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Bundesforschungsanstalt für Ernährung, Institut für Chemie und Biologie, Karlsruhe

Hot Water Treatment to Control Gloeosporium Disease on Apples during Long-term Storage*

B. Trierweiler, H. Schirmer, and B. Tauscher

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Summary

Synthetic fungicide treatments are not allowed in organic apple farming orchards a few weeks before harvest in order to reduce post-harvest diseases during long-term storage. Hot water treatments (53 °C, 2 minutes) of organically farmed apples are able to control *Gloeosporium* disease, the most dangerous fungal disease of organically produced apples during storage. A reduction of *Gloeosporium* rot below 10 % after a storage time of five to six months could be achieved with hot water treatments after harvest, irrespective of storage conditions (cold storage or controlled atmosphere storage). In comparison we found over 90 % disease on untreated apples stored at 1 °C in air, and even 40 % of these apples stored under controlled atmosphere showed the typical *Gloeosporium* rot after five to six months of storage. Investigations on the internal quality of hot water treated apples showed no difference between the treated apples and the untreated control-apples.

Introduction

In the last ten years the number of organic farming plants almost doubled to over 7000. The use of effective fungicides in organic farming to reduce fungal diseases during storage is forbidden and so storage of organically produced apples is difficult. Some post-harvest diseases only develop during storage and stay unnoticed until the apples come out of the storehouse. *Gloeosporium* rot, the most dangerous post-harvest disease of organic apples can lead to over 50 % loss during storage. First appearances of *Gloeosporium* disease can be observed after a few months of cold storage or at the latest when apples are moved out of the storehouse and during marketing. Considerations, with which method the *Gloeosporium* rot can be reduced on biologically produced apples led to the hot water treatment. This is not a new procedure of plant protection. Hot water treatments have been used since the 20th century e.g. for the fight of loose smut with barley (GREWE, 1970; JAHN, 2002). Since 1999 the effect of hot water treatment on *Gloeosporium* rot of organically produced apples, cultivar 'Topaz', has been investigated at our institute. First attempts were carried out in the laboratory yardstick with ten apples from the above mentioned cultivar. The results of these attempts showed a clearly better reduction of the *Gloeosporium* rot as the bio fungicides examined in comparison to it (SCHIRMER et al., 2000). The successful employment of the hot water treatment for the reduction of post-harvest diseases with apples, peaches, nectarines, citrus fruits, mangos and bananas, which are caused by mold fungi or insects, has been described by different authors (BURCHILL, 1964; EDNEY and BURCHILL, 1967; REYES et al., 1998; PRUSKY et al., 1999; PORAT et al., 2000; SMITH et al., 2000; FALLIK et al., 2001; KARABULUT et al., 2002).

Due to the very good laboratory results concerning the reduction of the *Gloeosporium* rot through the hot water treatment, a dipping plant which holds 20 kg fruit boxes has been built at the Federal Research Centre for Nutrition, Karlsruhe.

The aim of this study was to investigate the influence of the hot water treatment on the *Gloeosporium* rot and the quality of organically produced apples.

Material and Methods

For the investigations different apple cultivars were received directly from organic farmers and dipped with the plant which holds 20 kg fruit boxes. Because of the results of the laboratory experiments a water temperature of 53 °C and a duration of treatment of 2 minutes proved to be the best process conditions. Further special treatments before storage, e.g. active drying of the dipped apples, were not carried out. After the thermal treatment in September 2001 the fruits were stored at 1 °C in air or in controlled atmosphere with 1 % oxygen and 3 % carbon dioxide. The apples were examined for *Gloeosporium* rot in December, January and March.

To examine the influence of temperature on the growth of the fungus *Gloeosporium* sp. spore solutions were kept at different temperatures for 2 minutes. After the thermal treatment, 100 µl of spore solution was brought to a special culture medium (DSMZ 190) and incubated at room temperature for 4 days. Growth of the fungus was determined visually. The microbial state of the dipping water was examined by determination of the total microbial population, number of yeast and fungi on special culture media e.g. standard nutrient agar and malt extract agar.

After 4 to 5 months storage at 1 °C in air or under controlled atmosphere (1 % oxygen, 3 % carbon dioxide) apples were investigated for *Gloeosporium* rot. To categorize the internal quality of hot water dipped apples in comparison to untreated fruits the vitamin C content was determined after storage (enzymatic test, Boehringer). Furthermore, sensory properties of the hot water dipped apples were examined by a trained sensory panel according to a sheme (DIN 10952).

