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Rangahau Ahumāra Kai

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Adding value to Marlborough waste streams

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Project 1: Bioconversion of grape marc using insects

This pilot study was carried out by The New Zealand Institute for Plant and Food Research Limited (PFR) staff at Mt Albert in Auckland in collaboration with PFR Marlborough staff. It investigated the ability of nine insect species to feed on Sauvignon blanc grape marc (Table 1). In each case, the species were given grape marc in combination with their normal food so that the individuals did not starve if they did not feed on the marc.

Table 1. Pilot studies with a variety of insect species for their ability to feed on grape marc.

Insect type	Species	Food given	Number tested	Outcome
Lepidoptera	Spodoptera litura (tropical armyworm)	Artificial lima-bean diet + grape marc	Two experiments: 1. 6 individuals 2. Group of many individuals	1. Substrate was too wet, insects drowned 2. Dried all food. Did not feed on grape marc
	Helicoverpa armigera (corn ear worm)	Artificial lima-bean diet + grape marc	Two experiments: 1. 6 individuals 2. Group of many individuals	1. Substrate was too wet, insects drowned 2. Dried all food. Did not feed on grape marc
	Epiphyas postvittana (light brown apple moth)	Artificial “general purpose diet” + grape marc	Two experiments: 1. 10 individuals 2. 10 individuals	1. Substrate was too wet, insects drowned. 2. Dried all food. Did not feed on grape marc
	Achroia grisella (wax moth)	Bees wax + grape marc	Two experiments: 1. 6 individuals with wax 2. 6 individuals without wax	1. Indications of some feeding on grape marc. 2. Fed on small amount of grape marc but not significant enough to continue
Orthoptera	Teleogryllus commodus (black field cricket)	Mixed cricket foods + grape marc	10 individuals	Fed on small amount of grape marc but not significant enough to continue
Diptera	Eristalis tenax (rat-tailed maggot)	Some decomposing material + grape marc	Two experiments: 1. 10 individuals with grape marc and water 2. 10 individuals with decomposing grass and grape marc	1. Did not survive 2. Fed on small amount of grape marc but not significant enough to continue

Insect type	Species	Food given	Number tested	Outcome
	Hermetia illucens (black soldier fly)	Grape marc only	A group of larvae	Fed on grape marc and survived
Coleoptera	*Hylurgus lingiperda* (golden haired bark beetle)	Grape marc only	2 groups of 5 individuals	Fed on small amount of grape marc but not significant enough to continue
	Tenebrio molitor (mealworms)	Wholemeal flour + grape marc	10 sets of 100 larvae	Fed on grape marc but some groups had a lot of fungus growing on the food (Further experiments detailed in Table 2)

These experiments showed that only two of the tested species fed on grape marc to any significant degree. These were mealworms (*Tenebrio molitor*) and black soldier fly (*Hermetia illucens*). Both these species are known for feeding on a wide range of food waste and organic by-products (Fowles and Nansen 2020).

Our test with black soldier fly was limited to initial testing to determine whether the insects survived when fed with grape marc. Further tests are needed to determine the quantity of marc this species can digest and the results of that digestion in terms of weight gain, survival and reproduction, and value of outputs (e.g. quality of insect frass as a fertiliser).

We were able to conduct some preliminary tests with mealworms (Table 2). These tests showed that the mealworm larvae kept at 25°C needed to be fed an amount of grape marc approximately equal to their body weight to survive and gain weight over a 1-week period. We also found that a small amount of wholemeal flour (less than half the weight of grape marc) had to be added with the grape marc because the larvae appeared to lose weight if they were only given grape marc to feed on. However, this was only tested over a 1-week period, so further tests could be done to see if the larvae do better when left for a longer time period with grape marc as the only food source. The larvae fed grape marc + flour successfully pupated, emerged as adults, and were able to produce off-spring, suggesting that this diet was adequate to maintain the population. Comparisons between larvae fed their normal diet (flour plus cabbage) and those fed grape marc + flour showed that these diets appeared equivalent in terms of development speed and success (i.e. approximately equal numbers of larvae pupated and became adults over the same time period).

