# Contracts for Grain Biosecurity and Grain Quality

**Hoda Abougamos, Ben White and Rohan Sadler**

**School of Agricultural and Resource Economics, University of Western Australia, Crawley, WA 6009.**

Contributed paper prepared for presentation at the 56th AARES annual conference,
Fremantle, Western Australia, February7-10, 2012

# Contracts for Grain Biosecurity and Grain Quality

**Hoda Abougamos, Ben White and Rohan Sadler**

**School of Agricultural and Resource Economics, University of Western Australia, Crawley, WA 6009.**

## Abstract

The export of grain from Western Australia depends upon a grain supply network that takes grain from farm to port through Cooperative Bulk Handling receival and storage sites. The ability of the network to deliver pest free grain to the port and onto ship depends upon the quality of grain delivered by farmers and the efficacy of phosphine based fumigation in controlling stored grain pests. Phosphine fumigation is critical to the grain supply network because it is the cheapest effective fumigant. In addition, it is also residue free. Unfortunately, over time, common stored-grain pests have evolved to develop resistance to phosphine and there is a risk that phosphine will become less effective and may need to be replaced with more expensive alternative fumigants. Currently the alternative fumigants will involve substantial capital investment or leave residues in the grain which may restrict grain exports. There is some evidence that phosphine resistance develops on farm due to inadequate biosecurity management. As a first step to analysing this problem, this paper considers the design of farm biosecurity contracts using a principal-agent approach.

## Keywords

Principal-agent model, supply contracts, moral hazard, stored grain, biosecurity

# Introduction

Managing stored grain biosecurity (defined here as ensuring that grain is insect-free for export) in the short term involves the effective use of phosphine fumigation, in particular for the management of stored grain on farm and through the CBH network. In the medium term, there are implications for CBH storage assets as the prevalence of weak and strong resistance of grain beetles (Lesser Grain Borer Red, Rust Flour Beetle, Rice Weevil, Saw Tooth Grain Beetle, Flat Gain Beetle) to phosphine increases leading to a requirement that grain is fumigated in sealed stores. The situation in Western Australia is summarised by Chami et al (2011)

> *"The Western Australian stored grain industry is heavily reliant on phosphine to meet export market demand for insect and residue-free grain. The industry is threatened by phosphine resistance in grain insects due to the use of phosphine at all stages of the value chain, unrestricted use in poorly sealed storages and the lack of suitable alternatives. To preserve the life of phosphine, extension of responsible fumigation practices along with grain insect resistance monitoring and management has been conducted since 1984. Data show a slow increase in frequency of weak phosphine resistance but strong resistance has, until recently, only been detected in intercepted quarantine goods. The Western Australian focus is on monitoring to identify phosphine resistance, followed by effective treatment and eradication of strongly resistant strains."*

The grain supply network in WA (Figure 1 give the Kwinana Port zone) is currently at risk due to widespread weak phosphine resistance. Strong phosphine resistance has already been identified on two farms in WA (Chami et al., 2011) and this indicates that it could start to spread undetected throughout the WA grain supply network as it has in Eastern Australia. In the long term, the emergence of strong resistance will entail the introduction of alternative residue free fumigants such as nitrogen and carbon dioxide, but this would need to be linked to a significant investment in new storage facilities. Given the sunk investment costs (estimated by CBH to have a three billion dollar replacement value) in storage technology based on phosphine, the most cost efficient strategy for the medium term (the next ten to fifteen years) is likely to involve better use of existing infrastructure and more effective fumigation with phosphine at higher pressures in sealed stores. This may entail closing recieval stores and not accepting grain from farm stores that represent an excessive biosecurity risk.

The spread of strong phosphine resistance in the Eastern States is thought to be due to the misuse of phosphine on farm and in bulk grain stores over a prolonged period. Newman (2010), in his review of the evolution of phosphine use in Western Australia identifies how resistance has probably emerged and the importance of phosphine to the grain industry in WA:

> *"Phosphine has been available to famers since the 1950s when the label recommendations included the use of the product in unsealed storages and admixture to a grain stream. … It is suggested that continued use of phosphine in this manner for many decades in Australia has led to an escalating resistance in stored grain insects. In the 1980s CBH…created sealed storage in which to use phosphine exclusively for the protection of export grain. …placed more reliance on phosphine for the profitability of the entire grain storage industry in WA.*" (Newman, 2010, p99)

In terms of economics and management, a three pronged strategy is considered. First, provide farmers with an incentive to deliver insect-free and residue-free grain to CBH stores; second, within CBH, use existing infrastructure to ensure that neither infestations nor resistance emerges and third develop monitoring methods that are able to identify outbreaks of strongly resistant grain beetles quickly and cheaply, and isolate and eradicate the outbreak (Newman, 2010).

