الفصل السادس عشر

المكافحة المتكاملة لأمراض وآفات ما بعد الحصاد

كما فى أمراض وآفات الزراعات المحمية، فإن أمراض وآفات ما بعد الحصاد تحتاج مكافحتها الاهتمام بمختلف وسائل المكافحة التى أسلفنا بيانها فى فصول هذا الكتاب، إلاّ أن الخصوصية التى تتميز بها ظروف ما بعد الحصاد تؤهلها إلى معاملات أخرى خاصة بها للمكافحة المتكاملة لا تتوفر لغيرها؛ الأمر الذى نتناوله فى هذا الفصل.

المعاملات الحرارية

يمكن أن تؤدى المعاملات الحرارية للخضر والفواكه الطازجة بعد الحصاد إلى حمايتها من الإصابة بالأعفان أثناء التخزين، وتُجرى هذه المعاملة — التى تعرف أيضًا باسم المعالجة curing — إما بالغمر فى الماء الساخن، وإما بالتعريض للبخار الساخن أو للحرارة الجافة؛ وإما بالشطف فى الماء الساخن مع التفريش brushing.

تؤثر المعاملة الحرارية بصورة مباشرة بإبطاء استطالة أنابيب الإنبات الجرثومية، أو بوقف نشاط الجراثيم النباتية أو قتلها؛ الأمر الذى يقلل من فرصة الإصابة بالأعفان.

كذلك قد تؤدى المعاملة الحرارية فعلها من خلال الاستجابات الفسيولوجية لأنسجة الثمار لها. وتتضمّن تلك الاستجابات تكوين العائل لمركبات مضادة للفطريات تثبط نموها فى الأنسجة الثمرية، وكذلك تحفيز التئام الجروح. كما قد تستحث المعاملة الحرارية تكوين بروتينات الـ PR مثل الشيتينيز chitinase، والـ β-1,3-glucanase، كما أنها تثبت وضع الأغشية الخلوية، وقد تثبط تمثيل الإنزيمات المحللة للجدر الخلوية (الـ polygalacturonases)، وتؤخر معدل تحلل المواد المضادة للفطريات والتى تكون سابقة التكوين فى الثمار ذاتها.

ومما تحدثه المعاملة الحرارية بالثمار كذلك أنها قد تؤدى إلى اختفاء اللوائح الشمعية wax platelets التى توجد طبيعيًا فى الثمار غير المعاملة؛ مما يجعل سطح الثمرة متجانسًا نسبيًا؛ بما يعنى امتلاء شقوق أديم الثمار والجروح المتناهية الصغر والثغور كليًا أو جزئيًا بالشمع، مع حصر الجراثيم التى أنبتت مبكرًا داخل الشمع المنصهر ووقف نشاطها.

تعرف المعاملة الحرارية للثمار باسم معالجة curing لأنها تعمل على علاج الجروح والأضرار التى تحدث بالثمار أثناء التداول، كما تُعرف — كذلك — باسم "تهيئة" conditioning لأنها تمكن المنتج من تحمل الظروف القاسية مثل الحرارة الأقل من الحرارة المثلى أثناء النقل والتخزين.

وتقسم المعاملات الحرارية إلى قسمين:

١- المعاملة لفترة قصيرة لا تزيد عن الساعة — فى الماء على حرارة ٤٥-٦٠°م.

٢- المعاملة لفترة طويلة تستمر من ١٢ ساعة إلى أربعة أيام فى الهواء على حرارة ٣٨-٤٦°م، وتلك هى التى يطلق عليها — غالبًا — اسم معاملة المعالجة.

ونظرًا للتكلفة العالية لمعاملة المعالجة — والتى تستلزم تعريض كل المنتج للحرارة العالية لمدة قد تصل إلى ثلاثة أيام — فإن المعاملة الأكثر شيوعًا هى الغمر فى الماء على حرارة ٥٠-٥٣°م لمدة ٢-٣ دقائق. ولقد أثبتت هذه المعاملة فاعليتها مع عديد من الثمار.

وعند اقتران المعاملة الحرارية مع المبيدات — مثل الـ imazalil والـ thiabendazole — فإن ذلك يزيد من فاعلية المبيدات ويقلل من الجرعة التى تلزم استخدامها منها؛ بسبب زيادة المعاملة الحرارية لسرعة نفاذية المبيد من خلال أديم الثمار (Schirra وآخرون ٢٠٠٠).

وقد أدى غمس ثمار الفلفل الحلو الحمراء المصابة طبيعيًا بأى من الفطر *Botrytis cinerea* مسبب مرض العفن الرمادى، أو الفطر *Alternaria solani* مسبب مرض العفن الأسود، أو الثمار المحقونة (المعدية) بأى من الفطرين .. أدى غمسها فى الماء

على حرارة ٥٠°م لمدة ثلاث دقائق إلى وقف نمو الفطر *B. cinerea* كلية، وإلى تقليل العفن الذى سببه الفطر *A. solani* جوهريًا. هذا .. وقد لوحظت أضرار للحرارة العالية على الثمار عندما كان غمسها فى الماء على حرارة ٥٠°م لمدة خمس دقائق. أو على حرارة ٥٥°م لمدة دقيقة واحدة، أو لمدة تزيد عن ذلك، وكانت الأضرار على صورة تشققات ونقر ظهرت على سطح الثمرة (Fallik وآخرون ١٩٩٦).

