The Reduction of Grains Loss and the Control of Mycotoxins by Package Innovation

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Outline

I. Team Profile

II. Food security in China

III. R & D of technology to reduce food loss and control mycotoxins

I. Team Profile

The Development History of Our Team

2006.07-2017.09

Research Group on Mycotoxin Control in Food and Feed

Liu Yang
Prof. / PhD.

2017.10-2021.04

Innovation Team:
Prevention and Control of Mycotoxins in Agricultural Products

2021.04-2021.12

Prevention and Control of Mycotoxins in Agricultural Products
Chief Scientist

Fuguo Xing
Prof. / PhD.

2022.01-to date

Grain and Oil Loss Reduction and Mycotoxin Control Innovation Team
Chief Scientist

Team Profile

Grain and Oil Loss Reduction and Mycotoxin Control Innovation Team

Prof.
Xing Fuguo

Prof.
Guo Wei

Prof.
Gao Meixu

Associate Prof.
Wang Gang

Associate Prof.
Jin Jing

Associate Prof.
Yang Bolei

Assistant Prof.
Li Weizhao

Assistant Prof.
Tai Bowen

Assistant Prof.
Han Susu

The average age of team members is 37.3

- 45 Team members
- 9 Staffs
- 10 PhD students
- 27 Master degree
- 5 International students

Personal Introduction

- **Chief scientist**, Grain and Oil Loss Reduction and Mycotoxin Control Innovation Team of CAAS
- **Leading agricultural talents** of the Chinese Academy of Agricultural Sciences
- **Research area:** Grain and oil loss reduction, the prevention and control of mycotoxin in food and feed, and detoxification of mycotoxins in agro-products
- **Projects:** Presided over 2 key research and development projects, 4 natural science foundation projects, 1 public welfare industry special project, a 973 program sub-project, and 2 Beijing Foundation projects
- **Major academic awards:** Won 2 outstanding scientific and technological innovation awards from the CAAS (No.1/No.2), 2 award from China Cereals and Oils Association (No.2), and 2 scientific and technological progress awards of Shandong province (No.2 / No.4).
- **Major academic publications:** Published 138 papers, including 87 SCI papers and 44 authorized invention patents.

Fuguo Xing
PhD./Prof.
Doctoral supervisor

Major Academic awards

Name	Award type	Year	Rank
Innovation and application of key technologies for the prevention, control and grading of mycotoxins in corn during harvest and storage	Outstanding Scientific and Technological Innovation Award of the CAAS	2022	1
Green prevention and control technology of aflatoxins and application in peanut processing	Outstanding Scientific and Technological Innovation Award of the CAAS	2016	1
Green prevention and control technology and application of peanut aflatoxin	Shandong Science and Technology Progress Award	2022	2
Research and application of key technologies for full chain monitoring and early warning of typical mycotoxins in grain, as well as reduction and control of fungi and mycotoxins	Science and Technology Award of the China Grain and Oil Society	2023	2
Green precision prevention and control technology and application of aflatoxin for peanut storage and processing	Science and Technology Award of the China Grain and Oil Society	2022	1
Green prevention and control technology and application of peanut processing aflatoxin	Shandong Science and Technology Progress Award	2018	2


中国农业科学院
科学技术成果奖
证书


中国农业科学院
科学技术成果奖
证书

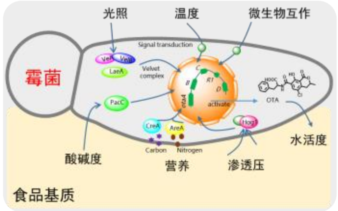

山东省科学技术奖
证书


中国粮油学会科学技术奖
获奖证书
为表彰在全国粮油行业科学研究、技术创新、成果推广、高新技术产业化中做出突出贡献，特发此证。


中国粮油学会科学技术奖
获奖证书
为表彰在全国粮油行业科学研究、技术创新、成果推广、高新技术产业化中做出突出贡献，特发此证。

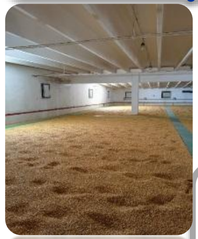
Research Fields

Regulation of mycotoxins synthesis



Monitoring and early warning of fungi in stored grain

Grain storage prevention and control technology system

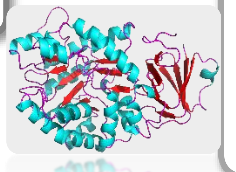


Light and simple storage facilities

Intelligent sorting of grain contaminated with mycotoxins

Whole chain control of post harvest losses of grain

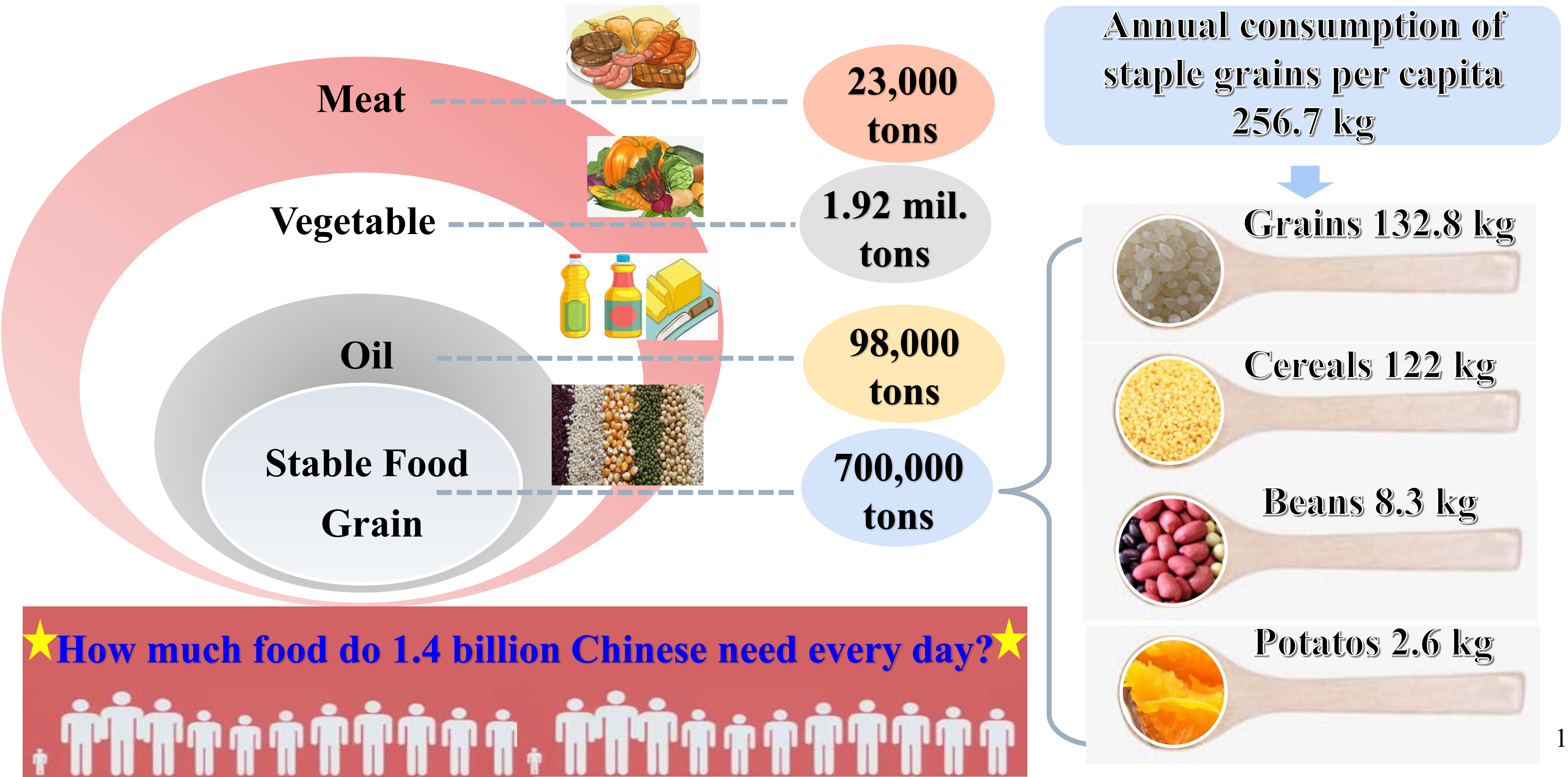
Grain drying and storage equipment



Safe detoxification of mycotoxins

II. Food security in China

It is equivalent to the annual food consumption of a small economy of 4 million people



Food Security in China

- As the world's largest food producer and consumer, China has made food security a top priority on its agenda.
- The International conference on Food Loss and waste was hold in Jinan of China on September 9-11, 2021.

Food Security in China

- ➢ It has not only succeeded in feeding 20% of the world population, with only 9% of the world’s arable land, but also eliminated absolute poverty nationwide, an accomplishment that goes down the history.
- ➢ China has a fine tradition of cherishing food and has been exploring approaches to reduce food loss and waste across the value chain.

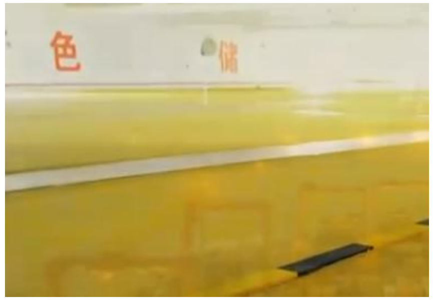
Journey of the Grains

Tillering

Flowering

Harvesting

Drying



Storage

Transportation

Inspection, Processing

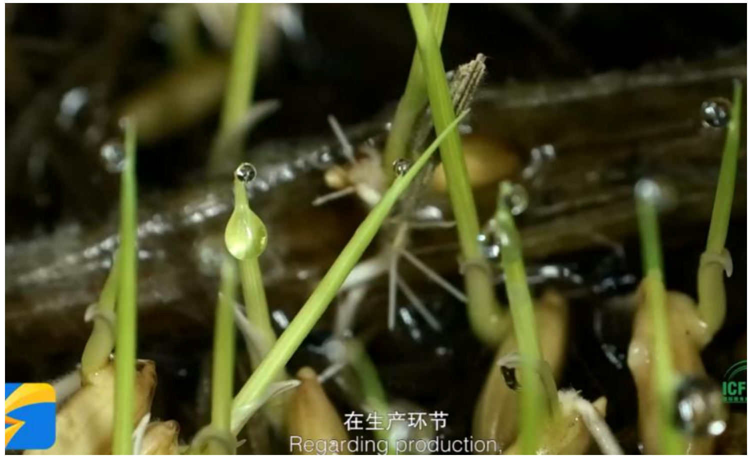
Marketing

Cooking to consumption

Table

This is the journey of the grains we eat every day.

Production



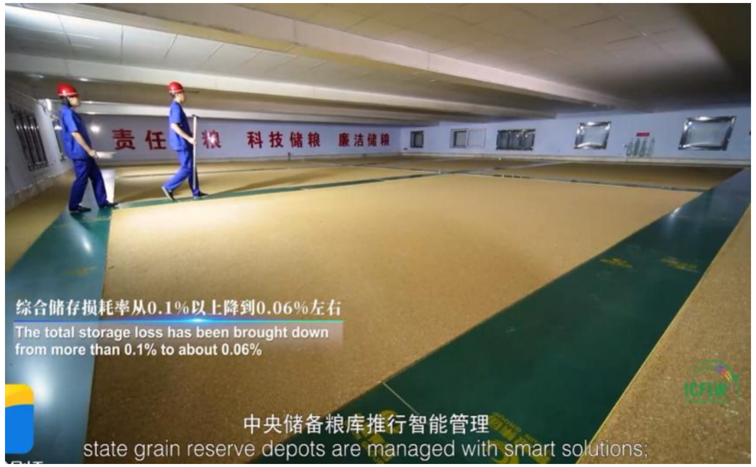
- Regarding production, China's hybrid rice has a record-setting yield as high as 18 tons per hectare.
- High-yield cultivation practices, such as mechanical precision seeding, integrated pest management, and fertigation, have helped improve grain yield and quality.

Harvest

- Digital technologies have enabled faster improvement of production efficiency and farmer’s capabilities.
- Automotive combined harvesters are instrumental in reducing food loss.
- Competitions for combine drivers with least food loss are organized, with remarkable results.

Post-harvest

➤ **At the post-harvest stages**



State grain reserve depots are managed with smart solutions

Large agricultural players mainly use drying silos

Small Farmers widely use improved silos and eco-friendly technologies in grain storage

Food processors and agri-food businesses continue to improve their equipment and techniques effectively reducing food and nutrient loss.

Promote moderate processing

Consumption

- As with food consumption, the government officials take the lead in advocating simplistic, low-carbon, and healthy lifestyles and consumption choices.
- People are encouraged to take individual portions while dining and keep portion sizes in check.

Global Cooperation

- Food loss reduction is a formidable task that requires global cooperation.
- "Reducing food loss and waste for enhanced global food security".
- We look forward to joint efforts of all economies and their wisdom and solutions, for:

  Better production

  Better nutrition

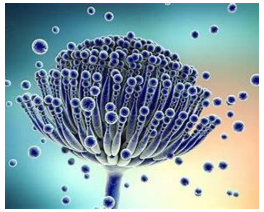
  Better environment

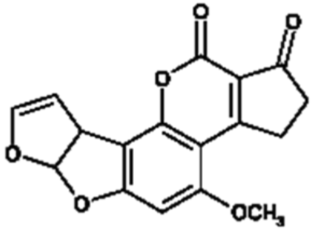
III. R & D of Technology to Reduce Food Loss and Control Mycotoxins

Introduction of Mycotoxins

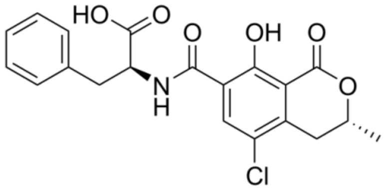
- **Mycotoxin:** It is a kind of toxic secondary metabolites produced by some fungi, such as *Aspergillus* spp., *Fusarium* spp. *Penicillium* spp.