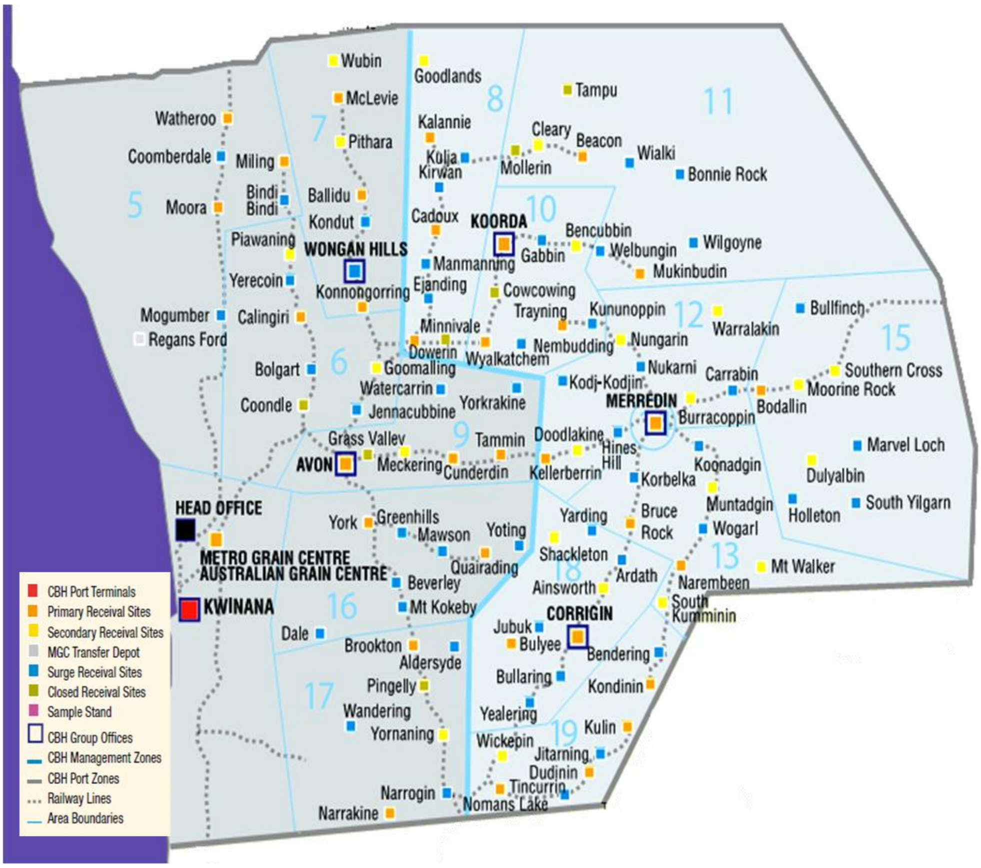


**Figure 1. CBH grain receival sites in the Kwinana zone**

The current contract is outlined in the Grain Operations Harvest Guide (CBH, 2010) which has two price levels; one for tier 1 receival sites and another for tier 2. The ability of a grain handler, such as CBH, to contract for grain that is insect and other contaminant free is complicated by twin problems of asymmetric information and moral hazard. Asymmetric information implies that the farmer knows how the grain has been managed in storage and at the farm, but CBH cannot observe this directly. The related problem of moral hazard is where the farmer does not have an incentive to manage stored grain according to industry best practice. There is widespread evidence that standards of stored grain management for biosecurity are not universally applied (Taylor and Slattery, 2010). The problem that CBH faces is one of a principal and an agent, where CBH devises a grain supply contract that pays producers a price premium for clean grain. Indirectly this induces the farmers to increase their biosecurity efforts on farm, but to reinforce this CBH must also engage in sampling for live insects and pests at the receival site.

