Summary of commercially available pheromones of common stored product moths

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DOI: 10.5073/jka.2010.425.491

1. Introduction

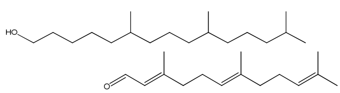
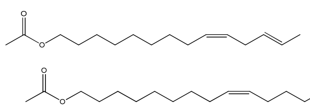
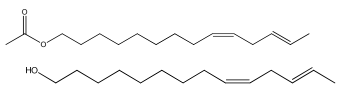
The use of synthetically created pheromones for insect monitoring and control has become a very important technique in the world of pest management. This concept has an origin that reaches back to 1913 when the French naturalist, J. H. Fabre conducted simple experiments with the great peacock moth (Fabre, 1913). In Fabre's study, a female peacock moth had emerged inside a cage. He noticed that male moths were attracted to the empty female's cage as well as the oak leaves the female had rested upon. This simple experiment led to the conclusion that there was a particular scent produced by the female to attract males. This scent is what we now refer to as pheromones.

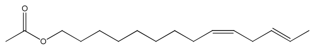
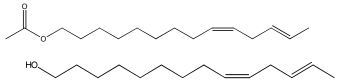
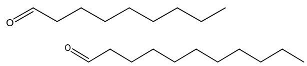
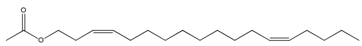
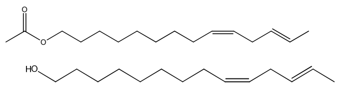
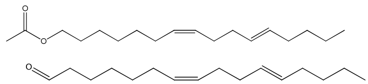
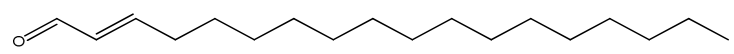
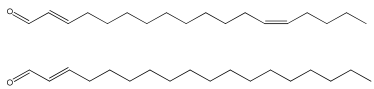
Pheromones are collectively grouped into one family of specific chemical signals designated as semiochemicals. 1961 marks the first year a pheromone was successfully isolated and characterized by the work of Butenandt and Hecker (Butler, 1967). Since then, an eruption of pheromone identification and synthetic creation has taken place. Pheromone use has proven to be an invaluable tool in monitoring and control of pest infestations; therefore, creating a market for synthetically created pest insect pheromones. Many stored product pest moths produce pheromones that can be classified as long-chain carbon, unsaturated alcohols, aldehydes and acetates. The unsaturated compounds consist of one or more double bonds that can be oriented into an E or Z conformation creating one or more isomers. These moth pheromones have become commercially available by designing multi-step organic syntheses that have inexpensive starting materials, easily produced chemical reactions and stable intermediates.

2. Commercially available pheromones for stored product months

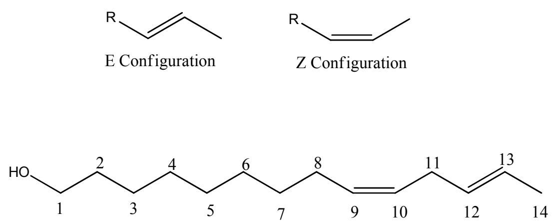
The majority of stored product pheromones range from 14-18 carbon chain compounds. Pheromones vary by functional group (i.e. alcohol, aldehyde, acetate), double bond position and the configuration of the double bond (E or Z). These factors are attractant determining for a variety of different moths, if a double bond is shifted to an adjoining carbon or retains an E configuration instead of a Z configuration, attraction will not occur for a targeted pest moth. The same holds true for alterations of functional groups. Through the use of organic syntheses, coupling of smaller organic compounds and the manipulation of long chain carbon compounds, these particular moth pheromones can be commercially produced.

Table 1 Commercially Available Stored Product Moth Pheromones for common stored product pests.