Results and Discussion

In a first control in December (2001) 7.8 % of the untreated apples (cultivar 'Topaz') stored at 1 °C in air showed the typical *Gloeosporium* disease. On the other hand only 0.4 % of hot water treated apples were affected by the *Gloeosporium* rot after cold storage in air. A similar result could be achieved by storing the untreated and hot water dipped apples at 1 °C under controlled atmosphere. The hot water dipped apples of the cultivar 'Topaz' showed almost no *Gloeosporium* disease in December, whereas on about 8 % of the control apples *Gloeosporium* disease could be detected. The difference in *Gloeosporium* rot between untreated and hot water treated apples became more evident in January and March 2002. *Gloeosporium* disease could be examined on 56.5 % of the apples in cold storage in January and 94.4 % in March respectively. In comparison hot water treated apples stored under the same cold conditions showed only 2.9 % *Gloeo-*

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sporium rot in January and 15.7 % in March (Fig. 1). Fig. 1 also shows a reduction of the *Gloeosporium* rot to 24.1 % and 41.4 % respectively in January and March only by the use of controlled atmosphere storage. A much better result could be achieved by the combination of hot water treatment and storage under controlled atmosphere. Only 0.8 % of the apples showed *Gloeosporium* disease in January after hot water treatment and controlled atmosphere storage. This result increased to 3.2 % in March and to 6.1 % after additional storage under room temperature for 7 days. The *Gloeosporium* rot of the untreated apples rose up to 54.3 % under these conditions after controlled atmosphere storage.

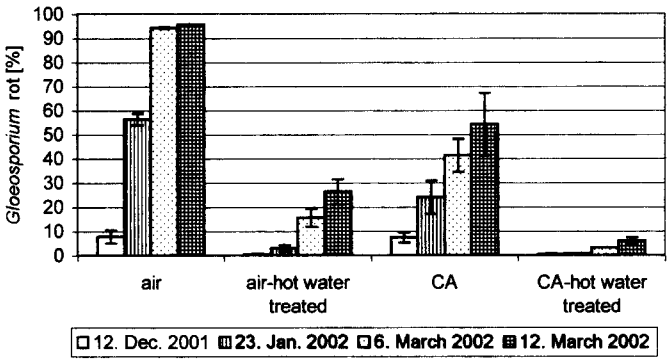

Fig. 1: *Gloeosporium* rot on organically produced apples, cultivar 'Topaz', after hot water treatment and long term storage (5 months) at 1 °C in air and controlled atmosphere (1 % oxygen, 3 % carbon dioxide). The results 12th of March were obtained after an additional storage at room temperature for 7 days.

To investigate the reason for the good reduction of *Gloeosporium* rot by hot water treatment, spores of the fungus were kept at different temperatures for two minutes. Afterwards the growth of the fungus on a special culture medium was observed. Experiments showed clearly that the growth of the fungus *Gloeosporium* was not inhibited up to 40 °C. An effective reduction in growth of the fungus could be observed when spores were kept at 45 °C for two minutes before incubation on the special culture medium. *Gloeosporium* growth on the culture medium was totally inhibited after hot water treatment of spores at 48 and 53 °C. Results of the growth experiments are shown in Fig. 2.

Because of the above mentioned results it can be assumed that the sensitivity of the fungus *Gloeosporium* to higher temperatures is the reason for the effective reduction of *Gloeosporium* rot on organically produced apples by hot water treatment.

With the positive influence of hot water treatment in preventing *Gloeosporium* rot the question about the microbial state of the dipping water arose. In connection with the microbial state the possibility of cross contamination of apples by dipping a few apple boxes into the same water was discussed. Microbial analysis of the dipping water during hot water treatment of 65 apple boxes showed no significant increase in the total microbial count, yeast and fungi in the dipping water (Fig. 3).

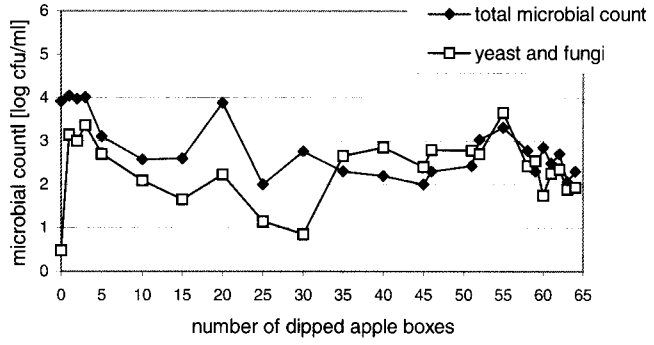

Fig. 3: Microbial state of the dipping water during two days of practice on an organic farm.