## Better Farm Intelligent Quality (BFIQ)

In Western Australia, Better Farm Intelligent Quality (BFIQ) is the quality scheme currently used to satisfy the international market requirements, as well as to benefit the farmer. First, regarding the international markets, BFIQ scheme meets the internationally recognized SQF 1000 code and is fully Hazard Analysis Critical Control Point (HACCP) compliant. The scheme was introduced for 2008/09 harvest with a $0.5 per tonne premium and free grain testing. However, the scheme was scaled back for the 2011/12 harvest with the removal of incentive payments. The justification for this was that the grain market was facing increased competition in a deregulated market.

## Principal-agent literature and Food Safety

In general, the marketing contract between principal and agent(s) plays an important role in controlling product quality and safety. On the one hand, the principal seeks a continuous supply of safe and good-quality products to reduce transaction costs incurred with faulty products. On the other, the agent(s) requires income stability, market security and access to technology and capital. Thus, contracts serve two purposes; they coordinate exchanges in the production process, and they provide a portion of control and risk-sharing between the contracting parties/members.

Agents(s) accepting a contract are expected to conform to all requirements of the contract. Nevertheless, it is hard for the principal to measure food safety and/or observe directly product properties at delivery time. Accordingly, establishing compliance is difficult. The problem with food risks starts when growers/agents know –in advance- that their process of production and the final product quality cannot be directly noticed by processors/principals. This result in growers'/agents' probable use of poor practices, the probability will increase with the profits that can be gained through opportunistic behaviour. Therefore, the difficulty of detection or enforcement of the contract allows the grower/agent to promise the delivery of safe product but does not fulfil his promise even under contract-terms represents a moral hazard problem.

Moral hazard or incentive problems stem from asymmetric/imperfect information among members of firm as agents' actions cannot be observed and hence cannot be contracted upon. Inspection and penalties can –to an extent- influence grower's behaviour. As penalty increase, the financial risk of breaking the rules increase and hence, compliance also increases.

Heuth et al, 1999, proposed four possible remedies for the problem of asymmetric information. First, try to monitor the grower's/farmer's activities by direct observation in the field. This option could work if principal's observations could fully reflect the actual performance of the grower according to a previously-stated plan. Second, try measuring product's quality and link some portion of the farmer's payment on realized quality. Third, try to find ways to gain more control over farmer's quality-related activities by directly specifying one or more inputs that can have direct impact on the final quality. Fourth, by making farmers responsible for bad quality products, such as to make the farmer's last payment directly-related to downstream price; this will make farmers residual claimants for their poor performance (Heuth, 1999).

Our analysis is related to previous literature on principal agent models addressing food safety through marketing contracts. Harris and Raviv (1976) addressed a principal-agent relationship in which the agent provides a productive input (e.g., effort) that cannot be observed by the principal directly. Their results relate to a very specific kind of imperfect monitoring of the agent's action which allows the principal to detect any shirking by the agent with positive probability. Holmstörm, (1978) studied efficient contractual agreements between a principal and an agent under different assumptions about what can be observed, and hence contracted upon. He found that when the procedures alone are observable, optimal contracts will be second-best as a result of a moral hazard problem. Therefore, he concluded that contracts can generally be improved by creating additional information systems (as in cost accounting), or by using other available information about the agent's action or the state of nature (Holmstörm, 1978).

Elbasha and Riggs (2003) showed that regardless of the orientation of the legal system, the levels of efforts exerted by the principal and the agent are suboptimal when efforts are complements, and ambiguous when efforts are substitutes. The impacts of a policy that forces agents to provide the principal with information about food preparation and handling can improve social welfare if information is complementary to efforts (Elbasha, Riggs, 2003).

Principals have many strategies for ensuring the growers'/farmers' delivery of safe food ingredients including the reduction in measurement error through improved diagnosis and the motivation of suppliers to provide safety signals. In some supply chains, such strategies are either not possible or very expensive. Therefore, designing careful contracts can be a relative inexpensive alternative with promising potential for safe food improvement (Starbird, 2005). Also, Starbird used the principal-agent theory to explain the interaction between sampling inspection, failure costs (penalties), and food safety. He found that the sampling inspection policy, the internal failure cost, and the external failure cost have a significant effect on the buyer's willingness to pay-price for safer food and, hence, on the supplier's willingness to exert-effort required to deliver safe food (Starbird, 2005).

In September 2006, and in response to the spinach E. colli outbreak, the Western Growers initiated the California Marketing Agreement that requires all signatory leafy greens handlers to buy only product from farmers who follow the newly developed Leafy Greens Good Agricultural Practices (GAP). As a result, direct relationships with farmers/agents are based on compliance with production practices and have allowed processors/principals to become much more involved than before in the production practices (Liang, 2008). In a study carried out by Olmos (2011), he concluded that when a principal makes an effort which has an impact on a product's quality as observed by consumers, this will weaken the grower's/farmer's incentive to exert quality effort (Olmos, 2011).