ومن المعروف أن المعاملة الحرارية تثبط نضج الثمار الكلايمكتيرية مثل الطماطم. وإن كانت تُسرع نضج ثمار المانجو.

وفى ثمار الأفوكادو يتواجد المركب diene المضاد للفطريات فى الجدار الثمرى الخارجى .. هذا المركب ينخفض تركيزه إلى أن يختفى مع نضج الثمرة. وفى الوقت ذاته يمكن أن يتواجد بالثمار إصابات كامنة (غير نشطة) بالفطر *Colletotrichum gloeosporioides*. وتؤدى المعاملة الحرارية الجافة إلى تأخير نضج ثمار الأفوكادو. بينما يؤدى غمس الثمار فى حرارة ٥٥°م لمدة ١٠ دقائق إلى إسراع ظهور أعراض المرض وكذلك إسراع تحلل المركب diene.

وتجدر الإشارة إلى أن تأثير المعاملة الحرارية يكون بتثبيط نشاط الفطر (fungistatic effect) وليس بقتله (fungicidal effect) (Schirra وآخرون ٢٠٠٠).

المعاملة بالماء المكلور

يستخدم محلول الكلورين فى تطهير الأسطح والعبوات والثمار.

يحضر المحلول — بتركيز ٧٠ جزء فى المليون كلورين — بإضافة لتر من محلول يحتوى ٥.٢٥٪ هيبوكلوريت الصوديوم sodium hypochlorite (مثل الكلوراكس المستخدم فى الأغراض المنزلية) لكل ١٠٠٠ لتر من الماء. يجب ألا ينخفض أبدًا تركيز الكلورين فى ماء الغسيل عن ٢٥ جزء فى المليون؛ ولذا .. يتعين تجديد المحلول على فترات متقاربة أو — على الأقل — يوميًا.

المعاملة بأملاح البيكربونات

أفادت المعاملة بأى من بيكربونات البوتاسيوم، أو بيكربونات الصوديوم فى مكافحة الفطر *Alternaria alternata* فى ثمار الفلفل بعد الحصاد (Ziv وآخرون ١٩٩٤).

المعاملة بكلوريد الكالسيوم

اقُترح معاملة ثمار الخيار بالكالسيوم قبل تعرضها للإصابة بالفطر *Botrytis cinerae* لأن المعاملة يمكن أن تزيد من مقدار الكالسيوم المرتبط بالجدر الخلوية؛ وبذا تقل فرصة هضم الكالسيوم بواسطة إنزيمات الفطر البكتينوليتية pectinolytic enzymes (Chardonnet & Doneche ١٩٩٥).

كما أدى غمر ثمار الكنتالوب المجروحة صناعيًّا فى محلول كلوريد كالسيوم بتركيز ١١٪ Ca^{+2} إلى خفض إصابتها بالفطر *Myrothecium roridum* المسبب للعفن إلى نحو ٦٦٪ من شدة إصابة ثمار كنترول. ونظرًا لأن الكالسيوم لم يكن له تأثير مباشر على الفطر فى البيئات الصناعية؛ لذا .. يعتقد بأن العنصر يُحدث تأثيره بطريق غير مباشر، وذلك من خلال تأثيره على تطور الفطر المرض فى النسيج الثمرى (De Lima وآخرون ١٩٩٨).

التبخير بحامض الخليك

أوضحت دراسات Sholberg & Gaunce (١٩٩٥) أن تبخير ثمار بعض المحاصيل (الطماطم، والتفاح، والعنب، والبرتقال، والكيوى) بعد الحصاد بحامض الخليك Acetic Acid بتركيزات تراوحت بين ٢,٠ و ٤,٠ مجم/لتر من الهواء (بعد حقنها بفطريات متنوعة؛ هى: *Botrytis cinerea*، و *Penicillium expansum*، و *P. italicum*) منع تعفنها دون أن تحدث أية تأثيرات سلبية بها وقد أدت زيادة الرطوبة النسبية (من ١٧٪ إلى ٩٨٪) إلى زيادة فاعلية المعاملة عندما أجريت على أى من ٥°م أو ٢٠°م.

المعاملة بالمركبات العطرية والزيوت الأساسية

المعاملة بالمركبات العطرية الطبيعية التى تنتجها الثمار

يفيد تبخير ثمار الفراولة ببعض الغازات والمركبات العطرية القابلة للتطاير والتى تنتجها ثمار الفراولة بصورة طبيعية .. يفيد استعمالها فى تثبيط نمو الكائنات المسببة للأعفان، ولكن يتعين تحديد التركيز الذى يحقق الهدف دون التأثير على طعم الثمار أو نكهتها، ودون ترك أى متبقيات غير مرغوب فيها على المنتج الطازج. فمثلاً .. وجد أن المعاملة بغاز الأسيتالدهيد acetaldehyde بتركيز ١٥٠٠ جزء فى المليون لمدة ٤ ساعات أدى إلى خفض الإصابة بالعفن الرمادى بنسبته ٢٠٪ مع تحسين طعم الثمار ونكهتها كذلك. هذا .. إلا أن الأسيتالدهيد يمكن أن يقلل من حموضة الثمار ومحتواها من المواد الصلبة الذائبة، وإلى زيادة محتواها من الكحول الإثيلى، والإثيل أسيتيت ethyl acetate، والإثيل بيوتريت ethyl butyrate. كذلك يمكن للمركبين الطبيعيين اللذان تنتجهما ثمار الفراولة، وهما: benzylaldehyde، و 2-nonanone .. يمكنهما تثبيط نمو الفطر *B. cinerea* دون إحداث تأثير سلبى على طعم الثمار أو نكهتها (عن Perkins-Veazie & Collins ١٩٩٥).