However, there are two aspects to keep in mind with these results. Firstly, we tested the loss of weight from grape marc kept in containers without mealworms, and this marc lost approximately 80% of its weight over 7 days at 25°C, presumably from evaporation. Consequently, some of the loss of grape marc weight and bulk seen in these studies was a result of evaporation. Secondly, the mealworms did not consume the grape seeds, so some of the weight of grape marc that was given to the larvae was removed again as intact seeds at the end of the week. Having said that, the mealworms reduced the weight and bulk of the rest of the marc into dry and dust-like frass (Figure 1). Analysis of this frass by Hill Laboratories suggests it may be a useful fertiliser (Table 3).

Table 2. Experiments with mealworm larvae feeding on grape marc.

Test	Aim	Weight of insects used	Weight of grape marc	Outcomes
1	To determine an approximate amount of grape marc that mealworm larvae can consume over 1 week at 25°C	Three groups: Approx. 30, 45, 80 g	Approx. 35 g in all cases	After 1 week, all groups had lost some weight (suggesting grape marc alone is not an ideal diet for this species) but the largest group (80 g of larvae) had reduced the weight of the grape marc the most: 13 g dust-like frass; 2 g seeds/stems.
2	To assess development of mealworm larvae over time when fed grape marc and a small amount of flour to provide extra nutritional requirements	Six groups starting with 27–30 g of larvae in each	Approx. half the weight of mealworms in grape marc, plus 5–10 g flour each week	Experiment conducted from 5 March to 21 April 2021. Mealworms fed weekly with flour + grape marc*. Larvae grew and pupated over time. Pupae were removed and kept separately to monitor development into adult beetles. Each week, the mealworms reduced the weight of the food by about half (it was not possible to separate the flour from the grape marc so the food was weighed as a single unit at the end of each week). For example, in the final week, the remaining 20–35 g of mealworms in each group converted their body weight in food (composed of 1/3 flour, 2/3 grape marc) into 10–15 g# of frass and seeds.
3	To compare the development of mealworm larvae when fed grape marc + flour vs their normal diet (flour + cabbage leaves)	Three groups fed grape marc, three groups fed normal diet. 40 g of larvae in each group	Each week, larvae in each group were given approx. their weight in food – either 2/3 grape marc +1/3 flour, or 2/3 flour + 1/3 cabbage	Experiment conducted from 24 March to 9 June 2021 by which time very few larvae remained in each group because most had pupated and become adults. The groups of larvae appeared to develop equally on the two diets, with up to 50 larvae pupating each week towards the end of the experiment. The amount of food we needed to give to the larvae increased over time (to 1.5 times their weight) to reduce the number of freshly pupated individuals that were eaten by the larvae if we added too little food.
4	To determine if the mealworm larvae would consume more grape marc if they were fed every 2–3 days rather than only once a week	Four groups of 40 g each. More larvae added where larvae pupated during the first 3 weeks to maintain 40 g	Each group given approx. 10 g grape marc + 5 g flour every 2–3 d (i.e. a total of 45 g food each week	Experiment ran from 28 April to 23 June 2021. The remaining grape marc and insect frass were weighed at the end of each week, as were the larvae. The remaining weight of grape marc and frass did not appear substantially different to Test 3 where the larvae were fed weekly. Larval development into pupae and adults also did not appear different to when the larvae were fed once a week.

* Grape marc changed from Sauvignon blanc to Pinot noir on 7 April 2021.
# Note that this reduction in food weight includes loss of moisture from the grape marc (approximately 80% of its weight) over the week.