曲 霉
Aspergillus



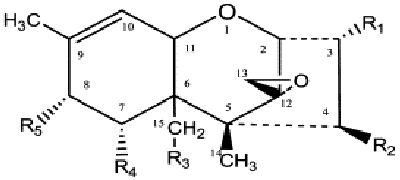


Aflatoxins

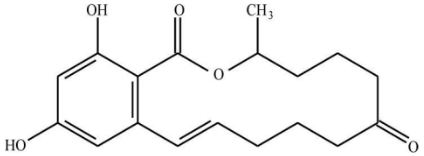


Ochratoxin A

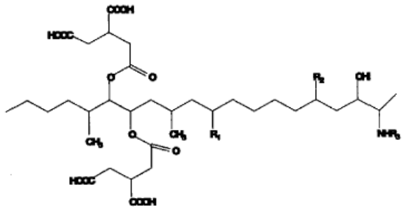
镰刀菌
Fusarium



呕吐毒素
Deoxynivalenol

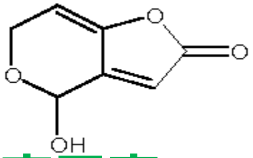


玉米赤霉烯酮
Zearalenone

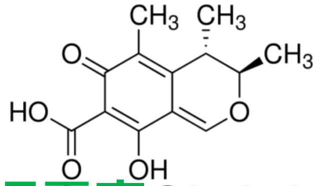


伏马菌素
Fumonisin

青 霉
Penicillium



展青霉素Patulin



橘霉素Citrinin

400+

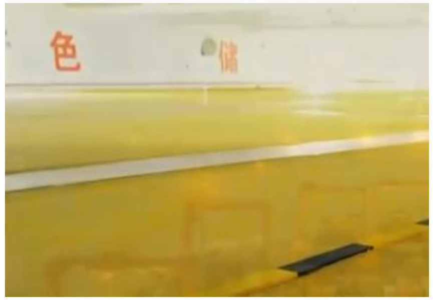
Journey of Grains

Tillering, heading

flowering, milk development

harvesting

drying



Storage

Fugal diseases→reduced grain yield, decreased quality

Fugal infection→Grain loss、Quality deterioration

Transportation

Inspection, processing

marketing

Cooking to consumption

Table

Fungi and mycotoxins contamination can occur ta multiple stages.

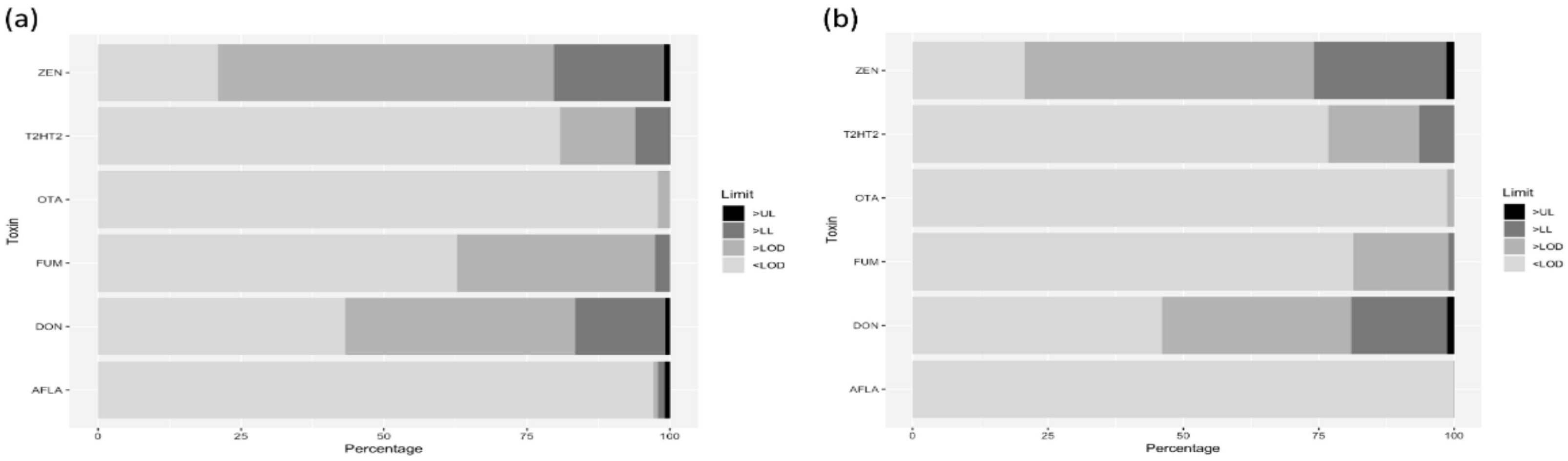
Controlling fungi and toxins is the key to reducing losses.

Mycotoxins threaten food security in world

In 1985, FAO estimated that more than **about 25%** of grains crops were contaminated with mycotoxins

Current mycotoxin occurrence above the EU and Codex limits appears to confirm the FAO 25% estimate （**20%**）, while the occurrence above the detectable levels (**up to 60–80%**)

Rudolf Krska
Crit. Rev. Food Sci. Nutr. 2020, 60: 2773–2789



Mycotoxins threaten food safety

应重视大肝癌的综合治疗

中华医学杂志 2006 年 6 月 27 日

吴孟超

肝癌是威胁人类健康的一大疾患，是一种常见的恶性肿瘤。据统计，世界每年新发肝癌约 25 万余例。在我国城市居民的肝癌死亡率，仅次于肺癌；而农村居民中的肝癌死亡率则居各种癌症首位[1]。病因与肝炎病毒、黄曲霉毒素、环境污染等因素有关。令人遗憾的是肝癌的复发率较高，尤其是大肝

Time to face the fungal threat

Changing crop selection and improving food storage might reduce global rates of liver cancer, says Felicia Wu.

Nature 2014,516（S7)

Moulds that grow naturally on food can produce toxins that have serious effects on health, even causing cancer. Certain moulds — especially those that grow in maize (corn), peanuts and tree nuts such as almonds and pistachios — produce aflatoxin, a carcinogen that is estimated to cause up to 28% of the total worldwide cases of hepatocellular carcinoma (HCC), the most common form of liver cancer. Many people are unaware of the link between naturally occurring food contaminants and cancer. Educa-tion, stricter ... quality controls and ... cultivation of alternative crops can have ...

Aflatoxin is generated by the fungi *Aspergillus flavus* and *Aspergillus parasiticus* and, in addition to liver cancer, it has been associated with acute poisoning ... children. People whose livers are already compromised by infection with hepatitis B virus (HBV) are particularly susceptible to aflatoxin-induced liver cancer.

Studies by my team ... suggest that up to 172,000 cases of HCC per year can be attributed to exposure to aflatoxin in the diet, and most of these individuals are infected with HBV. The majority of cases occur in sub-Saharan Africa, southeast

AFLATOXIN-INDUCED LIVER CANCER

Growing the food is just part of the problem, however: aflatoxin also accumulates in crops after they have been harvested. The fungi that produce aflatoxins thrive in damp conditions, so storage facilities must be kept cool and dry. Pests such as rodents and insects must be controlled because they can transport the fungus to other stored foods. If these tactics fail and the food gets contaminated, it can still be salvaged: clays or chlorophyllin (chlorophyll-derived compounds) can be added to the food, either before or after distribution to consumers, to temporarily sequester aflatoxin in the gastrointestinal tract ... foods that are contaminated with aflatoxin. Dietary changes in Qidong, China, show just how effective this can be. Market reforms introduced in the 1980s ... and less maize. Decreased maize consumption (from around 10 ... kilograms per person in the 1970s to almost none ...) resulted in lower exposure ... a 45% decrease in liver-cancer mortality. This effect is independent of China's HBV vaccination programme, which began in 2002.

Qidong provides evidence that introducing dietary diversity can reduce the effects of

Up to 28% of hepatocellular carcinomas are caused by aflatoxin in worldwide

Mycotoxins: The most dangerous food contaminants that occur naturally

AFB_1 toxicity: 10 times that of potassium cyanide, 68 times that of arsenic

Aflatoxins: The strongest naturally occurring chemical carcinogen, one of the leading causes of liver cancer

Aflatoxin pollution seriously threatens food safety and human health

Known Symptoms of Major Mycotoxin Poisoning

	Mycotoxin	Contaminated food	Producing Fungi	Main symptoms and lesions
1	AFs	Peanuts, nuts, grains and by-products, soybeans, beans, etc.	*Aspergillus flavus, A. parasitics*	Liver cancer, acute poisoning, animal abortion
2	DON	Wheat, corn grains and their products	*Fusarium graminearum, F. oxysporum, F. moniliforme, F. cladosporium, F. roseum, F. nivale*	Acute poisoning symptoms such as anorexia, vomiting, diarrhea, fever, unstable standing, slow reaction, etc.
3	ZEN	Grains such as corn, wheat, rice, barley, millet and oats	*F. graminearum*, *F. oxysporum*	Estrogen action, reproductive system, animals produce estrogen hyperactivity, which can cause abortion, stillbirth and malformation
4	FUM	Corn and its products, occasionally in sorghum, soybeans and peas	*F. moniliforme* and *F. oxysporum*	Carcinogenic, associated with esophageal cancer; damage to liver and kidney function; equine leukomalacia and porcine pulmonary edema
5	OTA	Wheat, cereals, coffee, wine, animal food, kidney, liver	*Penicillium viridicatum*, *A. ochraceus*, *A. carbonarius, A. niger*	Nephrotoxicity, hepatotoxicity, teratogenicity, carcinogenicity, mutagenicity and immunosuppression
6	T-2	Cereals and by-products	*F. tricinctum*	Tissues and organs with vigorous cell division, such as thymus, bone marrow, liver, spleen, lymph nodes, gonads and gastrointestinal mucosa, etc.
7	PUT	Apples and other fruits, apple juice, silage	*Penicillium*, etc. *A. gigantic*, *A. terreus*, etc.	Nausea, vomiting; teratogenicity, damage to the respiratory and urinary systems, resulting in nerve paralysis, pulmonary edema, and renal failure
8	Citrinin	Fruits, vegetables, etc.	*Monascus*	Nephrotoxicity and genotoxicity
9	Ergosterol	All food and feed	Fungal cell wall components Ergot base, ergot alkaloid, ergot amine, ergot alkali	Ergot poisoning Numbness, spasm, gangrene, etc.
10	Alternaria phenols	Fruits, vegetables, cereals, etc.	Alternaria: Alternaria methyl ether, Alternaria ketoacid, Alternaria, Alternaria toxin and AAL toxin	Chickens: chronic or acute toxic effects such as loss of appetite, lethargy, diarrhea, muscle weakness and coma, mutagenicity, carcinogenicity and teratogenicity

Mycotoxin Contamination Poisoning Incident

1960

100,000 turkeys dies in the UK, AFs contaminated peanut meal

1974

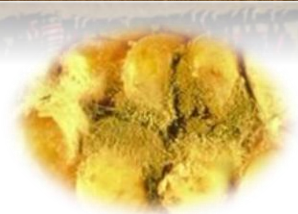
397 cases and 106 deaths of toxic hepatitis in India, AFs contaminated corn

1991

130,000 people in Anhui were acutely poisoned, DON contaminated wheat

2004

125 people died in Kenya, AFs contaminated corn



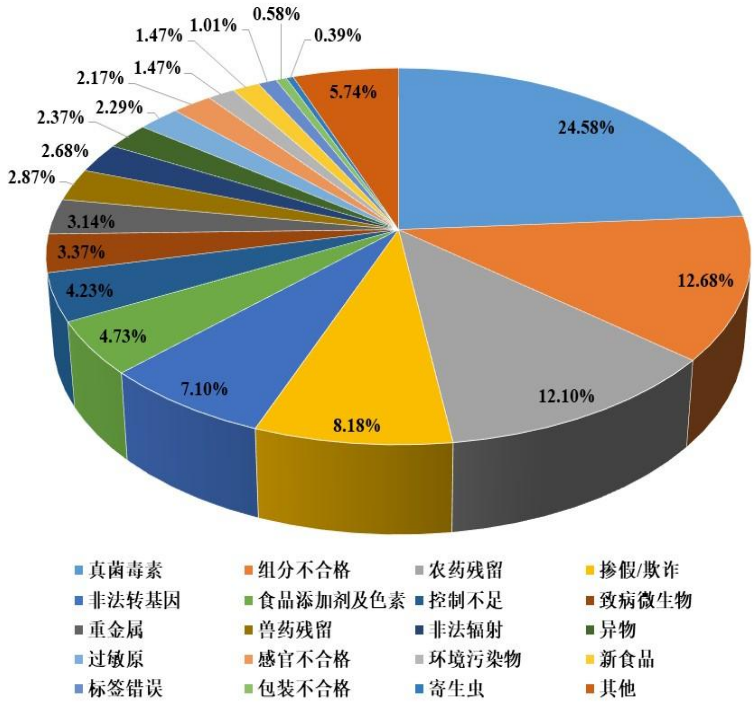
2011

The milk of two companies, AFM_1 exceeds the standard

Prevention and control of mycotoxin contamination is an important need to ensure food safety in all economies

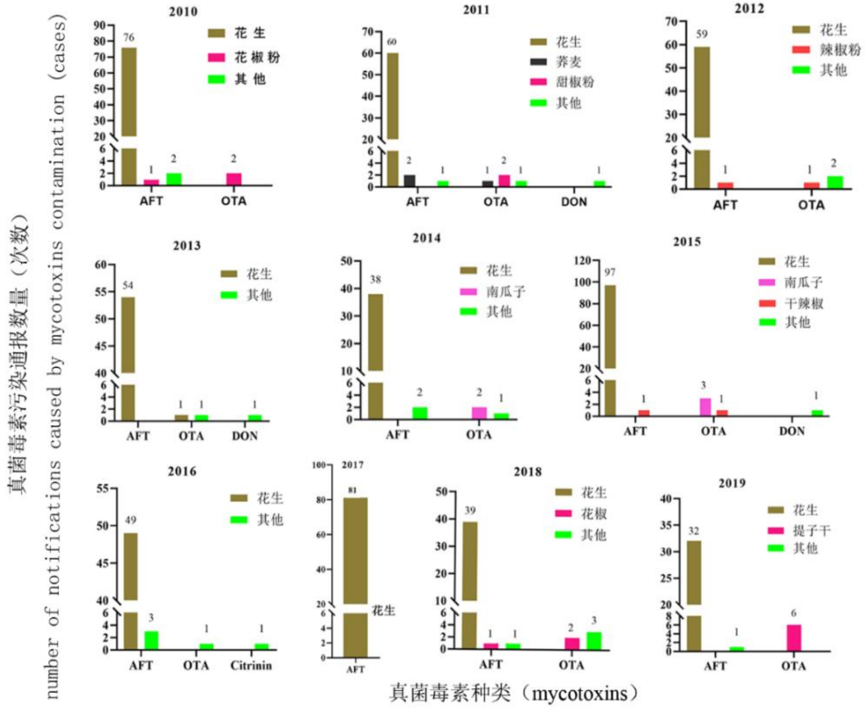
Aflatoxins restricts China's foreign trade