كذلك أثبت المركب (E)-2-hexenal فاعلية فى مكافحة أعفان الثمار، وظهر — فى البيئات الصناعية — أن عملية إنبات جراثيم الفطر *B. cinerea* كانت أكثر حساسية للمركب عن عملية نمو الغزل الفطرى. وقد أدت التركيزات المنخفضة من المركب إلى تحفيز النمو الفطرى، وهو الأمر الذى حدث — كذلك — عند معاملة الثمار ذاتها؛ مما يعنى ضرورة زيادة تركيز المركب لكى يكون فعّالاً فى تثبيط أعفان الثمار بعد الحصاد (Fallik وآخرون ١٩٩٨).

كذلك أدت معاملة الفراولة بهذا المركب العطرى المتطاير (E)-2-hexenal إلى إحداث نقص جوهرى فى الإصابة بالعفن الرمادى عند إجراء المعاملة أثناء تخزين الثمار لمدة ٧ أيام على ٢ °م، ثم نقلها — بعد توقف المعاملة — إلى ٢٢ °م لمدة ٣ أيام، وذلك مقارنة بثمار معاملة الكنترول. وبالمقارنة فإن المعاملة بأى من المركبات العطرية (E)-2-hexenal diethyl acetal، أو benzaldehyde، أو methyl benzoate لم تكن مؤثرة (Ntirampemba وآخرون ١٩٩٨).

وعندما عرضت ثمار فراولة مصابة طبيعيًا بالفطر *B. cinerea* لأبخرة عديد من المركبات المتطايرة التى تتواجد طبيعيًا فى الثمار، وجد أن الكثير من تلك المركبات، مثل: benzaldehyde، و methyl benzoate، و methyl salicylate، و 2-nonanone، و 2-hexenal diethyl acetal، و hexanol، و (E)-2-hexen-1-ol تثبط نمو الفطر عند تركيزات منخفضة تقدر بالجزء فى المليون. كذلك كان لبعض المركبات تأثيرات سلبية على جودة الثمار. وبينما كانت بعض المركبات فعّالة بعد فترة قصيرة من المعاملة بها، لزم استمرار المعاملة على الدوام بمركبات أخرى لكى تكون فعّالة (Archnold وآخرون ١٩٩٧).

المعاملة بالمثيل جاسمونيت

تفيد معاملة ثمار الفراولة بالمثيل جاسمونيت methyl jasmonate فى مكافحة الأعفان. وهذا المركب رخيص نسبيًا ولا يلزم للمعاملة به سوى كميات بسيطة، فلا يحتاج الأمر لأكثر من ٢٥ مل (سم^{٣}) منه لمعاملة حمولة شاحنة كاملة، وهو لا يترك أى أثر متبق.

تجرى المعاملة فى حرارة ٢٠°م باستعمال أبخرة المركب، ولهذا السبب فإنها ربما لا تكون مجدية مع محصول التصدير الذى يتعين تبريده أوليًا فى خلال ساعة واحدة من حصاده، بينما تتطلب المعاملة بالمركب ساعتين على الأقل.

وقد درس Perez وآخرون (١٩٩٧) تأثير المثيل جاسمونيت على نضج ثمار الفراولة المقطوفة وذلك بحصادها وهى خضراء غير مكتملة النمو، وزراعتها فى بيئة تحتوى على ٨٨ مللى مول سكروز فى إضاءة مقدارها ٣٠٠ ميكرومول لكل م^{٢} فى الثانية، لمدة ١٦ ساعة يوميًا، مع حرارة مقدارها ٢٥°م نهارًا، و ١٥°م ليلاً، ورطوبة نسبية ٨٥٪، مع إضافة المثيل جاسمونيت إلى البيئة بتركيز ٥٠ ميكرومولاً. وقد وجدوا أن إضافة المثيل جاسمونيت أحدثت زيادة معنوية فى كل من معدل التنفس وإنتاج الإثيلين بكل من الثمار البيضاء والوردية. كما ازداد نمو الثمار المعاملة بالمثيل جاسمونيت بمقدار ٥٥٪، مقارنة بزيادة مقدارها ٣٣٪ فقط فى ثمار الكنترول. وأدت المعاملة كذلك إلى إحداث

تأثيرات معنوية فى تلوين الثمار، حيث حفزت تمثيل الأنثوسيانين فى خلال يومين من المعاملة، مع زيادتها لمعدل تحلل كلوروفيل أ، وكلوروفيل ب، وبدرجة أقل البيتاكاروتين والزانثوفيلات xanthophylls.

