForumProceedings.pdf>
- Xiaoxi Qi, Shaobin Zhong, Paul Schwarz, Bingcan Chen, **Jiajia Rao\***. (2022) Mechanisms of antifungal and mycotoxin inhibitory properties of thyme essential oil and their major chemical constituents in emulsion-based delivery system. *Proceedings of the 2022 National Fusarium Head Blight Forum*; Tampa, FL. December 4-6, 2022. Retrieved from: <https://scabusa.org/forum/2022/2022NFHBForumProceedings.pdf>
- **Jiajia Rao\***. Application of Essential Oils to Control Fungal Spoilage and Mycotoxin Production in Cereal Foods. 2022 International Symposium on Food Nutrition and Future Food, 2-3 December, 2022 (*Invited online talk*).
- Haiyang Jiang, **Jiajia Rao\***. Antifungal activity of hop essential oil against Fusarium species and their mycotoxin production. 2022 Institute of Food Technologists (IFT) Annual Meeting, July 10–13, Chicago, USA.
- Haiyang Jiang, **Jiajia Rao\***. Antifungal and mycotoxin inhibitory activity of hop extracts. 2021 National Fusarium Head Blight Forum, December 6-7, 2021 Virtual.
- **Jiajia Rao**. Essential oil based nanoemulsions as antifungal agents in food processing. 2021 National Fusarium Head Blight Forum, December 6-7, 2021 Virtual (*Invited talk*).
- Haiyang Jiang, **Jiajia Rao\***. Chemical composition, antifungal and mycotoxin inhibitory activities of essential oil nanoemulsions from leaves and buds of clove. 2021 Institute of Food Technologists (IFT) Annual Meeting, July 18–21, Virtual.

## Publications, Conference Papers, and Presentations

Please include a listing of all your publications/presentations about your FHB work that were a result of funding from your FY21 grant award. Only citations for publications published (submitted or accepted) or presentations presented during the **award period** should be included.

### Did you publish/submit or present anything during this award period?

- Yes, I've included the citation reference in listing(s) below.  
 No, I have nothing to report.

### Journal publications as a result of FY21 award

List peer-reviewed articles or papers appearing in scientific, technical, or professional journals. Include any peer-reviewed publication in the periodically published proceedings of a scientific society, a conference, or the like.

Identify for each publication: Author(s); title; journal; volume; year; page numbers; status of publication (published [include DOI#]; accepted, awaiting publication; submitted, under review; other); acknowledgement of federal support (yes/no).

- Xiaoxi Qi, Bingcan Chen, Jiajia Rao\*. Natural compounds of plant origin in the control of fungi and mycotoxins in foods. *Current Opinion in Food Science*. 2023 (*accepted*) <https://www.sciencedirect.com/science/article/pii/S2214799323000681>. Acknowledgment of Federal Support: Yes.
- Haiyang Jiang, Xiaoxi Qi, Shaobin Zhong, Paul Schwarz, Bingcan Chen, Jiajia Rao\*. Effect of treatment of Fusarium head blight infected barley grains with hop essential oil nanoemulsion on the quality and safety of malted barley. *Food chemistry*, 2023, 421. DOI: 10.1016/j.foodchem.2023.136172. Acknowledgment of Federal Support: Yes.
- Xiaoxi Qi, Shaobin Zhong, Paul Schwarz, Bingcan Chen, Jiajia Rao\*. Mechanisms of antifungal and mycotoxin inhibitory properties of *Thymus vulgaris* L. essential oil and their major chemical constituents in emulsion-based delivery system. *Industrial Crops and Products*, 2023, 197. DOI: 10.1016/j.indcrop.2023.116575. Acknowledgment of Federal Support: Yes.
- Haiyang Jiang, Shaobin Zhong, Paul Schwarz, Bingcan Chen, Jiajia Rao\*. Antifungal activity, mycotoxin inhibitory efficacy, and mode of action of hop essential oil nanoemulsion against *Fusarium graminearum*. *Food chemistry*, 2023, 400. DOI: 10.1016/j.foodchem.2022.134016. Acknowledgment of Federal Support: Yes.
- Haiyang Jiang, Shaobin Zhong, Paul Schwarz, Bingcan Chen, Jiajia Rao\*. Chemical composition of essential oils from leaf and bud of clove and their impact on the antifungal and mycotoxin inhibitory activities of clove oil-in-water nanoemulsions. *Industrial Crops and Products*, 2022, 187 (part B). DOI: 10.1016/j.indcrop.2022.115479 115479. Acknowledgment of Federal Support: Yes.

### Books or other non-periodical, one-time publications as a result of FY21 award

Report any book, monograph, dissertation, abstract, or the like published as or in a separate publication, rather than a periodical or series. Include any significant publication in the proceedings of a one-time conference or in the report of a one-time study, commission, or the like.

Identify for each one-time publication: Author(s); title; editor; title of collection, if applicable; bibliographic information; year; type of publication (book, thesis, or dissertation, other); status of publication (published; accepted, awaiting publication; submitted, under review; other); acknowledgement of federal support (yes/no).

- Haiyang Jiang, Xiaoxi Qi, Paul Schwarz, Jiajia Rao\*. (2022) Impact of hop essential oil-in-water nanoemulsion treatment to control the safety of malting barley using naturally Fusarium Head Blight (FHB)-infected barley grains. *Proceedings of the 2022 National Fusarium Head Blight Forum*; Tampa, FL. December 4-6, 2022. Retrieved from: <https://scabusa.org/forum/2022/2022NFHBFForumProceedings.pdf>
- Xiaoxi Qi, Shaobin Zhong, Paul Schwarz, Bingcan Chen, Jiajia Rao\*. (2022) Mechanisms of antifungal and mycotoxin inhibitory properties of thyme essential oil and their major chemical constituents in emulsion-based delivery system. *Proceedings of the 2022 National Fusarium Head Blight Forum*; Tampa, FL. December 4-6, 2022. Retrieved from: <https://scabusa.org/forum/2022/2022NFHBFForumProceedings.pdf>

### Other publications, conference papers and presentations as a result of FY21 award

Identify any other publications, conference papers and/or presentations not reported above. Specify the status of the publication.

Nothing to Report