Mycotoxins exceeded the standard 24.58%



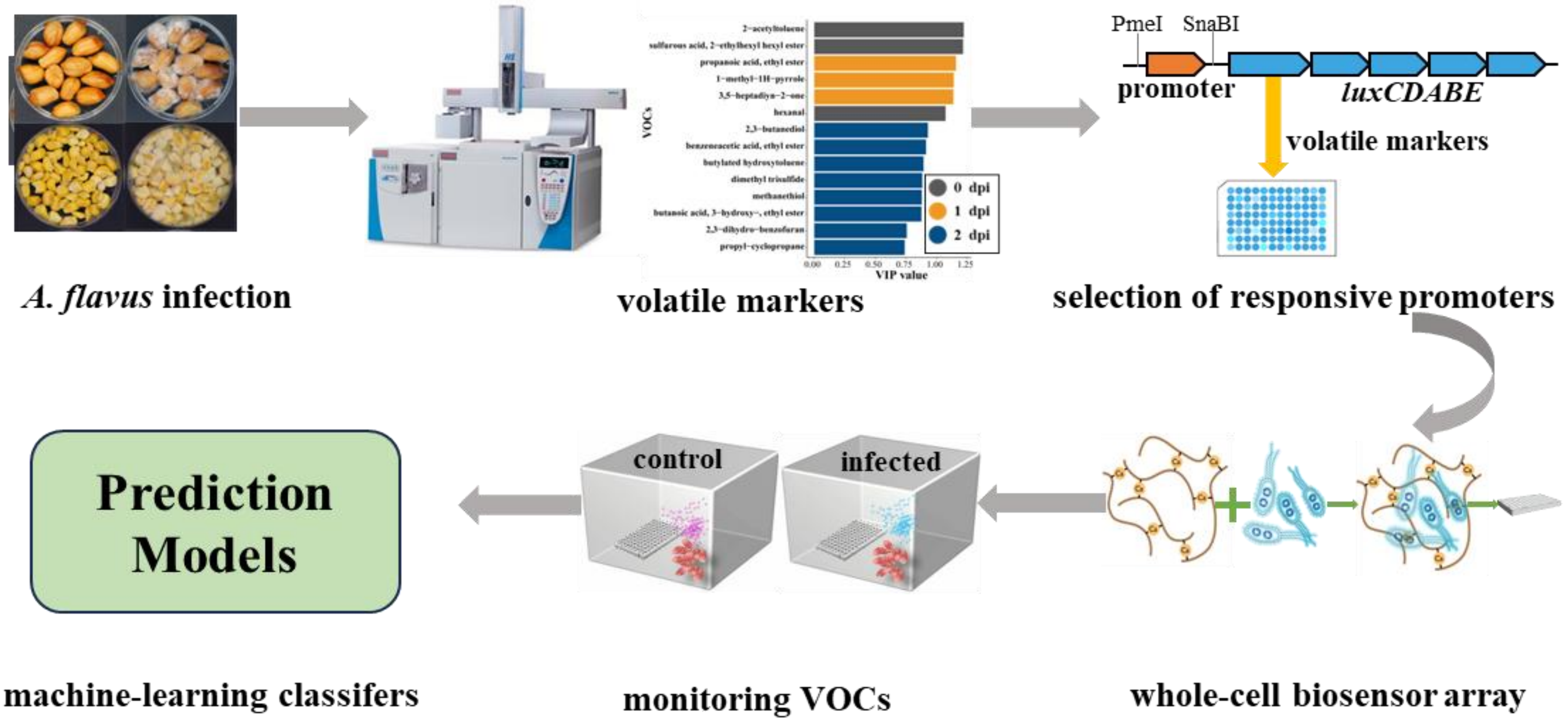
Hazard categories of EU RASFF notify cation on China exported food in 2010-2019

AFs account for 94.8%



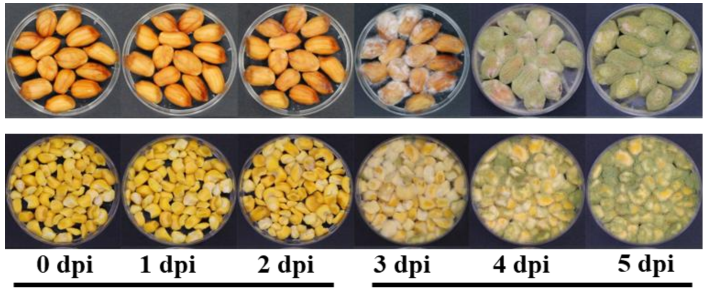
Mycotoxins and product categories of EU RASFF notification on China exported food in 2010-2019

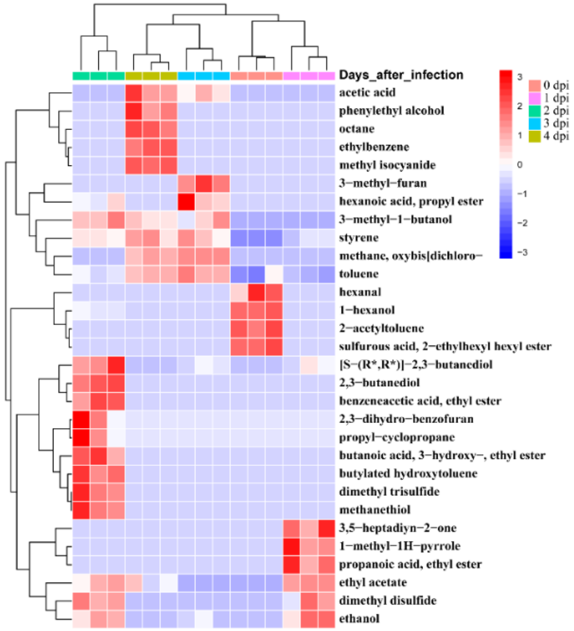
3.1 Monitoring Fungal Occurrence in Maize and Peanuts Using a Whole-Cell Biosensor Array and Machine Learning Prediction Models



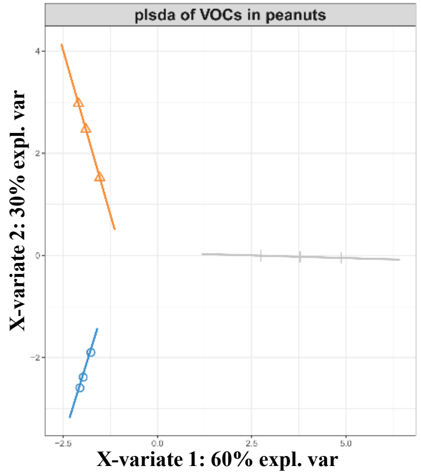
3.1 Monitoring Fungal Occurrence in Maize and Peanuts Using a Whole-Cell Biosensor Array and Machine Learning Prediction Models

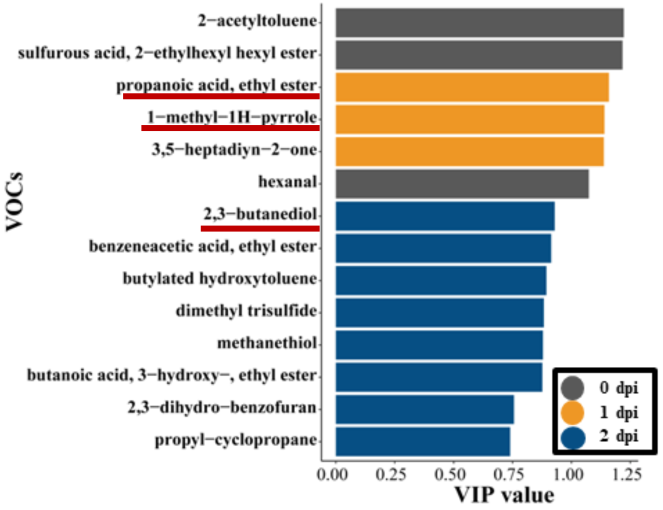
(1) GC-MS identified VOCs from peanuts infected by *A. flavus* were identified using GC-MS





Hierarchical cluster analysis of 30 VOCs



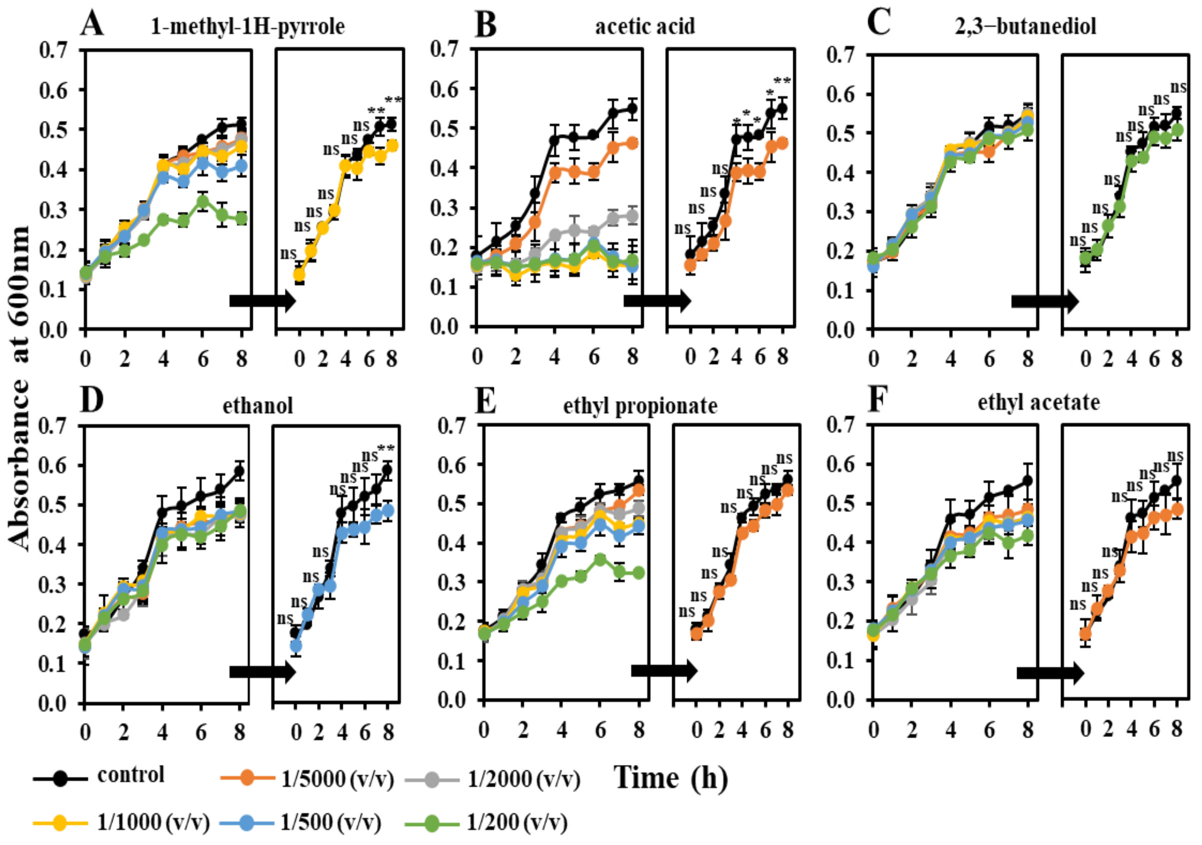


PLS-DA analysis followed by VIP ranking

- GC-MS analysis identified 30 VOCs in peanuts infected by *A. flavus*.
- PLS-DA analysis followed by VIP ranking identified three specific VOCs (1-methyl-1H-pyrrole, 2,3-butanediol, ethyl propionate) in the pre-mold stages of peanuts.
- A literature search revealed commonly occurring VOCs (acetic acid, ethanol, ethyl acetate) after *A. flavus* infection.

3.1 Monitoring Fungal Occurrence in Maize and Peanuts Using a Whole-Cell Biosensor Array and Machine Learning Prediction Models

(2) Subinhibitory concentrations of 6 volatile markers against *E. coli* DH5α



- **Subinhibitory concentrations of 6 VOCs:**

  A: Elevated concentrations led to early and strong inhibition for 1-methyl-1H-pyrrole, acetic acid, and ethanol.

  B: Even at maximum concentrations, 2,3-butanediol did not inhibit.