كما أدت معاملة ثمار الطماطم بأبخرة المثيل جاسمونيت methyl jasmonate إلى تثبيط إنتاج الجراثيم وإنباتها فى الفطر المسبب للأنثراكنوز *Colletotrichum coccodes* على الرغم من عدم تأثير تلك الأبخرة على إنبات جراثيم الفطر وتكوين مستعمراته فى البيئات الصناعية؛ بما يعنى أن المثيل جاسمونيت يؤثر على الفطر فى الثمار من خلال دور له فى التفاعلات بين الثمار والفطر المرض (Tzortzakis ٢٠٠٧).

المعاملة بالزيوت الأساسية

أوضحت عديد من الدراسات فاعلية بعض الزيوت الأساسية فى وقف نمو الفطر *Botrytis cinerea*. ومن بين الزيوت التى تأكد جدواها فى هذا الشأن كلاً من الزعتر الأحمر *Thymus zygis*، والفصوص البرعمية لـ *Eugenia caryophyllata*، وأوراق القرفة *Cinnamomum zeylanicum*. كذلك فإن الزيت الأساسى لكل من *Monarda citrodora*، و *Melaleuca alternifolia* تظهر نشاطًا مضادًا لمدى واسع من الفطريات التى تصيب الخضر والفاكهة بعد الحصاد.

ويبدو أن تأثير الزيوت لا يرجع إلى مركب واحد بعينه فى الزيت الأساسى، وإنما إلى تأثير تداؤبى synergistic لعدد من تلك المركبات، وهى التى تتواجد فى كل زيت — عادة — بالعشرات وربما بالمئات (Sydney Postharvest Laboratory Information Sheet — الإنترنت — ٢٠٠٧).

وقد أدى غمس ثمار الطماطم فى مستحلب زيت الزعتر thyme بتركيز ٥٪ أو زيت الـ oregano بتركيز ١٠٪ إلى خفض إصابتها أثناء التخزين بكل من الفطرين *Botrytis cinerea*، و *Alternaria arborescens* (Plotto وآخرون ٢٠٠٣).

كما أدت معاملة ثمار الطماطم بالمركب trans-cinnamaldehyde بتركيز ١٣ ملى مول (وهو مركب يتواجد طبيعيًا فى النباتات) إلى خفض أعداد البكتيريا والفطريات على

سطح الثمرة إلى العُشر عندما كان غمس الثمار لمدة ١٠ دقائق، وإلى تأخير ظهور أى نموات فطرية لمدة أسبوع كامل عندما كان الغمس لمدة ٣٠ دقيقة مع حفظ الثمار بعد ذلك فى جو معدل على ١٨°م؛ علمًا بأن *Penicillium* sp. كان هو الفطر السائد على كأس الثمار المخزنة (Smid وآخرون ١٩٩٦).

وفى الكمثرى .. أمكن مكافحة الفطر *Penicillium expansum* — مسبب مرض العفن الأزرق — فى الثمار المخزنة بالمعاملة بأبخرة بعض المركبات المتطايرة ذات الأصول النباتية، مثل:

trans-2-hexenal	carvacrol
trans-cinnamaldehyde	citral

وكانت أفضل المعاملات فى مكافحة الفطر هى التعريض لأبخرة trnas-2-hexanal بمعدل ١٢,٥ ميكروليتر/لتر على مدى ٢٤ ساعة تبدأ بعد ٢٤ ساعة من الحقن بالفطر المرض (Neri وآخرون ٢٠٠٦).

هذا .. ويمكن أن تنتقل يرقانة القواقع slugs (*Deroceras reticulatum*) مع درنات البطاطس من الحقول إلى المخازن إذا ما كان الموسم رطبًا وأُجرى الحصاد والتربة رطبة، حيث تنتقل اليرقانة مع الطين الذى قد يكون ملتصقًا بالدرنات؛ بما يعنى استمرار حدوث الأضرار فى المخازن. وقد وجد أن معاملة الدرنات المخزنة بمانع التبرعم المحتوى على الكارفون carvone (التحضير التجارى Talent) بمعدل ٥٠ مل من المركب التجارى لكل طن من الدرنات أدت إلى مكافحة اليرقانات فى خلال أيام قليلة (Ester & Trul ٢٠٠٠).

التعريض للأشعة فوق البنفسجية

أدى تعريض درنات البطاطس للأشعة فوق البنفسجية بجرعة ١٢,٥ أو ١٥ كيلوجول/م^2 (kJ/m^2) إلى تثبيط إصابتها بكل من العفن الجاف الذى يسببه الفطر *Fusarium solani*، والعفن الطرى الذى تسببه البكتيريا *Erwinia carotovora* بصورة تامة، وذلك عندما كان تخزين الدرنات فى حرارة ٨°م لمدة ٣ شهور، دون أى تأثير

للمعاملة على التبرعم، أو على قوام الدرنات أو صلابتها أو لونها (Ranganna وآخرون ١٩٩٧).

كما أدت معاملة جذور البطاطا بالأشعة فوق البنفسجية UV-C بجرعة ٣,٦ كيلوجول/م^{٢} إلى الحد — بشدة — من إصابتها بالفطر *Fusarium solani* — المسبب لعفن الجذور الفيوزارى — أثناء التخزين، وكان ذلك مصاحبًا بزيادة فى نشاط الـ phenylalanine ammonia-lyase فى الجذور المعاملة (Stevens وآخرون ١٩٩٩).