Especially relevant to this study are the studies that highlight how the marketing contract between the principals and the growers/farmers affects agricultural production. Several studies have explored the effects of contracting using theoretical and empirical approaches. Liang (2008) found that the optimal premium is higher and the base payment is lower under the contract with a marketing agreement and that the processor earns less under the contract with a marketing agreement.

Until now, however, no formal studies of agricultural contracts have examined the relationship between grain bulk handler (CBH ltd. as the principal) and grain-farmer (as an agent) relationship in a principal-agent context within grain supply chain with the objective of improving final grain quality.

The contribution of this paper is to determine two issues: (i) whether the farmer's effort level affects the CBH's profit function, i.e. better farmer performance increases CBH's profit, and (ii) whether increasing monitoring effort by the CBH has an impact on farmer's performance in farm, i.e. whether a CBH's inspection effort induces farmer to exert more effort at farm.

## Principal Agent Model

The model assumes that a profit maximising risk neutral bulk handler (CBH) procures grain from a group of farmers. The aim of CBH is to maximise profit from selling grain to the world market at price $\mathrm{p_w}$ less biosecurity costs. CBH's expected costs depend on the level of effort exerted by the producer to deliver clean grain, monitoring costs for CBH and the price premium paid to provide an incentive for delivering un-infested ('clean') grain.

The model is developed in two stages. The first version of the model has the farmer's effort as non-verifiable, but CBH are able to identify the status of the grain (either infested or insect free) without cost. This module is further modified to show the case where CBH can contract directly for biosecurity effort.

## ***Non-verifiable effort and perfect information***

The merchant's objective function is given by the expected net margin per tonne of grain:

$$Z = \max_{0 \le e^f \le 1, \theta \ge 0,} \{ p_w - (e^f(1+\theta)p_f + \left(1-e^f\right)p_f + (1-e^f)c^b)\} \qquad (1)$$

Where $e^f$ is the farmer's effort in storing and treating grain in a way that reduces the probability of infestation. It is convenient to define the effort index $0 \le e^f \le 1$ as the probability of grain being insect free (Laffont and Martimort, 2002, p168). The price $p_f$ is the reserve value of grain to the farmer when grain is sold to the domestic market or used on farm as seed or livestock feed. The variable $\theta$ gives the price premium if the grain is clean, the term $c^b$ is the cost of treating infested grain. The farmer's incentive to apply effort depends on the profit derived from selling grain to CBH. This constraint comes in two parts a participation constraint that assesses that profit is not reduced from selling to CBH:

$$e^f(1+\theta)p_f + \left(1-e^f\right)p_f - c_f\ (e^f) \ge 0 \qquad (2)$$

and an incentive constraint, that assesses if the marginal benefit of exerting effort exceeds marginal costs. As the incentive constraint (Laffont and Martimont, 2002, p195) implies the participation constraint we only consider the former, if the farmer's effort is non-verifiable:

$$(\theta)p_f - c_f'(e^f) \ge 0 \qquad (3)$$

where $c_f'(e^f)$ is the marginal cost of biosecurity effort. The assumptions on the cost function are that: $c_f'\left(e^f\right) > 0, c_f''\left(e^f\right) > 0, c_f'''\left(e^f\right) > 0$.

If CBH's objective function is maximized subject to (2) we obtain the first order condition:

$$\theta = (c^b - ec_f''\left(e^f\right))/p_f \qquad (4)$$

Substituting this back into the incentive constraint (2) yields an equation for the optimal effort:

$$\left(c^b - c_f'\left(e^f\right) - e^f c_f''\left(e^f\right)\right) = 0 \qquad (5)$$

## ***Verifiable effort***

If the merchant is able to observe effort, they would contract for an optimal level of effort and pay the farmer the reserve price, $p_f$. The necessary condition is:

$$\left(c^b - c_f'\left(e^f\right)\right) = 0$$

Non-verifiable effort implies a higher optimal effort level than the first-best.