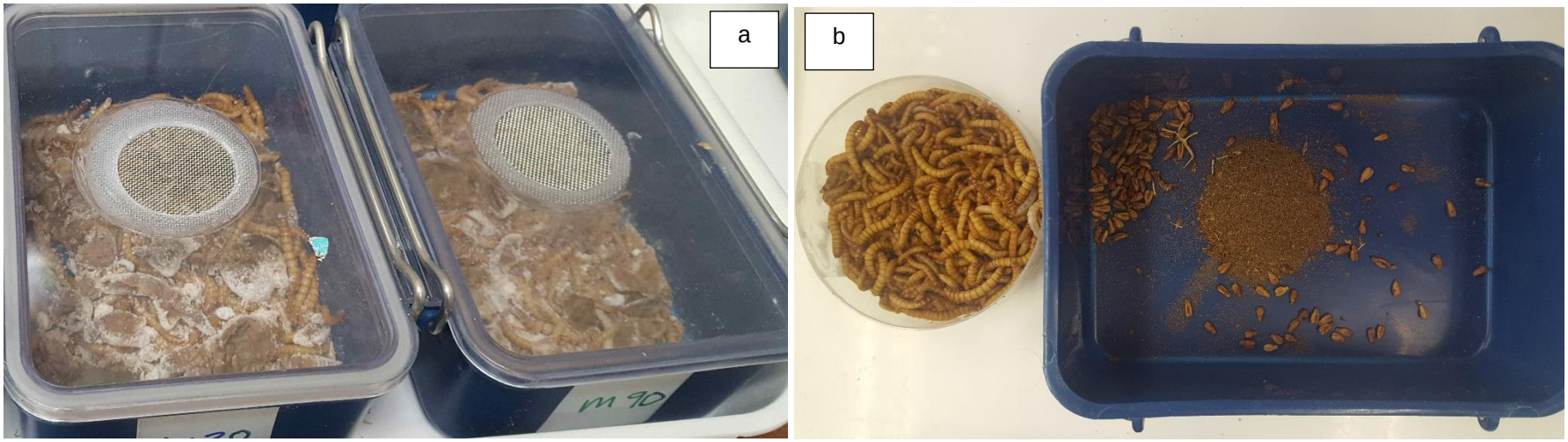

Figure 1. Conversion of grape marc and flour into dust-like frass and grape seeds. (a) Mealworm larvae were fed grape marc plus a small amount of wholemeal flour and left for a week at 25°C. (b) After a week, the larvae were removed and weighed, and the resulting frass and grape seeds were also weighed. The weight of the grape marc was reduced by about half, but the bulk was much reduced.

Table 3. Comparison of the results of a water extractable analysis of Sauvignon blanc grape marc (produced 2020) and mealworm frass (produced from feeding on different marc from that analysed in 2020).

	Sav. blanc grape marc 2020	Mealworm frass 2021 (Sav. blanc marc)	Mealworm frass 2021 (Pinot noir marc)	Units
pH	3.5	4.2	4.3	
EC	1.4	9.2	6.8	mS.cm
Nitrate-N	10.75	17	12	mg/L
Ammonium-N	6	522	98	mg/L
Phosphorus	51.5	729	450	mg/L
Potassium	370	2800	1811	mg/L
Sulphur	15	167	98	mg/L
Calcium	17.75	50	39	mg/L
Magnesium	18.5	253	120	mg/L
Sodium	2	15	6	mg/L

Next Steps

Mealworms and black soldier fly appear to be able to digest grape marc. Further work is needed to determine whether this can be scaled up to a level where these insects are a useful method for converting large quantities of grape marc into more valuable products. We have submitted an expression of interest to the Ministry for the Environment Waste Minimisation Fund seeking the funding needed to further these investigations. Our aims in that work will be to determine (1) the amount of grape marc these species can consume; (2) the quantity of insect proteins and lipids that are produced as a result; (3) the uses for these proteins and lipids as components of livestock feed, fish feed or pet food; and (4) the logistics of setting up a facility to use insects to bioconvert grape marc and other organic waste sources into these products. Insects are emerging as a sustainable solution to organic waste, with the potential of reducing carbon emissions and, at the same time, providing an alternative source of proteins, lipids and other biopolymers (see https://meticulousblog.org/top-10-companies-in-black-soldier-fly-market/). We can learn from these overseas facilities, although to our knowledge none are using insects to process grape marc.
If our application to this fund is unsuccessful, we will apply for alternative funds, for example, from the bioprocessing alliance, to enable us to conduct this work.