كذلك أدى تعريض الأسبرجس للأشعة فوق البنفسجية UV-C بطول موجى ٢٥٤ نانوميتر بجرعة قدرها أكثر من ٠,٠١ جول/سم^{٢} إلى نقص جوهرى فى معدل إصابة المهاميز بالفطر *Botrytis cinerea* تحت ظروف العدوى الصناعية به (Marquenie وآخرون ٢٠٠٢).

المعاملة بالأوزون

أظهرت معاملة جذور الجزر — أثناء التخزين — بالأوزون بتركيز ٦٠ ميكروليتر/لتر نقصًا قدره ٥٠٪ فى النمو اليومى لكل من الفطرين *Botrytis cinerea*، و *Sclerotinia sclerotiorum*؛ مما يدل على أن للأوزون تأثير فطرى مثبط fungistatic (Liew & Prange ١٩٩٤).

كما أدى تعريض ثمار الطماطم — بعد الحصاد — للأوزون بتركيزات تراوحت بين ٠,٠٠٥، و ٥,٠ ميكرومول/مول إلى الحد من إصابتها بكل من الفطرين *Alternaria alternata* مسبب مرض البقع السوداء، و *Colletotrichum coccodes* مسبب مرض الأنثراكنوز، كما ازداد تأثير المعاملة بزيادة تركيز الأوزون المستعمل، إلاّ أن تركيز ٠,٢ ميكرومول/مول — وهو الحد الأقصى الحرج المسموح به فى دول السوق الأوروبية لكى لا تتأثر صحة الإنسان — كان مؤثرًا للغاية فى الحماية من إصابة الثمار بأى من الفطرين. هذا .. ولم تكن المعاملة بالأوزون مؤثرة على الفطر فى البيئات الصناعية؛ بما يدل على أن تأثير الأوزون فى النبات يرجع — ولو جزئيًا — إلى تغيرات يحدثها فى التفاعلات بين الثمار والمسببات المرضية (Tzortzakis وآخرون ٢٠٠٨).

التخزين فى الجو المتحكم فى مكوناته

يُستفاد من الجو المتحكم فى مكوناته – الذى ترتفع فيه كثيرًا نسبة ثنائى أكسيد الكربون وتنخفض فيه كثيرًا أيضًا نسبة الأكسجين – فى قتل الحشرات الحية التى قد تتواجد فى الخضر والفاكهة؛ الأمر الذى قد يمكن الاستفادة منه فى حالات الحجر الزراعى. هذا إلا لأن الحشرات تتباين كثيرًا فى الوقت الذى يلزم مروره للتخلص منها نهائيًا تحت تلك الظروف. وطبيعى أن الخضر والفاكهة تتباين كذلك فى مدى تحملها لتلك الظروف، وفى الفوائد التى تعود عليها منها، والأضرار التى تسببها لها (Ke & Kader ١٩٩٢).

التخزين تحت ضغط منخفض

أدى تعريض ثمار الفراولة بعد الحصاد لضغط جوى منخفض لمدة ٤ ساعات إلى تقليل الإصابة بالبوترتيس *Botrytis cinerea* عندما كان الانخفاض حتى ٠,٢٥ ضغط جوى، وإلى تقليل الإصابة بالعفن الريزوبى *Rhizopus* rot عندما كان الانخفاض فى الضغط حتى ٠,٥ ضغط جوى (Romanazzi وآخرون ٢٠٠١).

المكافحة الحيوية

مكافحة الأمراض الفطرية بالبكتيريا

أمكن مكافحة الفطر *Botrytis cinerea* مسبب مرض العفن الرمادى بمعاملة ثمار الطماطم – بعد الحصاد – بالبكتيريا *Bacillus amyloliquefaciens* (Mari وآخرون ١٩٩٦).

وأعطت معاملة درنات البطاطس بالبكتيريا *Entrobacter cloacae* (السلالة S11:T:07) عند تخزينها نقصًا قدره ٢١٪ فى إصابتها بالعفن الجاف الفيوزارى، مقارنة بنقص قدره ١٤٪ فقط عندما عوملت الدرنات بالمبيد الفطرى thiabendazole (Schisler وآخرون ٢٠٠٠).

كما أدى رش درنات البطاطس – أثناء مرورها على السيور قبل تخزينها – بمعلق

للسلالة S11:T:07 من البكتيريا *Entrobacter cloacae* إلى إحداث مقاومة للفطر *Fusarium sambucinum* مسبب مرض العفن الجاف الفيوزارى بدرجة تزيد بمقدار ٥٠٪ عن تلك التى يحققها استعمال المبيد الوحيد للاستعمال مع البطاطس المخصصة للاستهلاك الآدمى، وهو thiabendazole (عن وزارة الزراعة الأمريكية — الإنترنت — ٢٠٠٧).

وكانت لمعاملة ثمار الطماطم بأى من عدد من الأنواع البكتيرية المتوسطة القدرة على تحمل الملوحة قدرة عالية على خفض الإصابة بالفطر *Botrytis cinerea* مسبب مرض العفن الرمادى. ومن بين الأنواع البكتيرية التى تم اختبارها وأعطت نتائج جيدة، ما يلى (Sadfi-Zouaoui وآخرون ٢٠٠٨):

Bacillus spp. (*subtilis* or *licheniformis*)
Planococcus rifietoensis
Halomonas subglaciescola
Halobacillus lutorglis
Marinococcus litoralis
Salinococcous roseus
Halovibrio variabilis
Halobacillus halophilus
Halobacillus trueperi

مكافحة الأمراض الفطرية بالخميرة

أدى رش نباتات الفراولة أثناء إزهارها بالخميرة *Cryptococcus albidus* (وهى التى كانت قد عُزلت — أصلاً — من ثمار فراولة ناضجة) إلى خفض معدل إصابة الثمار الناضجة بالفطر *Botrytis cinerea* — مسبب مرض العفن الرمادى بنسبة تراوحت بين ٢١٪، و ٣٣٪ (Helbig ٢٠٠٢).