## *Non-verifiable effort and imperfect and costly CBH monitoring*

In this model set up, we consider the realistic situation where the farmer's effort is non-verifiable and the CBH engages in costly monitoring. There is now a number of possibilities summarised in Table 1

**Table 1: Event Table**

| | CBH detects grain status | |
|---|---|---|
| Farm biosecurity state | Detected | Not detected |
| Insect free | $e^f e^m$ | $e^f(1-e^m)$ |
| Infested | $(1-e^f)e^m$ | $(1-e^f)(1-e^m)$ |

To simplify this model, the following notation is introduced. First the probability of paying the premium is $\alpha^s(e^f, e^m) = e^f e^m + (1-e^f)(1-e^m)$. Second, the expected cost of bad grain $c^b(e^f, e^m) = (1-e^f)e^m c_0^b + (1-e^f)(1-e^m)c_1^b$. The first term is the expected cost when infested grain is detected and has to be segregated, the second term is the expected cost when infested grain is not detected and is allowed to infest a batch of grain. It is expected that: $c_1^b > c_0^b$. With this notation, the objective function is:

$$Z = \max_{0\le e^f \le 1, 0\le e^m \le 1, \theta \ge 0,}\{ p_w - (\alpha^s(e^f, e^m)(1+\theta)p_f + \left(1-\alpha^s(e^f, e^m)\right) p_f + c^b(e^f, e^m) + c^m(e^m)\}$$

Subject to the incentive constraint:

$$\alpha^s_{e^f}\theta p_f - c_f'(e^f) \ge 0$$

Where variables as subscripts indicate partial derivatives, for instance $\alpha^s_{e^f}$. The condition for an optimal selection of biosecurity effort between the farm and the monitoring effort on the part of the CBH is given by:

$$\frac{c^b_{e^m} + c'(e^m)}{c^b_{e^f} - h(e^f, e^m)c_f''(e^f)} = \frac{\left(\alpha^s_{e^m} + 2\,h(e^f, e^m)\right)}{(\alpha^s_{e^f})}$$

Where $h(e^f, e^m) = -(\alpha^s(e^f, e^m)/\alpha^s_{e^f})$. That is the marginal expected cost of infested grain equals the corresponding increase in the probability of grain being assessed as 'clean'.

For a given monitoring scheme for CBH, the farmer exerts the following effort:

$$\left(-c^b_{e^f} - c_f'(e^f) - h(e^f, e^m)c_f''(e^f)\right) = 0$$

## Parameters

The module has a relatively small number of parameters most are straightforward, such as the WA wheat price. The price of rejected grain or infested grain is set as a parameter in relation to the WA price. The only nonlinear elements in the module are the costs of farm effort and the costs of CBH monitoring. These functions are calibrated from available data (Taylor and Dibley, 2009).

The cost of infested grain involves two terms: when infested grain is identified, then it can be separated and treated at a relatively low cost. However a more substantial cost is incurred when infested grain is not detected and is combined in a larger batch.

**Table 2: Parameters of the Model**

| Parameter or function | Value or function | units |
|---|---|---|
| $p_w$ export wheat price 2008 | 326 | $ per tonne |
| $p^f$ farmer's reserve wheat prize | 0.7 $p_w$ | $ per tonne |
| $c_f\ (e^f) = \beta_0 \left(\frac{1}{1-e^f}\right)^{\beta_1}$ | $\beta_0 = 6.17;\ \beta_1 = 0.365961;$ | $ per tonne |
| $c_m(e^m) = \phi_0 \left(\frac{1}{1-e^m}\right)^{\phi_1}$ | $\phi_0 = 10;\ \phi_1 = 0.5;$ | $ per tonne |
| $c_0\ , c_1$ | $c_0 = 30, c_1 = 120$ | $ per tonne |

## Results

The results of this model give a clear message that asymmetric information reduces the profits of both the farm and CBH. New technology that reduces the cost of monitoring to CBH is beneficial as it reduces CBH costs, but also induces a higher level of biosecurity effort by the farmer.

The results in Table 3 illustrate the information that the biosecurity contract module produces. CBH, as the principal offers a contract to a producer that includes a price premium, when clean grain is detected, fixes a level of monitoring of grain quality and targets a level of farm effort, and that entails labour and material costs related to managing biosecurity on farms.