  C: At the lowest concentration, there was no inhibition, but increasing concentrations significantly inhibited ethyl propionate and ethyl acetate

- **Subinhibitory concentrations were: 1/1000、1/5000、1/200、1/500、1/5000、1/5000**

3.1 Monitoring Fungal Occurrence in Maize and Peanuts Using a Whole-Cell Biosensor Array and Machine Learning Prediction Models

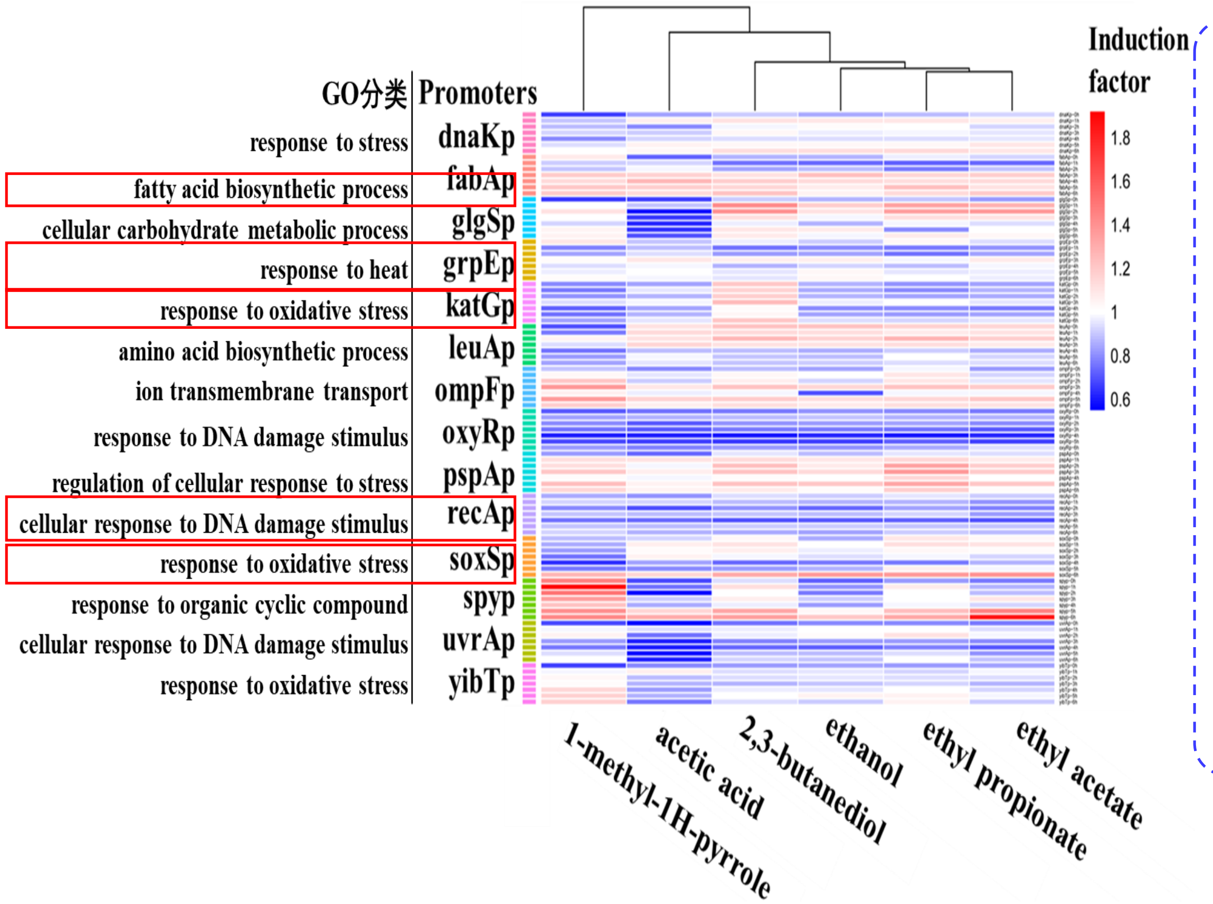
(3) Selection of 14 promoters

Promoters	GO category
dnaKp	response to stress, cellular response to stimulus
fabAp	response to acidic stress
glgSp	cellular carbohydrate metabolic process
grpEp	response to heat
katGp	response to oxidative stress
leuAp	amino acid biosynthetic process
ompFp	ion transmembrane transport
oxyRp	response to DNA damage stimulus; response to oxidative stress
pspAp	regulation of cellular response to stress
recAp	cellular response to DNA damage stimulus
soxSp	response to oxidative stress
spyp	response to organic cyclic compound
uvrAp	cellular response to DNA damage stimulus
yibTp	-

- **9 promoters were identified from the study of potato soft rot monitoring**
- **5 additional stress-responsive promoters were selected based on literature research**

3.1 Monitoring Fungal Occurrence in Maize and Peanuts Using a Whole-Cell Biosensor Array and Machine Learning Prediction Models

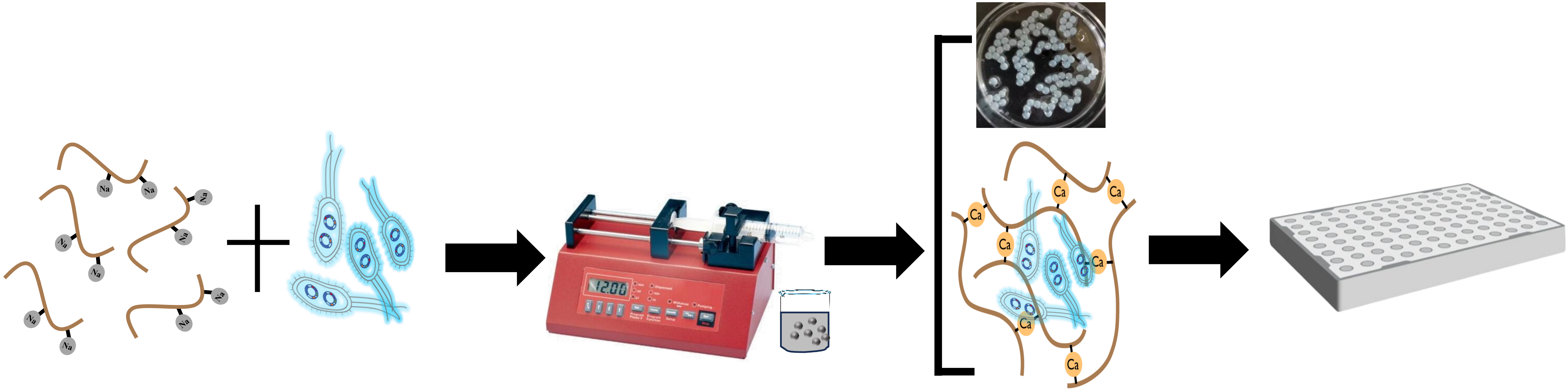
(2) The response of 14 stress-related promoters to 6 VOCs



- **Ethyl propionate and ethyl acetate exhibit similar patterns, upregulating *spyP, pspAp, glgSp, fabAp, leuAp*, and *ompFp*.**
- **The highest difference is observed with 1-methyl-1H-pyrrole, followed by acetic acid, which upregulates *spyp, mopFp, pspAp, yibTp*, and *glgSp*.**
- **The 14 promoters exhibit distinct response patterns to 6 VOCs, all of which can be used as sensing elements to construct a sensor array.**

3.1 Monitoring Fungal Occurrence in Maize and Peanuts Using a Whole-Cell Biosensor Array and Machine Learning Prediction Models

(3) Immobilization of *E. coli* reporter strains in calcium alginate microbeads



Sodium alginate

***E. coli* reporter strains**

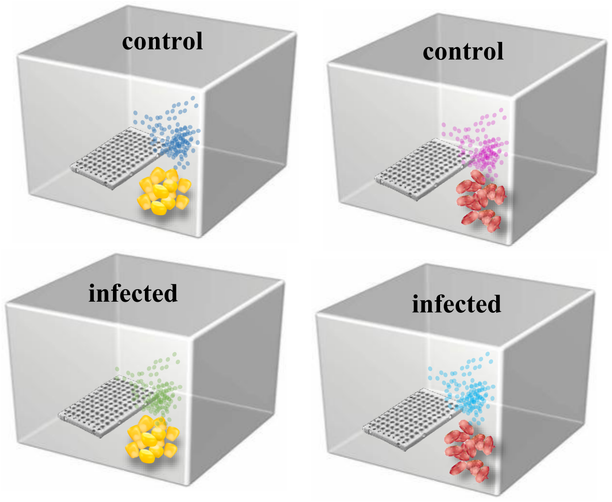
syringe pump

***E. coli* reporter strains immobilized in calcium alginate microbeads**

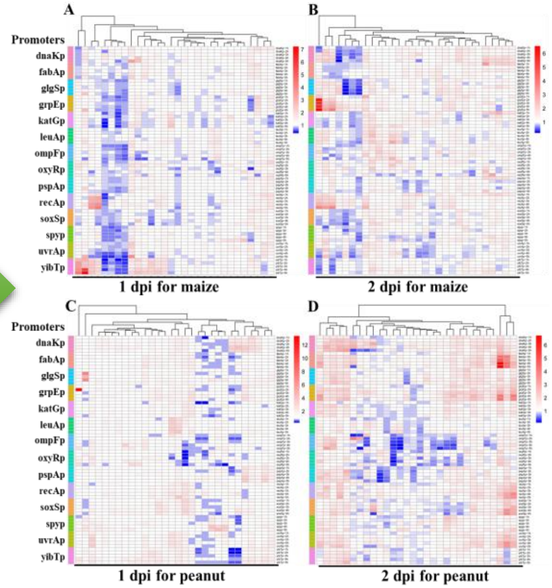
Plating on 96-well plate to fabricate whole-cell biosensor array

3.1 Monitoring Fungal Occurrence in Maize and Peanuts Using a Whole-Cell Biosensor Array and Machine Learning Prediction Models

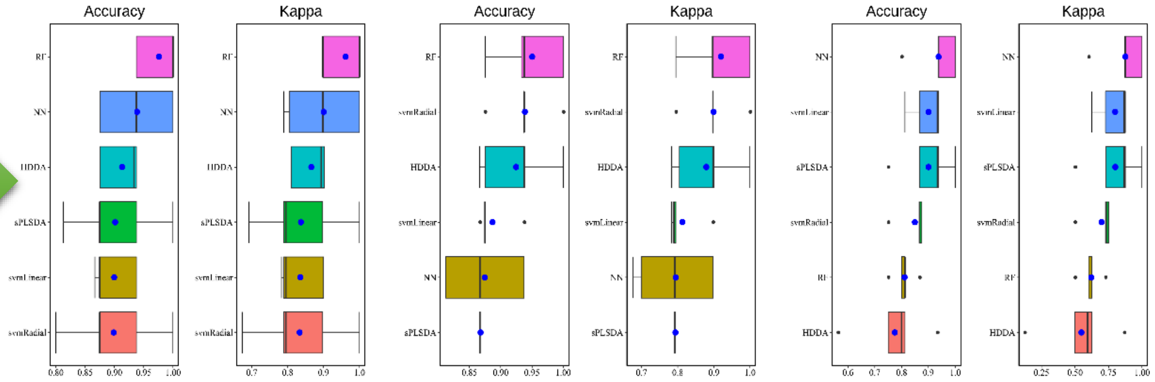
（4）Constructing machine-learning prediction models



Monitoring organic volatile compounds from moldy samples



Respone patterns



Pre-moldy maize VS control

97.5%

Pre-moldy peanuts VS control

97.5%

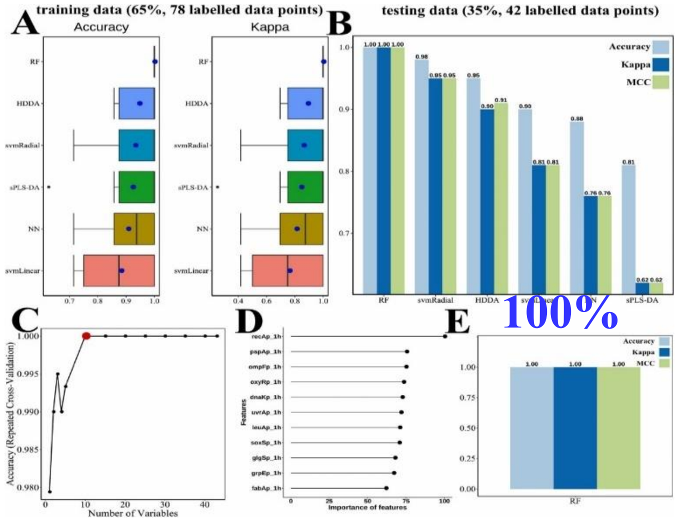
Moldy peanuts VS moldy maize

92.8%

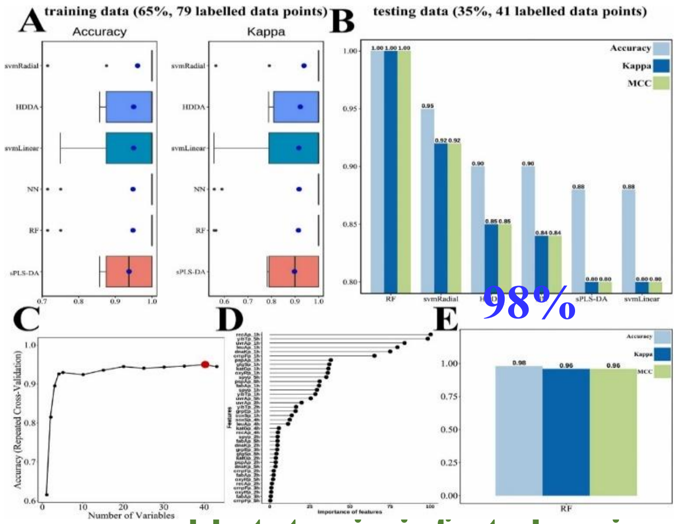
Comparing and optimizing six machine learning models

- A whole-cell biosensor array produced varying response patterns, where 72% showed induction factor between 1 and 2, and 2.5% had induction factor exceeding 2, possibly due to synergistic effects.
- Six machine learning models were compared and optimized to classify different response patterns, achieving high accuracy of 97.5% for early-stage aflatoxin-infected peanuts and corn, and 92.8% for distinguishing between aflatoxin-infected peanuts and corn, demonstrating strong predictive performance.