كما أدت المعاملة المختلطة بكل من الخميرة *Candida utilis* والشيتوسان chitosan إلى مكافحة عفن ثمار الطماطم الذى يسببه الفطرين *Alternaria alternata*، و *Geotrichum candidum* (Neeta وآخرون ٢٠٠٦).

وأدت معاملة ثمار الطماطم بعد الحصاد بالخميرة *Pichia guilliermondii* إلى حمايتها من الإصابة بكل من الفطريات *Alternaria solani*، و *Rhizopus stolonifer*، و *Botrytis cinerea* دون التأثير على صفات جودة الثمار (Zhao وآخرون ٢٠٠٨).

وقد أظهرت الخميرة *P. guilliermondii* الحية (وليست مزارعها المقتولة بالأتوكليف أو راشح مزارعها) قدرة على الحد من إصابة ثمار الطماطم بالفطر *Rhizopus nigricans* أثناء التخزين إذا ما عوملت الثمار بالخميرة أولاً. هذا ولا تنتج الخميرة مركبات مضادة للفطر، وإنما هى تُعد منافسًا قويًا له على كل من الغذاء والجروح التى ينفذ منها الفطر ليصيب الثمرة (Zhao وآخرون ٢٠٠٨).

هذا .. تؤدى الجروح — فى ثمار التفاح على سبيل المثال — إلى حث تكوين العناصر النشطة فى الأكسدة reactive oxygen species مثل فوق أكسيد الأيدروجين H_2O_2. وقد تبين أن الخمائر المستعملة فى مكافحة أمراض ما بعد الحصاد تقاوم تلك العناصر، وقد يكون ذلك هو الميكانيزم الذى تقوم عن طريقه بفعلها فى مكافحة بعض أمراض بعد الحصاد مثل البوتريتس (Castoria وآخرون ٢٠٠٣).

كما أدت المعاملة بالسيليكون فى صورة sodium metasilicate إلى زيادة كفاءة الخميرة *Cryptococcus laurentii* — بتركيز ١ × ١٠^{٧} خلية/ملليلتر — فى مكافحة الفطرين *Penicillium expansum*، و *Monilinia fructicola* بثمار الكريز الحلو على ٢٠°م، ويعتقد بأن مرد ذلك إلى أن معاملة السيليكون مع الخميرة تؤدى إلى زيادة أعداد الخميرة، بالإضافة إلى خاصية السمية المباشرة للسيليكون على المسببات المرضية، فضلاً عن إحداث السيليكون لزيادة معنوية فى نشاط كل من الـ phenylalamine ammonialyase، والـ polyphenol oxidase والـ peroxidase بثمار الكريز (Qin & Tian ٢٠٠٥).

مكافحة الأمراض الفطرية بالميكوريزا

أدى تلقيح درنات اليام الأبيض *Discorea roundata* بالجراثيم الكونيدية للميكوريزا *Trichoderma viride* قبل تخزينها لمدة أربعة شهور فى الجو العادى إلى خفض إصابتها بشدة بالفطريات المسببة للأعفان أثناء التخزين، مثل: *Aspergillus niger*،

و *Botryodiplodia theobromae*، و *Penicillum oxalicum* (Okigbo & Ikediugwu ٢٠٠٠).

المعاملة بمستحثات المقاومة الطبيعية

يرتبط تأثير عديد من الأساليب التى أسلفنا بيانها فى المكافحة بحث تطوير مقاومة طبيعية؛ الأمر الذى تكررت الإشارة إليه فى مواضع مختلفة من هذا الكتاب.

ونقدم — فيما يلى — أمثلة على حث تطوير المقاومة الطبيعية ببعض المعاملات.

المعاملة بالمركبات الكيميائية

أحدث رش نباتات الكنتالوب مرة واحدة بالـ benzothiadiazole (اختصارًا: BTH) قبل الحصاد بأسبوعين خفضًا معنويًا فى إصابات الثمار بعد الحصاد — بأمراض المخان؛ وخاصة تلك التى تسببها (فطريات *Fusarium*، و *Alternaria*، و *Rhizopus*؛ كذلك أعطى الرش أربع مرات كل ١٢ يومًا خلال مرحلتى الإزهار ونمو الثمار بكل من *B-aminobutyric acid* (اختصارًا: BABA)، و 2,6-dichloroisonicotinic acid (اختصارًا: INA) نتائج مماثلة. أما قبل الحصاد فقد أدت المعاملة بأى من الـ INA أو الـ BTH إلى خفض إصابة النباتات بكل من البياض الدقيقى والبياض الزغبى (Bokshi وآخرون ٢٠٠٦).