References

Fowles TM, Nansen C 2020. Insect-Based Bioconversion: Value from Food Waste. In: Närvänen E, Mesiranta N, Mattila M, Heikkinen A, eds. Food Waste Management: Solving the Wicked Problem. Cham: Springer International Publishing. p. 321–346.

Project 2: Developing a hydroseeding product using grape marc for native plant establishment

Overview

Grape marc is a bio-waste produced in large volumes from the wine industry each vintage and disposal is a major problem in the Marlborough region and nationally. The aim of this project is to develop a hydroseeding product from grape marc to replace imported hydroseeding material that is highly suited for sowing native groundcovers under horticultural crops, such as grape vines.
This project represents a technological approach aligned to a wider programme of work developing permanent native ground cover in vineyards and orchards. The principal goal of the overall programme is to eliminate chemical herbicide use, but if successful, the programme will generate a wide array of positive outcomes. These outcomes include: increased biodiversity, increased natural capital stocks (Caiati et al. 2020) and reduced fossil fuel inputs in horticultural production systems, while also promoting the wellbeing of communities living in proximity to horticulture (Paiola et al. 2020). A hydromulch product would be key to the establishment of native plants on a large scale at an affordable cost compared with hand planting of seedlings. The hydroseeding product would be formulated from processed grape marc and other ingredients, to deliver the moisture conditions, nutrients and physical performance required for excellent seed germination while suppressing weeds.

Project update

A funding application was submitted to Bioresource Processing Alliance (BPA) in November 2020 to develop a hydroseeding product using grape marc for the establishment of native plants in vineyards that could also be used by other horticultural crops. Unfortunately the proposal was unsuccessful but the team's intention is to reapply in the next funding round later in 2021. During the proposal process, PFR identified Erosion Control Co. Ltd as a potential industry partner and they have expressed interest in being involved in the manufacture of the product if successful. Erosion Control Co. Ltd specialise in hydroseeding (or hydro-mulching), a planting process that uses a slurry of seed and mulch for re-vegetation and erosion protection projects.

PFR has completed a full patent search to assess the freedom to operate for a grape marc-based hydromulch product. No patents were identified that may infringe on the use of grape marc in hydromulch products.

The project team expertise includes PFR biomaterial scientists and process engineers, soil and plant scientists, expertise in design and delivery of plot trials, intellectual property assessment and management. Erosion Control Co. Ltd and industry consultants contribute hydroseeding expertise.

Future work

A second funding proposal to BPA for developing grape marc as the base material for a formulated dry hydroseeding product is planned for August 2021. However, whether this application proceeds will be dependent on funding outcomes of other grape marc projects within the programme.

If funding is successful, the project will assess the plausibility of using grape marc as a hydromulch product. The project aims to achieve the following outcomes:

1. Establish key requirements for a successful grape marc hydroseeding mulch material.
2. Characterise the chemical, physical and microbiological properties of grape marc.
3. Determine the ability to modify grape marc to meet the specification requirements.
4. The feasibility will be assessed, considering properties vs specification requirements, seasonality and logistics, a speculative process and preliminary mass and energy balances and economic estimations.

References

Caiati C, Pollice P, Favale S, Lepera ME 2020. The herbicide glyphosate and its apparently controversial effect on human health: an updated clinical perspective. Endocrine, Metabolic & Immune Disorders-Drug Targets 20(4): 489–505.

Paiola A, Assandri G, Brambilla M, Zottini M, Pedrini P, Nascimbene J 2020. Exploring the potential of vineyards for biodiversity conservation and delivery of biodiversity-mediated ecosystem services: A global-scale systematic review. Sci Total Environ 706: 14.

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