The temperature of 53 °C probably inhibits germination of spores and multiplication of microorganisms. Even one night out of order the temperature of the dipping water came to 45 °C in the morning. This could be the reason for the relatively low microbial contamination of the dipping water because growth of *Gloeosporium* was effectively reduced at this temperature as Fig. 2 shows. The relatively low amount of microorganisms in the dipping water – even after dipping 65 apple boxes - lead to the conclusion that cross contamination by the dipping water could be excluded.

Another point of investigation in this study was the determination of the internal quality of hot water treated and untreated apples in comparison. For this reason we examined the vitamin C content of apples after 4 months of controlled atmosphere storage. Fig. 4 shows the vitamin C content of different apple cultivars. Apples of the cultivar 'Elstar' possessed 10 mg vitamin C in 100 g fresh weight either in hot water dipped and in control apples. A similar result could be detected in 'Topaz' apples. In hot water treated apples as in untreated fruits the vitamin C content reached 16 mg / 100g fresh weight after a storage term of 4 months. Fig. 4 also shows less vitamin C in hot water treated apples of cultivars 'Pinova' and 'Rubinette' in comparison to untreated fruits. Furthermore, one has to consider that the results are only from

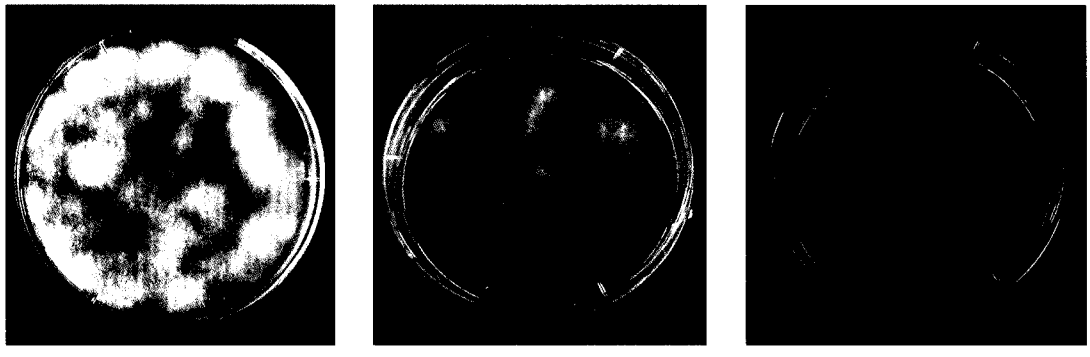

Fig. 2: *Gloeosporium* growth on a special culture medium (DSMZ 190) after spores were hot water treated at different temperatures for two minutes. Left picture: control spore solution without hot water treatment. Middle picture: spores hot water treated at 45 °C before incubation on the culture medium. Right picture: spores hot water treated at 48 °C and 53 °C respectively before incubation on the culture medium.

a one year trial and experiments have to be repeated in the following years to estimate possible influences of hot water treatment on the internal quality of fruits.

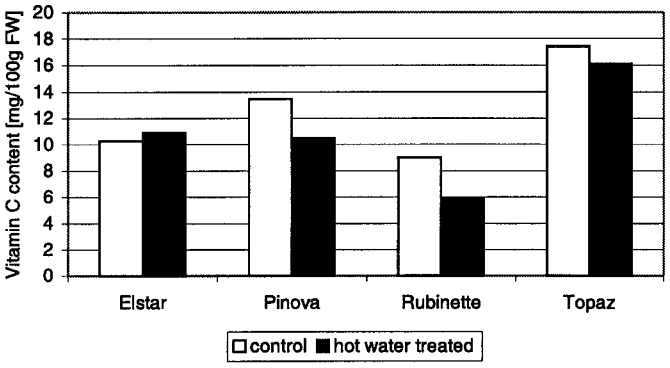

Fig. 4: Vitamin C content of different apple cultivars hot water treated and untreated (control) after 4 months of storage at 1 °C under controlled atmosphere. FW = fresh weight

The results so far show clearly an excellent effect of hot water treatment in reducing *Gloeosporium* rot on biological grown apples, and at the same time only little changes in vitamin C content. For consumers, sensory properties of foods are of great interest. Therefore, we investigated the sensory quality of hot water treated apples and untreated ones after storage for four months under controlled atmosphere. The trained sensory panel could not find any difference in quality between dipped apples and control-fruits for the main sensory parameters like taste, juiciness, and fruit pulp. The only differences could be detected for the surface quality of apples dipped in 57 °C hot water. The surface of 'Topaz' apples treated with hot water of this temperature was less positively judged because of the browning of the peel in comparison to control-apples or 53 °C treated ones (Fig. 5).