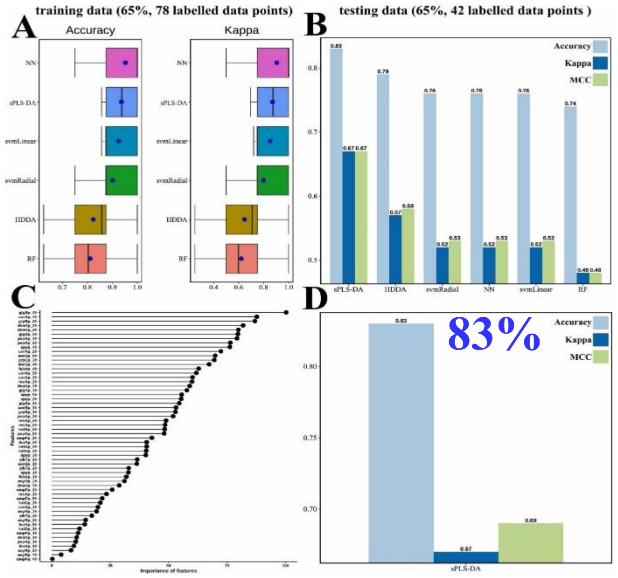
3.1 Monitoring Fungal Occurrence in Maize and Peanuts Using a Whole-Cell Biosensor Array and Machine Learning Prediction Models



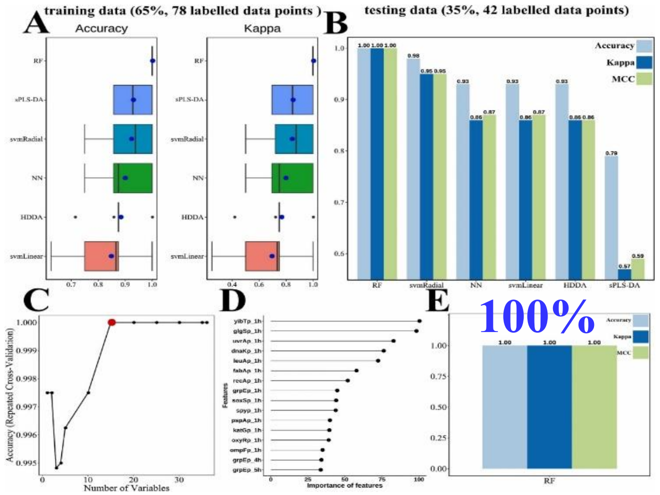
healthy from infected maize



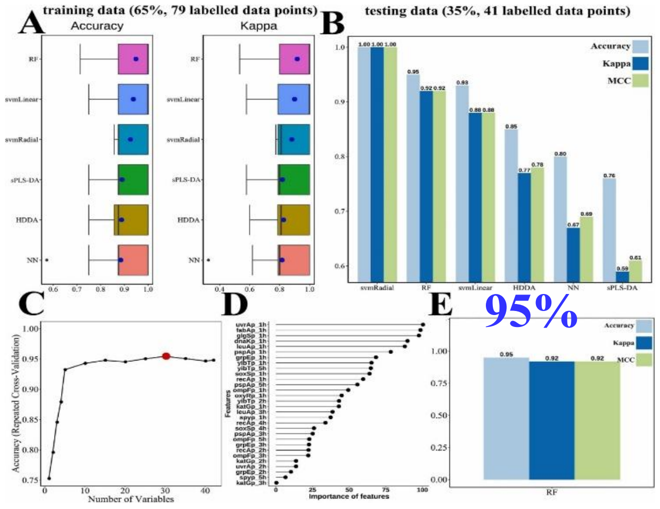
pre-mold status in infected maize



between infected peanuts and maize



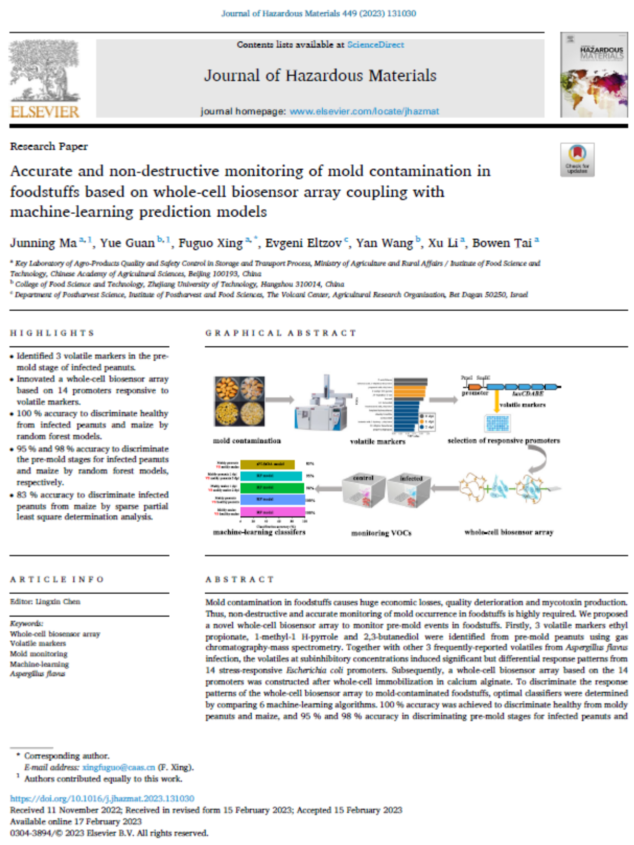
healthy from infected peanuts



pre-mold status in infected peanuts

3.1 Monitoring Mold Occurrence in Maize and Peanuts Using a Whole-Cell Biosensor Array and Machine Learning Prediction Models

- **Identified three early-stage organic volatiles in moldy peanuts via GC-MS: 1-methyl-1H-pyrrole, 2,3-butanediol, ethyl propionate;**
- **Determined subinhibitory concentrations of 6 VOCs on *E. coli* and unveiled diverse response patterns of 14 stress-responsive promoters in a liquid state;**
- **Created a whole-cell biosensor array using calcium alginate microspheres for monitoring moldy states in volatile headspace conditions;**
- **Optimized six machine learning models and developed a web app for deploying these models, enabling non-destructive, highly accurate monitoring and early warning of moldy grain and oil food products.**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Research Paper

Accurate and non-destructive monitoring of mold contamination in foodstuffs based on whole-cell biosensor array coupling with machine-learning prediction models

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[c] Department of Postharvest Science, Institute of Postharvest and Food Sciences, The Volcani Center, Agricultural Research Organization, Bet Dagan 50250, Israel

HIGHLIGHTS

- Identified 3 volatile markers in the pre-mold stage of infected peanuts.
- Innovated a whole-cell biosensor array based on 14 promoters responsive to volatile markers.
- 100 % accuracy to discriminate healthy from infected peanuts and maize by random forest models.
- 95 % and 98 % accuracy to discriminate the pre-mold stages for infected peanuts and maize by random forest models, respectively.
- 83 % accuracy to discriminate infected peanuts from maize by sparse partial least square determination analysis.

GRAPHICAL ABSTRACT

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Volatile markers
Mold monitoring
Machine-learning
Aspergillus flavus

ABSTRACT

Mold contamination in foodstuffs causes huge economic losses, quality deterioration and mycotoxin production. Thus, non-destructive and accurate monitoring of mold occurrence in foodstuffs is highly required. We proposed a novel whole-cell biosensor array to monitor pre-mold events in foodstuffs. Firstly, 3 volatile markers ethyl propionate, 1-methyl-1 H-pyrrole and 2,3-butanediol were identified from pre-mold peanuts using gas chromatography-mass spectrometry. Together with other 3 frequently-reported volatiles from *Aspergillus flavus* infection, the volatiles at subinhibitory concentrations induced significant but differential response patterns from 14 stress-responsive *Escherichia coli* promoters. Subsequently, a whole-cell biosensor array based on the 14 promoters was constructed after whole-cell immobilization in calcium alginate. To discriminate the response patterns of the whole-cell biosensor array to mold-contaminated foodstuffs, optimal classifiers were determined by comparing 6 machine-learning algorithms. 100 % accuracy was achieved to discriminate healthy from moldy peanuts and maize, and 95 % and 98 % accuracy in discriminating pre-mold stages for infected peanuts and

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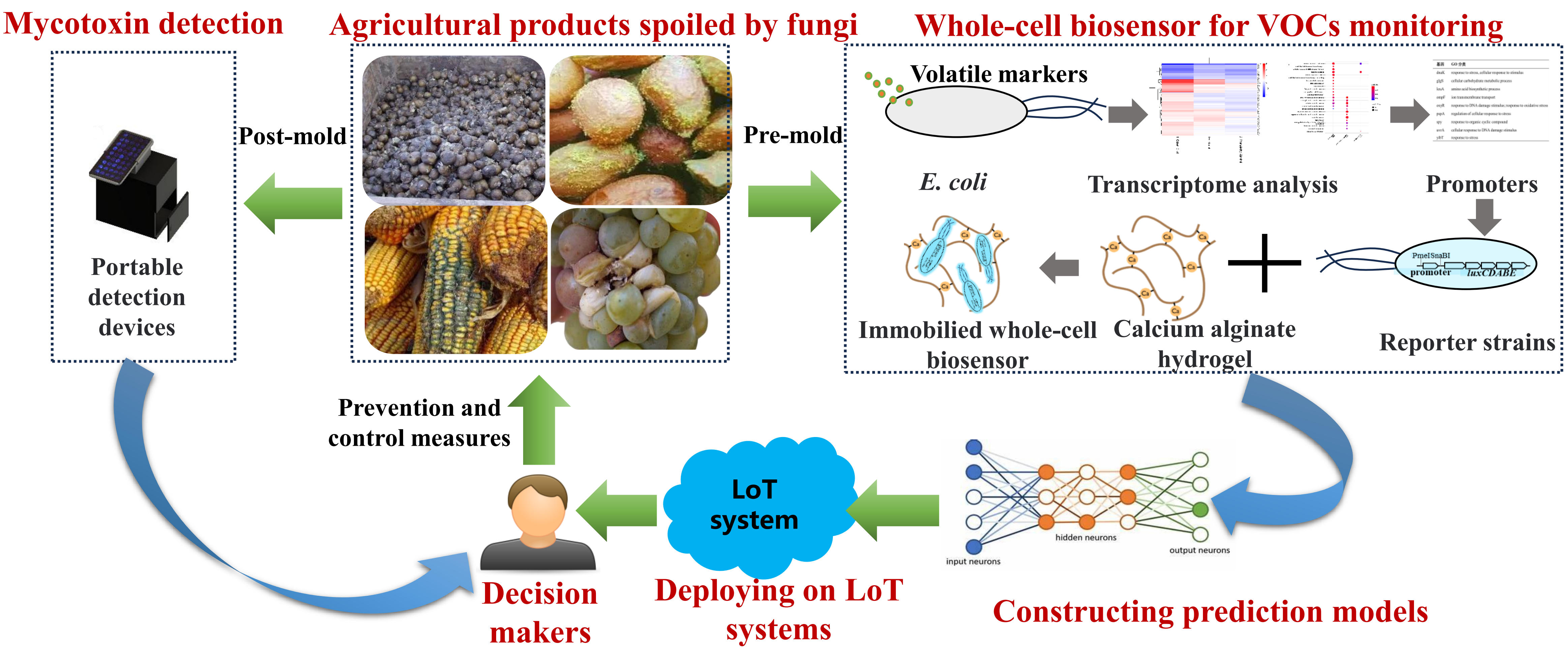
Conclusions and Perspectives

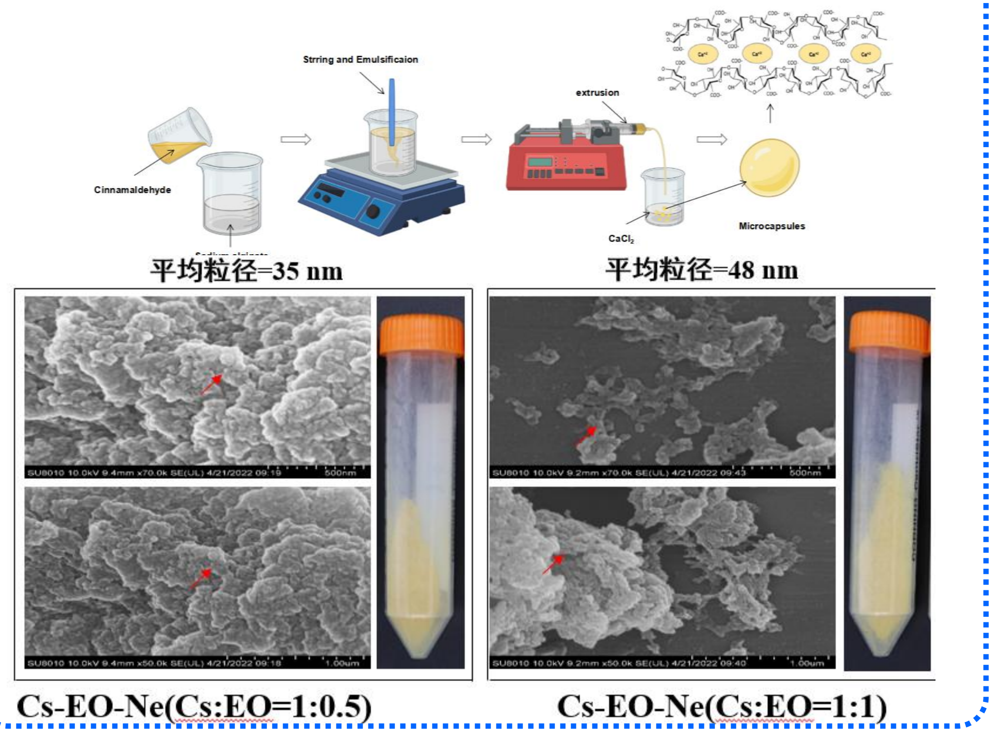


Online Monitoring and Early Warning Technology for Agricultural Product Mold and Rot

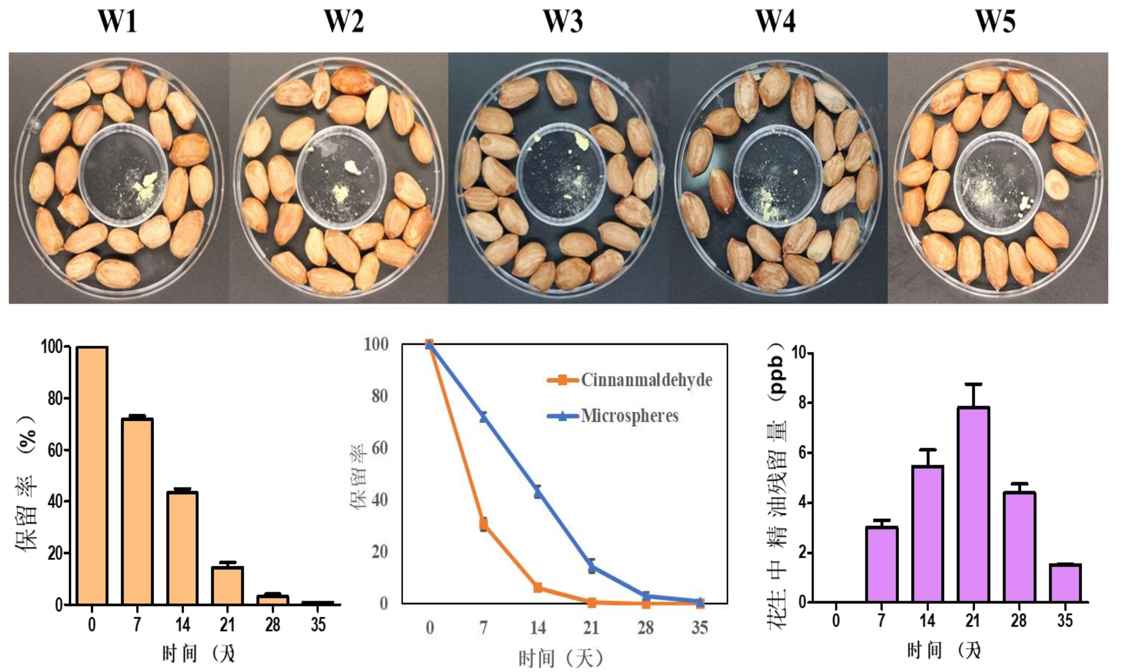
3.2 Green anti-mildew agent for grain storage

(1) Excavate green prevention and control resources such as plant extracts and microbial active components: Cinnamaldehyde, eugenol, citral, methyl jasmonate, etc.