كما أدى غمر ثمار الكنتالوب فى محلول harpin (وهو حاث بكتيرى لتفاعل فرط الحساسية) بتركيز ٩٠ جزء فى المليون إلى خفض إصابتها بالأعفان التى تسببها فطريات *Alternaria alternata*، و *Fusarium semitectum*، و *Trichothecium roseum*. وذلك من خلال حث المقاومة ضدها، علمًا بأن الـ harpin ليس سامًا لتلك الفطريات فى البيئات الصناعية (Yang وآخرون ٢٠٠٧).

المعاملة بالصدمات الحرارية

تؤثر معاملة ثمار الحمضيات بالصدمة الحرارية بعد الحصاد فى إنتاج الكيومارينات

coumarins المضادة للفطريات فى قشرتها. وفى الليمون الأضاليا أدت المعاملة الحرارية إلى إنتاج الـ scoparone بعد التعرض للإصابة بالفطر *Penicillium* sp.، وقد ارتبط هذا التراكم معنويًا بالمقاومة (Da Rocha & Hammerschmidt ٢٠٠٥).

المعاملة بالمثيل ساليسيلات

أدى تبخير ثمار الفراولة بالـ methyl salicylate إلى خفض إصابتها بالعفن الرمادى بنسبة الثلث مقارنة بالإصابة فى ثمار الكنترول. وقد تحول الـ methyl salicylate فى الثمار إلى حامض سلسيلك وأدى إلى زيادة نشاط الشيتينيز (Kim & Choi ٢٠٠٢).

المعاملة بالشيتوسان

أدت معاملة مكان اتصال عنق ثمرة الطماطم بالثمرة (مكان قطف الثمرة) بالشيتوسان chitosan إلى تثبيط إصابة الثمرة بالفطر *Alternaria alternata* مسبب مرض العفن الأسود، وذلك عندما تم حقنها بالفطر وخزنت على ٢٠°م لمدة ٢٨ يومًا. وكان ذلك التأثير لمعاملة الشيتوسان مصاحبًا بضعف فى نشاط الإنزيمات المحللة للأنسجة (polygalacturonase، و cellulase، و pectic lyase) فى النسيج المجاور للبقع المرضية، حيث انخفض نشاطها إلى أقل من ٥٠٪ مما كان عليه الحال فى ثمار المقارنة التى لم تُعامل بالشيتوسان. كذلك ثبطت المعاملة بالشيتوسان إنتاج الثمار لكل من حامضى الأوكساليك والفيوماريك (oxalic & fumaric acids) وهما من المركبات المخلبية، وكذلك سموم العائل alternariol، و alternariol monomethylether، وحفزت إنتاج الفيتوألاكسين ريستين rishitin فى أنسجة الثمرة (Reddy وآخرون ٢٠٠٠).

كما أدت معاملة الجزر المخزن بالـ chytosan hydrolysate (وهو الذى يحضر من الـ chitosan بفعل الإنزيم chitosanase N-174 *Streptomyces*) بتركيز ٠,٢٪ (وزن/حجم) إلى حماية جذور الجزر من الإصابة بالفطر *Sclerotinia sclerotiorum* أثناء التخزين، بحثها الجذور على تطوير مقاومة ضد الفطر (Molloy وآخرون ٢٠٠٤).

المعاملة بالأشعة فوق البفسجية

أدى تعريض ثمار الفلفل للأشعة فوق البنفسجية UV-C بأى جرعة (من ٠,٢٢ إلى ٢,٢٠ كيلوجول/م^{2} kJm^{-2}) إلى حيث تكوين مقاومة جهازية بالثمار أمكن معها مقاومة الإصابة بالبوتريتس (*Botrytis cinerea*) فى الثمار المخزنة على ١٣ أو ٢٠°م (Mercier وآخرون ٢٠٠١).

وأدت المعاملة بالـ UV-C إلى حث المقاومة ضد الإصابات المرضية فى أبصال البصل وجذور الجزر وثمار الفلفل والطماطم (Da Rocha & Hammerschmidt ٢٠٠٥).

أمراض المخازن البكتيرية ومكافحتها

تعد الإصابات البكتيرية من أهم أمراض المخازن؛ ولذا .. نولى وسائل مكافحتها اهتمامًا خاصًّا.

الإصابات البكتيرية التى تستمر من الحقل فى المخازن

تستمر كثير من الإصابات البكتيرية فى المخازن، وتؤثر على جودة ونوعية الخضر المخزنة، بعد أن تكون قد بدأت فى الحقل. ومن أهم الأنواع البكتيرية المسببة لتلك الإصابات ما يلى:

البكتيريا	المحصول
Clavibacter michiganensis subsp. *michiganensis*	الطماطم
C. michiganensis subsp. *sepdonicus*	البطاطس
Pseudomonas solanacearum	البطاطس
P. syringae pv. *apii*	الكرفس
P. syringae pv. *lachrymans*	الخيار، وشهد العسل
P. syringae pv. *maculicola*	القنبيط
P. syringae pv. *phaseolicola*	الفاصوليا
P. syringae pv. *pisi*	البسلة
P. syringae pv. *syringae*	الفاصوليا
P. syringae pv. *tomato*	الطماطم

البكتيريا	المحصول
Streptomyces scabies	البطاطس والبنجر
Xanthomonas campestris pv. *campestris*	الكرنب والقنبيط
X. campestris pv. *phaseoli*	الفاصوليا
X. campestris pv. *vesicatoria*	الطماطم، والفلفل، والفجل

الأنواع البكتيرية المسببة للأعفان الطرية

تعد الأعفان الطرية من أهم الأمراض البكتيرية فى مصر وأكثرها انتشارًا. ويبين جدول (١٦-١) قائمة بأهم هذه الأنواع - على المستوى العالمى - والأنواع المحصولية التى تصاب بها، والمجال الحرارى لانتشارها.