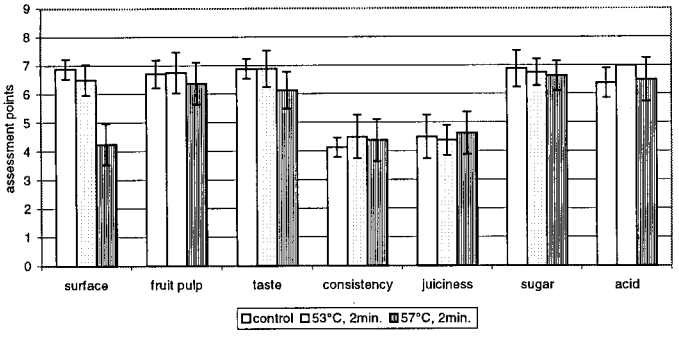

Fig. 5: Sensory quality of hot water treated apples after four months of storage under controlled atmosphere.

The results of our study clearly show that hot water treatment of organically produced apples is a very good method to reduce the most dangerous rot in organic farming, the *Gloeosporium* rot, during long term-storage. The strongest reduction of the *Gloeosporium* disease resulted from a combination of hot water treatment and controlled atmosphere storage. Investigations on the internal quality of hot water dipped apples in comparison to untreated fruits after long- term storage examined no negative influence on the apples by the treatment. Vitamin C content stayed more or less constant, sensory quality of the hot water treated apples was assessed as good as the quality of the untreated fruits. TRIERWEILER et al. (2003) also found no significant increase in fruit pulp temperature during a two minute hot water treatment and, therefore, no internal heat injuries. This result is not contrary to the above mentioned sensitivity of *Gloeosporium* to higher temperatures because the fungus occurs quiescent in the lenticells on the surface of the apples and not in the fruit pulp.

As a summary of our experiments we can say that hot water treatment of biologically produced apples is a very good alternative to the use of fungicides in organic farming. Therefore, it could also help to reduce the application of synthetic fungicides in conventional farming and to supply consumers with fruits of good quality.

Zusammenfassung

Heißwasserbehandlung zur Kontrolle der *Gloeosporium*-Fäule an Äpfeln während Langzeitlagerung

Im biologischen Apfelanbau dürfen vor der Ernte keine Lagerspritzungen am Baum mit hochwirksamen Fungiziden zur Reduzierung von Lagerschadpilzen vorgenommen werden. Durch eine 2-minütige Warmwasserbehandlung (53 °C) von ökologisch produzierten Äpfeln konnte das Auftreten der gefährlichsten Lagerkrankheit, der *Gloeosporium*-Fäule, sowohl während der Kalt- als auch der CA-Lagerung auf unter 10 % reduziert werden. Im Vergleich dazu wiesen unbehandelte Äpfel im Kaltlager zu ca. 90 % das typische *Gloeosporium*-Schadbild auf. Selbst im CA-Lager kommt es bei unbehandelten Äpfeln zu einem Ausfall durch die *Gloeosporium*-Fäule von ca. 40 %. Die Wirkung der Heißwasserbehandlung beruht wahrscheinlich auf der Temperaturempfindlichkeit des Schadpilzes, da das Wachstum des Pilzes, dessen Sporen zuvor zwei Minuten mit 45 °C warmem Wasser behandelt wurden, deutlich gehemmt wird und nach einer Behandlung mit 53 °C heißem Wasser nicht mehr feststellbar ist. Eine Anreicherung von Mikroorganismen im Tauchwasser konnte während einer 2-tägigen Heißwasserbehandlung von 65 Obstkisten nicht festgestellt werden, so dass eine Kreuzkontamination durch das Tauchwasser ausgeschlossen werden kann. Eine Beeinträchtigung der Qualität der Früchte durch die Warmwasserbehandlung konnte nicht festgestellt werden. Es konnte keine Abnahme im Vitamin C-Gehalt zwischen unbehandelten und heißwasserbehandelten Äpfeln beobachtet werden. Auch die sensorische Qualität der heißwasserbehandelten Äpfel unterschied sich nicht von derjenigen unbehandelter Früchte.

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Address of the authors:
Bundesforschungsanstalt für Ernährung, Institut für Chemie und Biologie, Haid-und-Neu-Straße 9, D-76131 Karlsruhe
e-mail: Bernhard.Trierweiler@bfe.uni-karlsruhe.de