**Table3: Results of the Biosecurity Contract Module (per tonne delivered)**

| Results | Index of farm biosecurity effort ($e^f$) | Index of CBH monitoring intensity ($e^m$) | Priice premium ($\theta$) | CBH profit | Farmer Profit | Total profit |
|---|---|---|---|---|---|---|
| 1. Perfect information | 0.849 | 1 | 14.52 | 80.94 | 228.20 | 309.14 |
| 2. Non-verifiable farm effort CBH zero cost | 0.732 | 1 | 13.65 | 79.77 | 228.20 | 307.97 |
| 3. Non-verifiable farm effort CBH monitoring costly | 0.657 | 0.803 | 16.03 | 49.33 | 228.62E | 277.95 |
| 4. Cooperative solution | 0.945 | 0 | 0 | 81.25 | 210.32 | 291.57 |

Consider the perfect information result (1) in this instance, CBH is able to detect infested grain costlessly and therefore selects $e^m$=1, also CBH is able to contract on a level of farm effort.

Results (2) and (3) shows the more realistic case where CBH depends on a price premium $\theta$ (or cost discount) to provide producers with an incentive to deliver insect-free grain then the incentive for farm effort declines and this is especially the case in (3) when the cost of CBH monitoring dictates that CBH engages in imperfect monitoring and occasionally mis-classifies grain as infested (when not-infested) and vice-versa. These errors of classification reduce the incentives to producers for biosecurity effort. Some of the reduction in total profit can be recovered through a cooperative solution where the farmer ensures insect-free grain on farm and CBH does not engage in monitoring.

## Discussion

This paper presents some provisional results on the design of contracts for grain quality. For the realistic alternative where farm effort is non-verifiable and CBH monitoring is costly, requires that CBH pays a price premium to the producer of around five per cent over the reserve price. Farmer monitoring and CBH monitoring is substitutable.

The model can be further developed by including contracting over farm grain-store investment. This would then allow farmers to signal their intention to store grain in a way that reduces the probability of infestation.

## References

Chami M., Newman C., and Emery R. (2011). Strong phosphine resistance eradication in Western Australia. Poster Paper Presented at CRC National Plant Biosecurity, Barossa Valley Science Exchange 2011 CRC5D151

Coleman J., (1990). "Foundations of Social Theory". Cambridge (MA). The Belknap Press of Harvard University Press.

Cooperative Bulk Handling Ltd (2011). CBH Operations Harvest Guide 2010/11. https://www.cbh.com.au/media/193281/operations_harvest_guide_2010_11_screen.pdf

Cooperative Bulk Handling Ltd (2009a). Better Farm IQ. http://www.cbh.com.au/media/59216/better_farm_iq_info.pdf.

Cooperative Bulk Handling Ltd (2009b). Better Farm IQ Amendments 2011/12 season https://www.cbh.com.au/our-business/operations/grain-quality/quality-assurance/on-farm-quality-assurance.aspx

Elbasha E., Riggs L., (2003). "The Effects of Information on Producer and Consumer Incentives to Undertake Food Safety Efforts: A Theoretical Model and Policy Implications". Wiley Periodicals, Inc.

GRDC, Liebe Group, (2008). "Frameworks for Forward Farming #2".

Heuth B., Ligon E., Wolf S., Wu S., (1999). "Incentive Instruments in Fruit and Vegetable Contracts: Input Control, Monitoring, Measuring, and Price Risk". Review of Agricultural Economics. 21(2), 374-389.

Holmstörm B., (1978). "Moral Hazard and Observability". The Bell Journal of Economics.

Laffont J., Martimort D. (2002). "The Theory of Incentives". Princeton University Press.

Liang J., Jensen H., (2008). "Marketing Agreement, Food Safety and Contract Design". Iowa State University.

Newman, C.R. (2010). A novel approach to limit the development of phosphine resistance in Western Australia. Paper presented at 10th International Working Conference on Stored Product Protection.

Olmos M., (2011). "Quality and Double Sided Moral Hazard in Share Contracts". Agricultural Economics Review. 12(1).

Plant Health Australia, (2011). "The National Plant Biosecurity, Status Report 2010".

Starbird S., (2005). Moral Hazard, Inspection Policy, and Food Safety”. American Journal of Agricultural Economics. 87(1), 15-27.

Starbird S., (2005). “Supply Chain Contracts and Food Safety”. The Magazine of Food, Farm, and Resource Issues. 20(2).

Taylor S., Dibley S., (2009). “Economic Analysis of Phosphine Management, Stage 1”. Cooperative Research Centre for National Plant Biosecurity, Technical Report.

Taylor S., and Slattery J. (2010). *Grains Knowledge Networks*. CRC Project CRC70096 Final Report. Canberra: CRC National Plant Biosecurity.