جدول (١٦-١): أهم الأنواع البكتيرية المسببة للأعفان الطرية، والمحاصيل التى تصيبها، والمجال الحرارى المناسب لنموها (عن **Lund** ١٩٨٣).

البكتيريا	المحاصيل التى تصاب بها	درجات الحرارة لنموها (م) الدنيا	المثلى	العظمى
Erwinia carotovora subsp. *atroseptica*	معظم الخضروات، وخاصة البطاطس	٣	٢٧	٣٥
E. carotovora subsp. *carotovora*	معظم الخضروات	٦	٢٨-٣٠	٣٧-٤٢
E. chrysnthemi	البطاطس	٦	٣٤-٣٧	< ٤٥
Pseudomonas marginalis	معظم الخضروات	< ٠,٢	٢٥-٣٠	< ٤١
P. viridiflava	الفاصوليا	—	—	—
P. chichorii	الشيكوريا، والهندباء، والكرنب، والخس	—	حوالى ٣٠	< ٤١
P. cepaci	البصل	< ٤	٣٠-٣٥	٤٠-٤١
P. gladioli pv. *allicola*	البصل	< ٤	٣٠-٣٥	٤٠-٤١
Bacillus polymyxa	البطاطس والفلفل	٥-١٠	—	٣٥-٤٠
B. subtilis	البطاطس والطماطم	٥-٢٠	—	٤٥-٥٥
Clostridium puniceum	البطاطس	٧	—	٣٩

طرق مكافحة أمراض المخازن البكتيرية

من أهم وسائل مكافحة أمراض المخازن البكتيرية ما يلى:

١- إجراء عملية العلاج أو المعالجة Curing بصورة جيدة عند الحصاد؛ بهدف العمل على التئام الجروح التى تشكل منافذ جيدة للإصابات البكتيرية؛ كما فى البطاطس، والبطاطا، والبصل.

٢- إجراء الحصاد فى مرحلة النضج المناسبة لذلك، مع تعريض المحصول لأقل قدر من التجريح.

٣- عدم تلويث المحصول بقدر كبير من التربة وبقايا النموات النباتية التى يمكن أن تشكل مصدرًا خطيرًا للإصابات المرضية فى المخازن.

٤- تبريد المحصول سريعًا واتباع أساليب التخزين المناسبة لتجنب انتشار أمراض المخازن (يراجع لذلك حسن ١٩٩٨).

٥- معاملة المحصول بمحاليل لمركبات كيميائية مؤثرة على البكتيريا بعد الحصاد:

لم تُجْدِ هذه الوسيلة كثيرًا فى مكافحة أمراض المخازن البكتيرية. وحتى فى الحالات التى أمكن إحراز نجاح فيها فإن أخطار الأعفان — التى يمكن أن تنتشر بسبب الماء الذى يتبقى على المنتج بعد المعاملة بالكيماويات — تفوق عملية المكافحة الأولية ذاتها.

ويعد استعمال الكلور فى الماء الذى تشطف فيه الخضروات أنجح المعاملات الكيميائية حتى الآن. ويضاف الكلور إلى ماء الشطف إما فى صورة غازية، وإما فى صورة أحد أملاح الهيبوكلوريت. ويعتبر تركيز ١٠ أجزاء فى المليون فى الماء — عند درجة التعادل (pH = ٧) لدقائق قليلة — كافيًا لقتل الخلايا البكتيريا غير المتجرثمة، ولكن — مع تواجد التربة وبقايا النموات النباتية مع المحصول — يلزم زيادة تركيز الكلور فى محلول الشطف إلى ٥٠ جزءًا — ١٠٠ جزء فى المليون لكى يكون فعّالاً. وتجدر الإشارة إلى أن معاملة الكلور هى للتطهير السطحى فقط للمنتج، ولا يمكنها القضاء على ما قد يوجد بداخله من إصابات بكتيرية.

٦- المعاملة بالمضادات الحيوية:

تعد المضادات الحيوية من أنجح المركبات التى تقضى على الإصابات البكتيرية ومن أمثلة هذه المضادات الحيوية ما يلى:

Streptomycin	Oxytetracycline
Polymyxin	Neomycin

وبالرغم من الفاعلية الفائقة للمضادات الحيوية فى مكافحة أمراض المخازن البكتيرية فى محاصيل الخضر، إلا أن معظم الدول تُحَرِّم استعمالها عندما يكون الجزء المأكول من النبات هو الجزء المعامل؛ لكى لا يتناول الإنسان كميات كبيرة من المضادات الحيوية مع طعامه، والتى يمكن أن تؤدى إلى مخاطر صحية كبيرة.

ولهذا السبب .. فإن المضادات الحيوية الهامة طبيًّا لا يجوز استخدامها فى معاملة الخضروات المعدة للاستهلاك (عن Lund ١٩٨٣).

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