(2) Research and development of new grain storage reagents by integrating nano-microsphere loading, base film cross-linking and ultra-micro-particle atomization fumigation, etc.

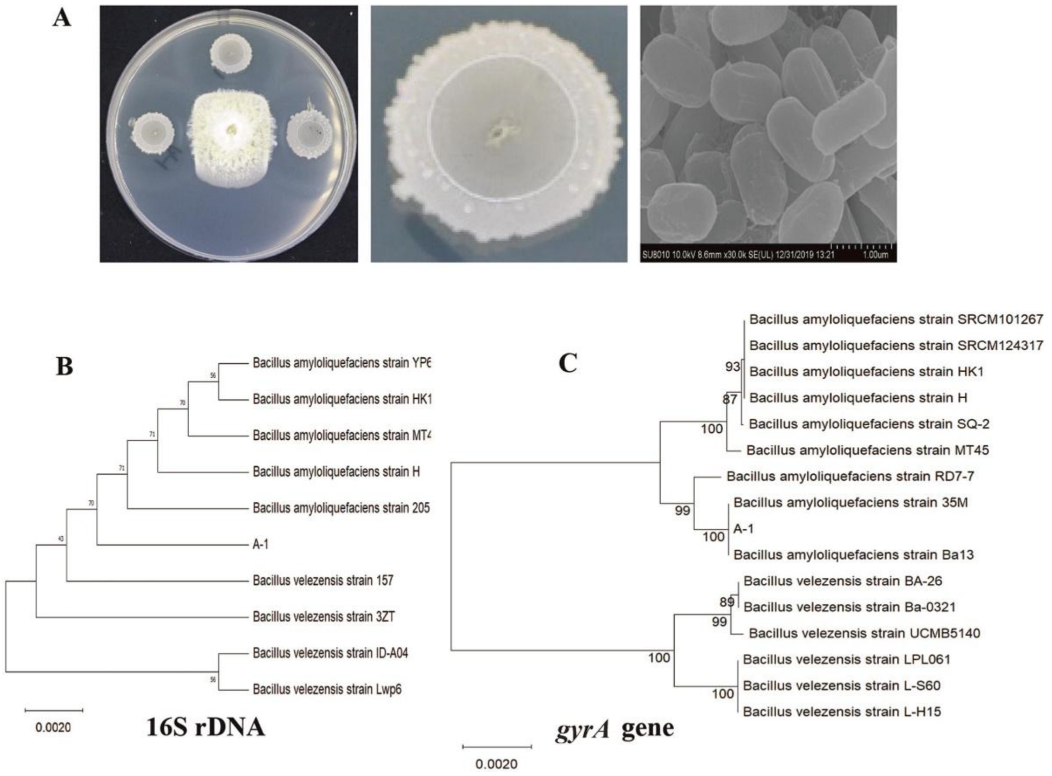


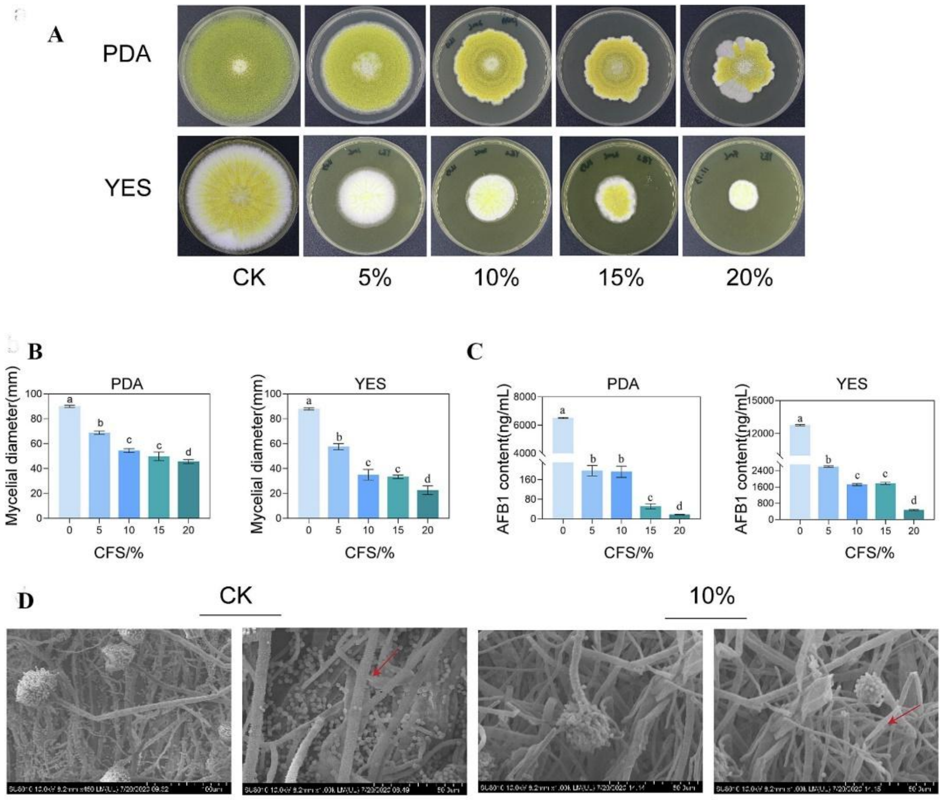
Plant essential oil treatment reduces the occurrence of corn mold



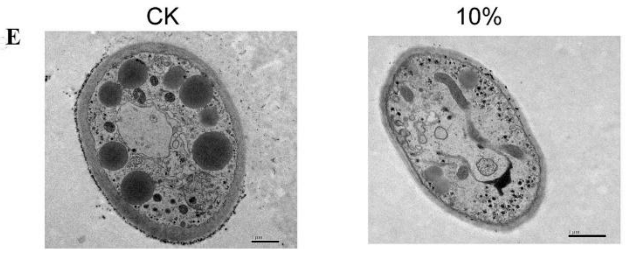
Plant essential oil treatment reduces the occurrence of *Aspergillus flavus*

3.3 *B. amyloliquefaciens* A-1 inhibiting fungal spoilage

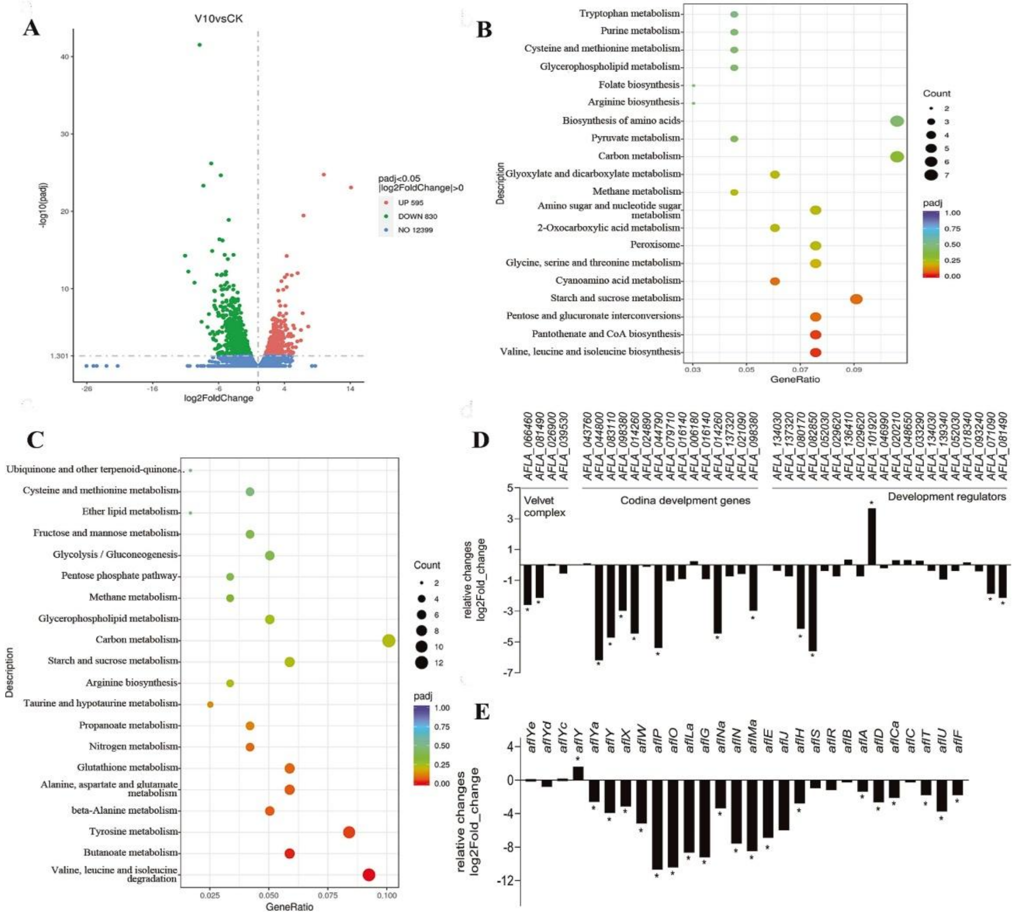


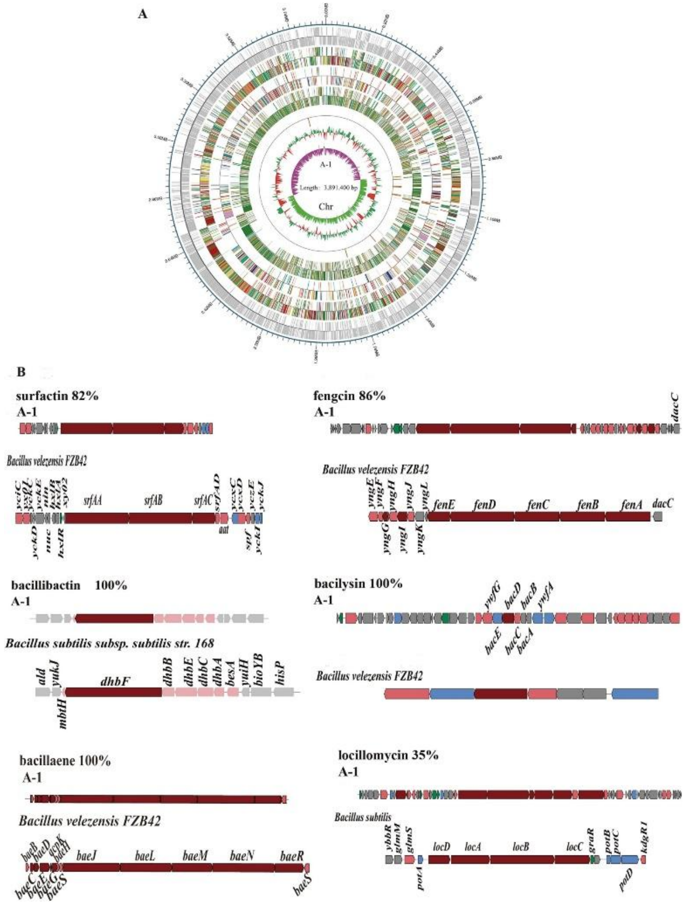


- ✓ CFS of A-1 can effectively inhibit fungal growth and AFB_1 production
- ✓ The cell wall and membrane structure were destroyed, the pores are in conidia and mycelium are twisted



3.3 *B. amyloliquefaciens* A-1 inhibiting fungal spoilage

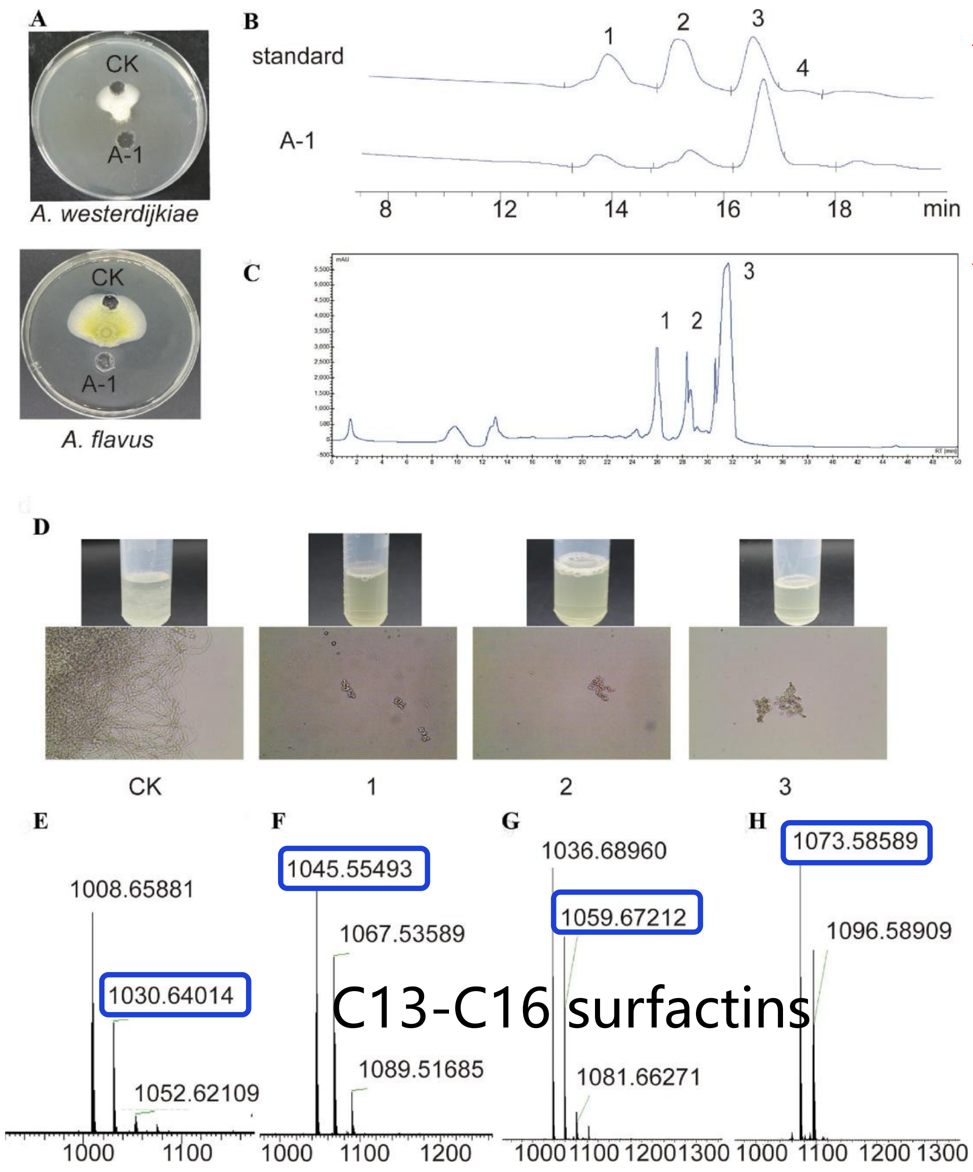




- ✓ Genes in biosynthesis of amino acid, pentose phosphate and CoA were up-regulated
- ✓ Genes in Velvet、conidia development, and mycotoxins synthesis were down-regulated