Scientific Name / Common Name	Pheromone Structure	Pheromone Name / Ratio
Corcyra cephalonica (Stainton) Rice moth		6,10,14-Trimethylpentadecan-1-ol (F) E,E-Farnesal (M)
Esphestia (Cadra) cautella (Walker) Almond moth		(Z,E)-9,12-Tetradecadienyl acetate (7) Z)-9-Tetradecenyl acetate (1)
Ephestia elutella (Hübner) Tobacco moth		(Z,E)-9,12-Tetradecadienyl acetate (3) (Z,E)-9,12-Tetradecadien-1-ol (0.3)

Scientific Name / Common Name	Pheromone Structure	Pheromone Name / Ratio
Ephestia figulilella (Gregson) Raisin moth		(Z,E)-9,12-Tetradecadienyl acetate
Ephestia kuehniella (Zeller) Mediterranean flour moth		(Z,E)-9,12-Tetradecadienyl acetate (5.6) (Z,E)-9,12-Tetradecadien-1-ol (1.2)
Galleria mellonella (L.) Greater wax moth		Nonanal (5) Undecanal (2)
Nemapogon granella (L.) European grain moth		(Z,Z)-3,13-Octadecadienyl acetate
Plodia interpunctella (Hübner) Indianmeal moth		(Z,E)-9,12-Tetradecadienyl acetate (1) (Z,E)-9,12-Tetradecadien-1-ol (1)
Sitotroga cerealella (Olivier) Angoumois grain moth		(Z,E)-7,11-Hexadecadienyl acetate (9) (Z,E)-7,11-Hexadecadienal (1)
Tinea pellionella (L.) Case-making clothes moth		(E)-2-Octadecenal
Tineola bisselliella (Hummel) Webbing clothes moth		(E,Z)-2,13-Octadecadienal (2) (E)-2-Octadecenal (1)

There are many similarities that can be observed between these commercially available pest moth pheromones. Looking closely, one can see that most of these pheromones are within two to four carbon chain links of one another. Most pheromone syntheses start with two smaller compounds to be coupled together to form these larger carbon chained compounds. Therefore, given the similarities between length of the pheromones, after an acceptable synthesis is discovered for one, other syntheses can be designed in the same manner by only adjusting the length of the two starting compounds. However, other factors for starting materials need to be considered such as functional group (alcohol, aldehyde or acetate) as well as double bond position and configuration (E or Z).



(Z,E)-9,12-Tetradecadien-1-ol

Figure 1 E and Z double bond configurations and double bond placement of (Z,E)-9,12-Tetradecadien-1-ol.

For the capture of certain particular pest moths, two closely related pheromones are used in specific ratios. This is the case for the almond moth, angoumois grain moth, Indianmeal moth, Mediterranean flour moth, tobacco moth and webbing clothes moth. Most of these multi-compound pheromones are used in very specific ratios, some having only one component making up 10% of the overall solution. Research has shown that specific ratios of closely related compounds have the ability to increase effectiveness of captures. Certain two compound pheromones can be observed to attract more than one moth. (Z,E)-9,12-Tetradecadienyl acetate and (Z,E)-9,12-Tetradecadien-1-ol are used to attract Indianmeal moth, Mediterranean flour and tobacco moth, however varying ratios of these two components has the ability to attract more of one than the others.

The stored-product moth pheromones presented are commercially available due to three factors:

1. The starting materials for synthesis are available and inexpensive: It would not make sense to start a multi-step synthesis with costly starting materials. The overall amount of money spent producing the final desired product will skyrocket when the cost of the smaller components used for coupling increase.
2. Ease of organic reactions and reproducibility is acquired: The chemistry preformed results in high yields and high purity. The complexity of the chemistry needed to produce a particular pheromone is low.
3. Syntheses contain highly stable intermediates: In multi-step syntheses the product between sequential reactions must be stable and not degrade before moving on to the next reaction.

Other pheromones that don't reach these criteria more than likely are pheromones consisting of more complex compounds and require more complicated chemistry to produce. Any organic synthesis of a stored product moth pheromone that meet the criteria above can be used in formulated lures bought from commercial suppliers.

Table 2 Commercial suppliers of formulated lures for stored-product pests

Cooper Mill Ltd., R. R. 3 Madoc, ON, Canada
Fuji Flavor, 358 Midorigaoka, Hamura-Shi, Tokyo, Japan.
Hercon Environmental, Emigsville, PA , USA.
ISCA Technologies, 1230 Spring St., Riverside, CA, USA
Insects Limited Inc., 16950 Westfield Park Road, Westfield, IN, USA.
Russell Fine Chemicals, Unit 68, Third Ave., Deside Industrial Park East, Deeside, Flintshire UK
Suterra Corporate, 20950 NE Talus Place, Bend, OR, USA
Trece Inc., P.O. Box 6278, 1143 Madison Lane, Salinas, CA, USA.

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