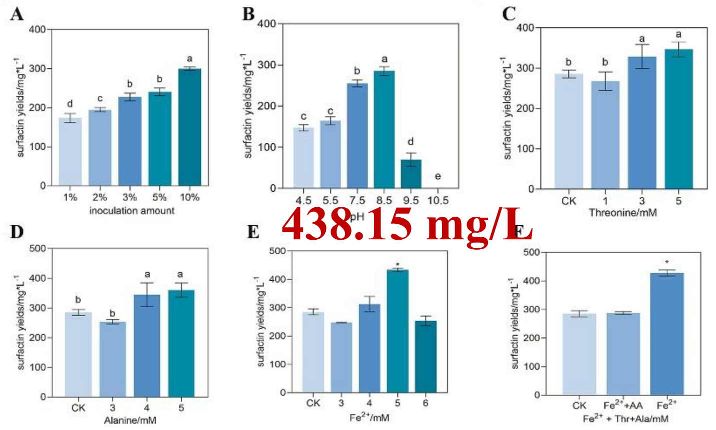
- ✓ By Genome sequencing and antiSMASH analysis, 6 secondary metabolites gene clusters were identified

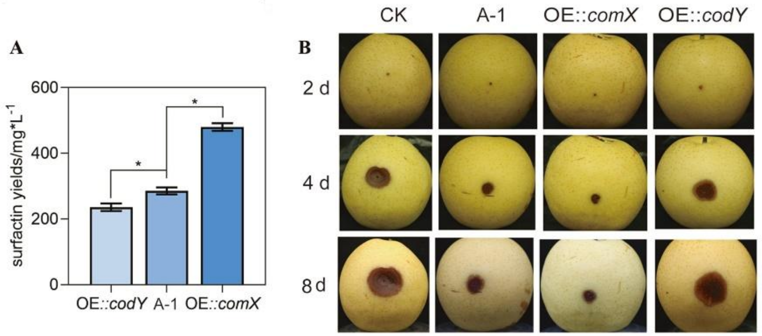
3.3 *B. amyloliquefaciens* A-1 inhibiting fungal spoilage



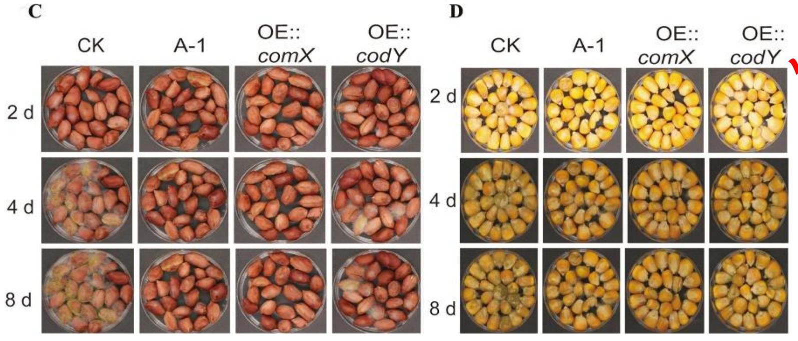
C13-C16 surfactins

- ✓ Alanine, threonine and Fe^{2+} increased surfactins production
- ✓ Optimal: inoculation account 10%、pH8.5、5mM Fe^{2+}





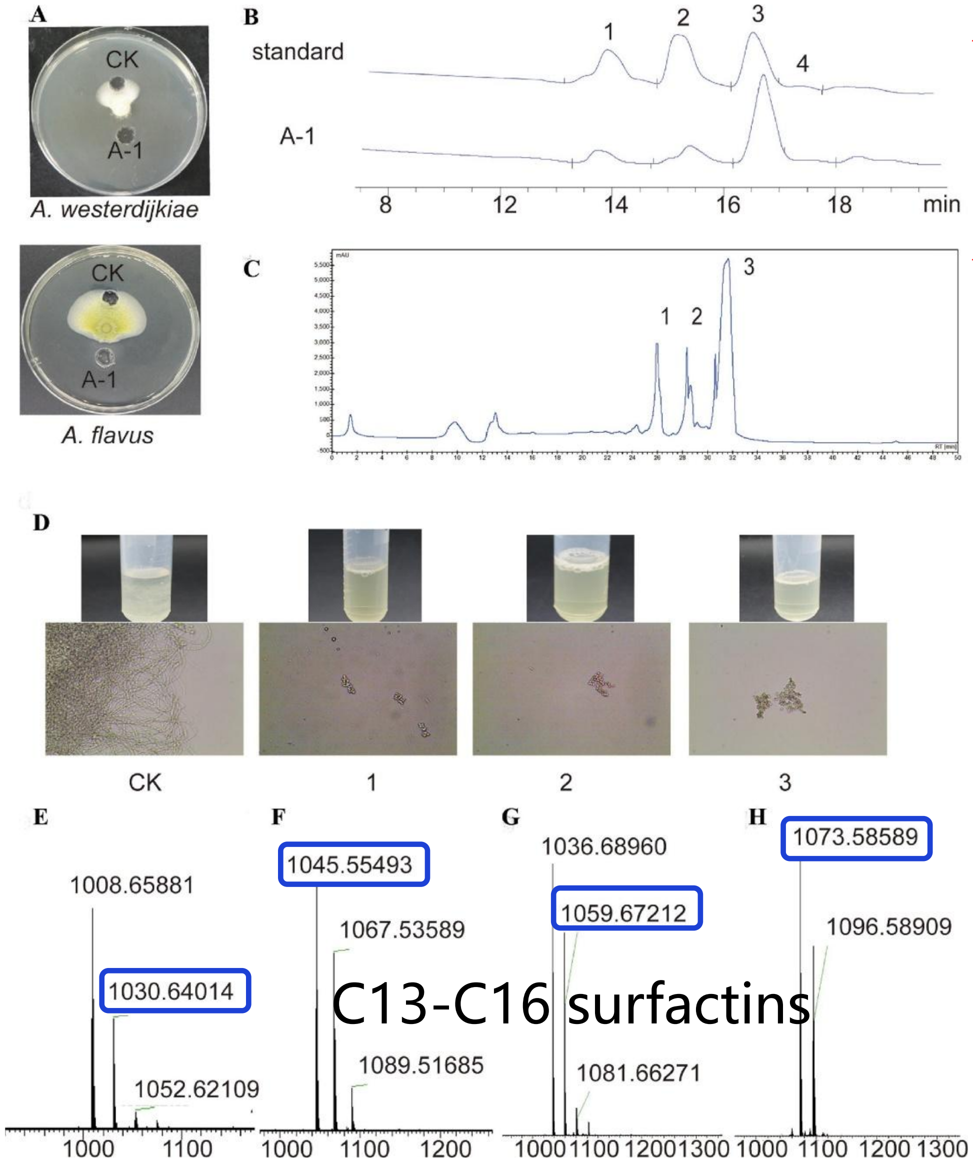
- ✓ Overexpression of *ComX* increased surfactin production with 80%, enhancing inhibition



- ✓ Overexpression of CodY decreased surfactin production, reducing inhibition

Hu YF, et al., Food Res Int, 2024; 发明专利：ZL202111274954.8

3.3 *B. amyloliquefaciens* A-1 inhibiting fungal spoilage



- ✓ Alanine, threonine and Fe^{2+} increased surfactins production
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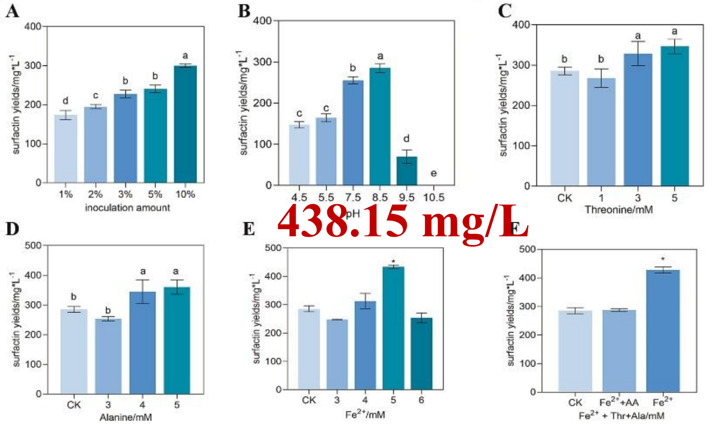
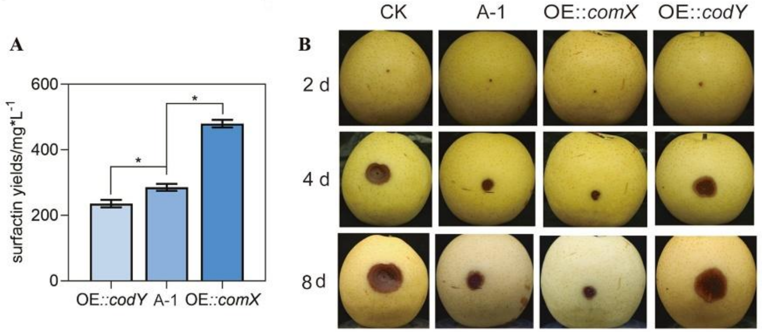
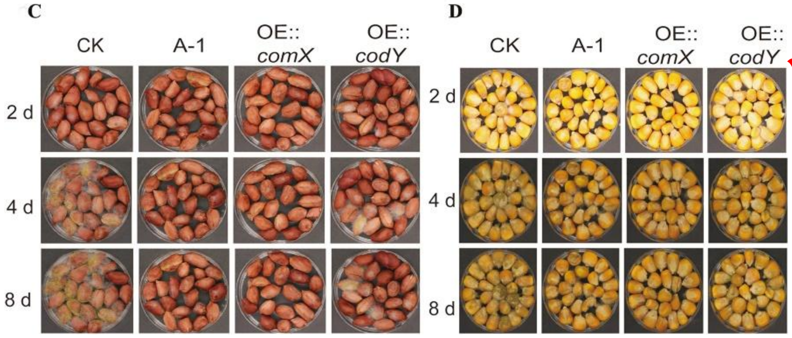




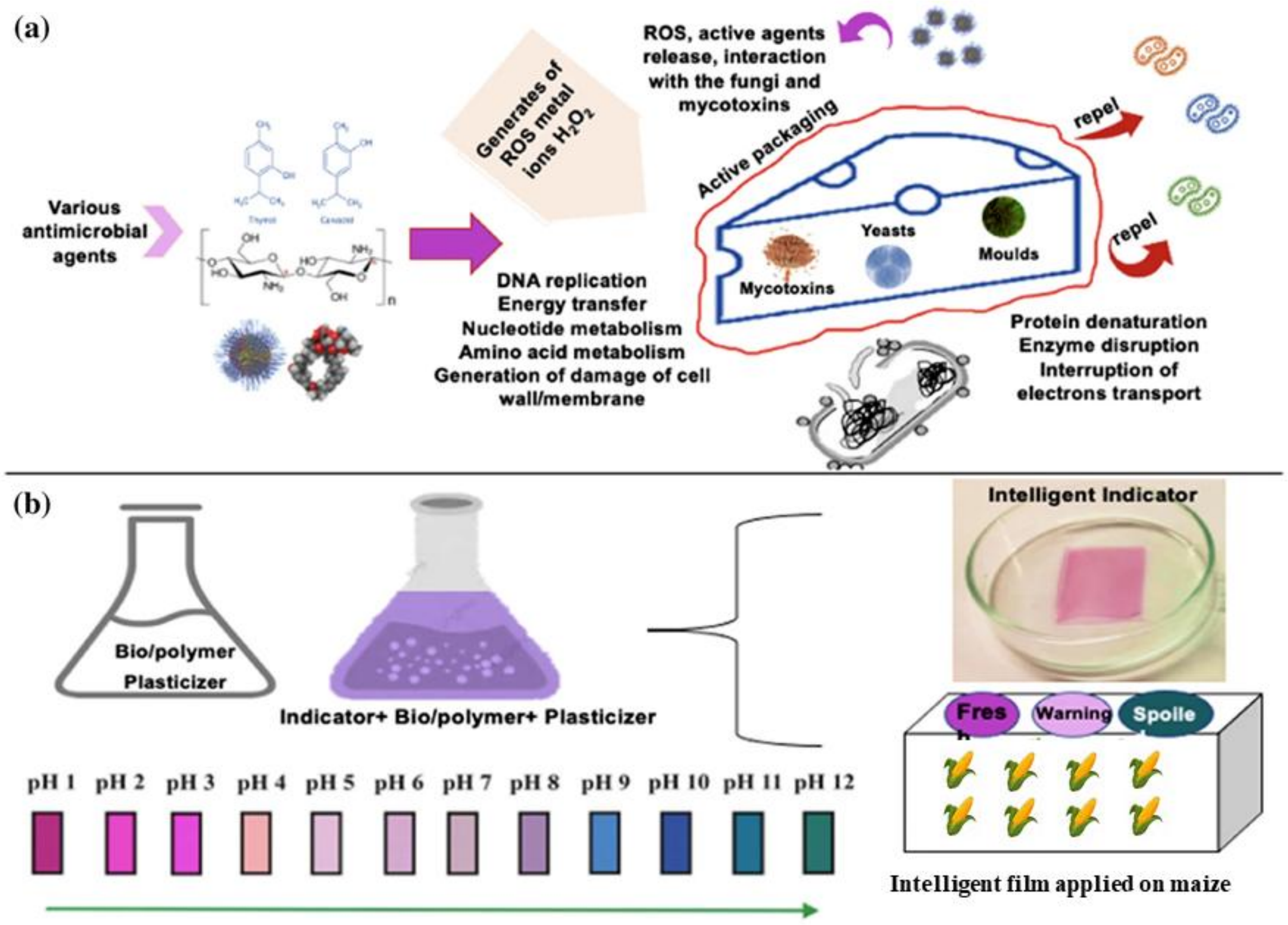
- ✓ Overexpression of *ComX* increased surfactin production with 80% , enhancing inhibition
- ✓ Overexpression of CodY decreased surfactin production, reducing inhibition



Hu YF, et al., Food Res Int, 2024; 发明专利：ZL202111274954.8

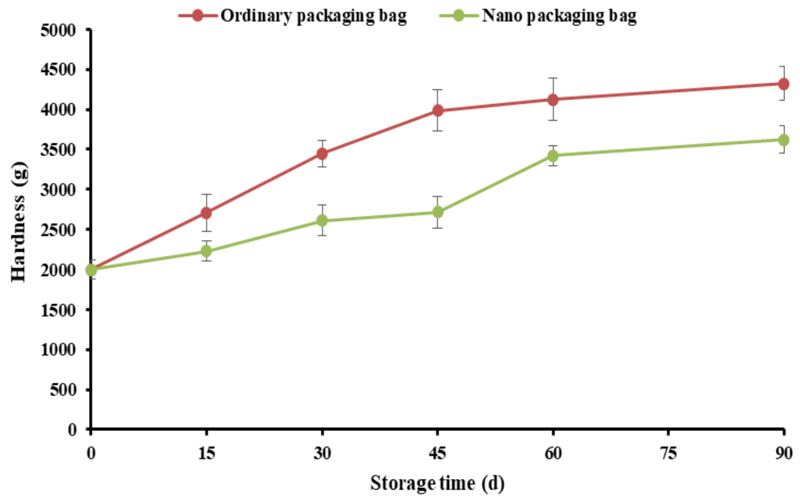
3.4 Green anti-mildew packaging material for grain storage

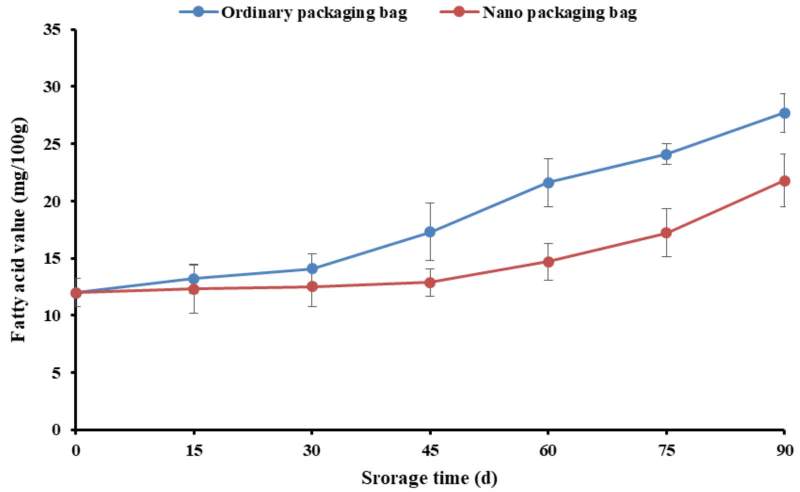
- The application of nanomaterials in grain packaging mainly includes improving the mechanical, thermal, and gas barrier properties of packaging materials
- Surface modification of nanoparticles with some active functional groups can be used as antifungal agents, oxygen or ultraviolet scavengers in packaging
- The intelligent packaging developed based on this can perceive real-time changes in biochemical indicators or microorganisms inside the packaging, serving as a grain safety tracker, indicating changes in grain safety indicators



3.4 Green anti-mildew packaging material for grain storage

- Ag/TiO_2 nano packaging material significantly delaying the changes in fatty acid value of rice
- The anti-fungal properties of Ag/TiO_2 nano packaging can reduce the number of fungal in rice, thereby reducing the content of lipase
- The gelatinization temperature is also significantly lower than that of rice stored in ordinary packaging, and the overall sensory quality is better than that of ordinary rice





Gelatinization characteristics of rice stored for 90 days

Peak viscosity	Peak viscosity （cP）	Minimum viscosity （cP）	Damage value （cP）	Final Viscosity （cP）	Gel value （cP）	Gelatinization temperature （℃）
Fresh rich	1611	1002	609	2136	1134	86.1
Nano packaging bag rice	1909	1312	597	2605	1313	86.3
Ordinary packaging bag rice	2131	1541	591	2862	1321	88.7

3.5 Light and simplified facilities suitable for small-scale grain storage of farmers

- ✓ **Develop and improve special storage bags for corn, wheat, rice, etc., removable storage warehouses, and air-conditioned storage technology using CO_2 or N_2**
- ✓ **Build a packaging mode and stacking mode suitable for small-scale storage of farmer**

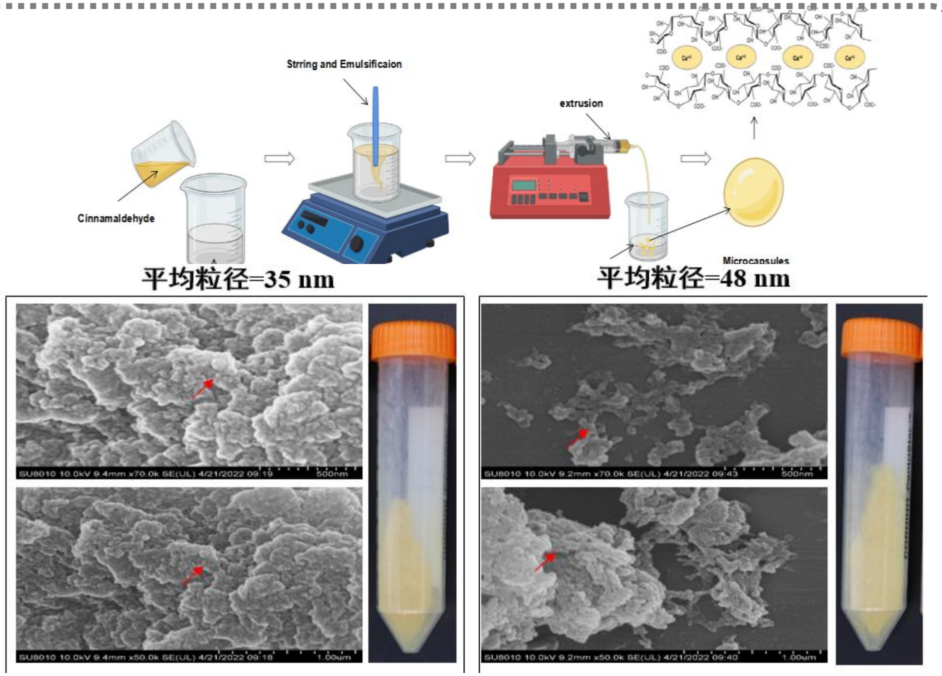
Different packaging and storage modes of agricultural products

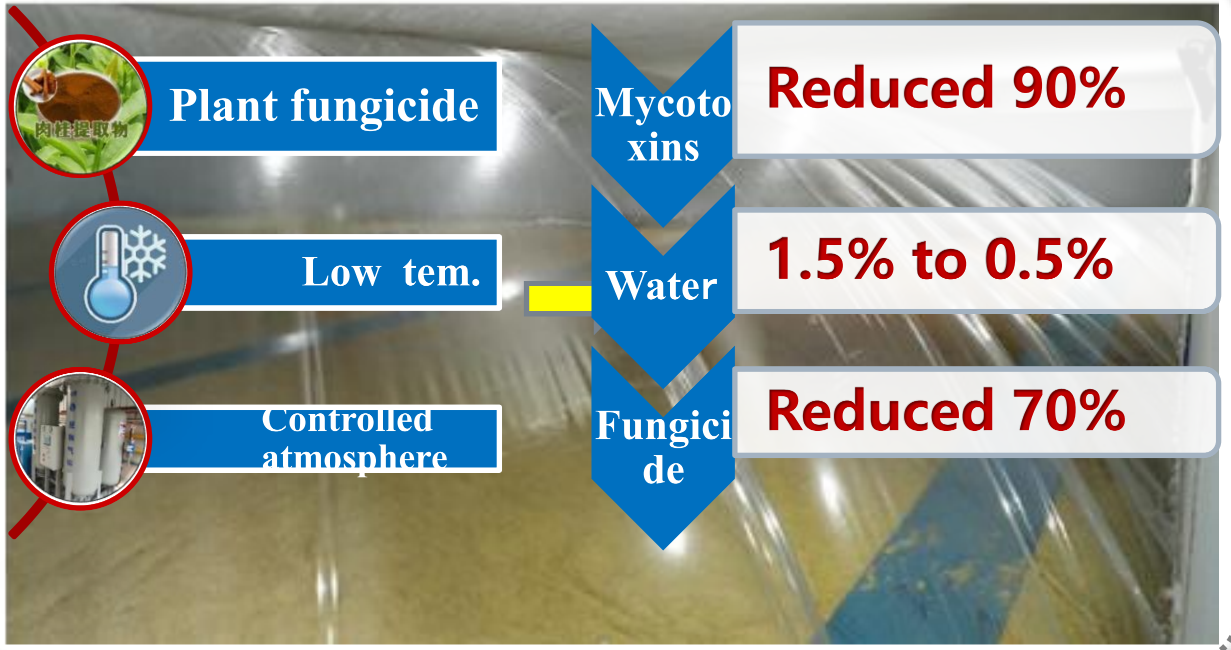
Screening of different packaging and stacking modes

Application of small nitrogen charging equipment

The use of simple grain storage equipment compared with the traditional farmer storage. The incidence of pests and mildew was reduced by 90%

3.6 Technical system of green prevention and control of fungi and mycotoxins in grain storage





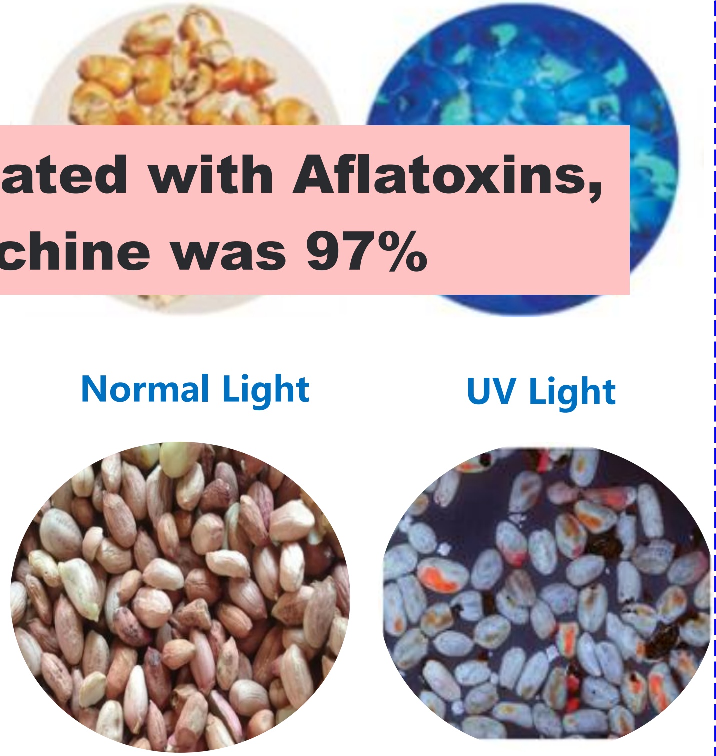
Coupled with plant source anti-mildew agents, low temperature and air conditioning, mycotoxin contamination of grain was reduced by 90%, water loss of grain was decreased from 1.5% to 0.5%, and chemical anti-pest and anti-mildew agent consumption was reduced by 70% in one year storage.

3.7 Non-destructive testing and intelligent sorting technology and equipment of grain

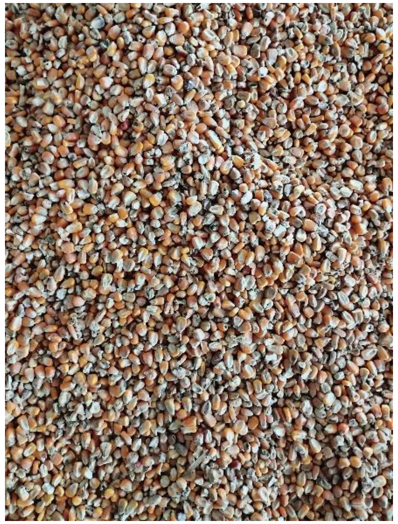
- ✓ For maize and peanuts contaminated with AFs, we invented non-destructive testing technology using laser scanning and spectral imaging.
- ✓ Fusion fluorescence detection, multi-spectral detection, high sensitivity sensing technology, we created an intelligent laser sorting machine.

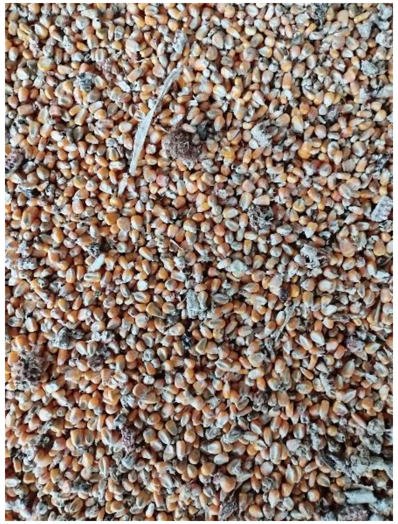
For peanuts and maize contaminated with Aflatoxins, the sorting rate of this machine was 97%

P-CV-Y+Toxin-specific sorting machine



3.7 Non-destructive testing and intelligent sorting technology and equipment of grain





- ✓ In Nov. 2023, Shangshui of Henan province, the corn grading and sorting were carried out
- ✓ After sorting, AFB_1 in corn decreased from **100 ppb** to **2 ppb**

Thank you for your attentions!

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