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Executive Summary

A major challenge for free range poultry farms is to maintain vegetation on the outdoor range area. Poultry are very destructive toward most plants with pecking and scratching activity the most damaging. Nevertheless, free-range accreditation programs stipulate that there must be vegetative cover on the range at all times. Additionally, there is the consumers' perception of free-range poultry happily foraging amongst green grassy pastures. However, in some poultry production regions of Australia (Western Australia, South Australia, Victoria, northern Tasmania and southern New South Wales) maintaining vegetation on the range will be an even bigger challenge due to low and/or erratic rainfall and poor soils. Highly adapted plant species suited to low rainfall conditions need to be considered for free-range poultry farms in marginal areas. A potential group of suitable plants are the saltbushes. Saltbushes are highly regarded by the pastoral grazing industries and they may also play an important role in the free-range poultry industry by providing shade, shelter and possibly forage for chickens.

There is potential for saltbush to be grown in many regions across Australia due to the plant's wide adaptation. However, the scientific literature did not provide any evidence of poultry eating saltbush *in situ* on the range. Layers will have the greatest capacity and opportunity to eat saltbush compared to meat chickens because they are more active and have access to the range for at least one year. Positive and maybe negative consequences to poultry production and health may arise from birds eating saltbush planted on the outdoor range, but at this stage we do not know what they are. The impact will be largely determined by the quantity of saltbush eaten by poultry. Like many plant species, saltbush contains anti nutritive factors and is high in sodium chloride. Therefore it is important to determine if there are negative consequences for poultry that may eat saltbush. The objective of this project was firstly to determine if free range laying hens and meat chickens eat saltbush and secondly what are the effects on production, welfare and product quality should free range laying hens and meat chickens consume saltbush?

Firstly, a trial was conducted to examine whether hens eat saltbush while ranging outdoors. Free range Hy-line Brown layer hens were provided "with" and "without" saltbush on the outdoor range throughout 11 weeks of early production (16 weeks – 27 weeks). The quantity of saltbush eaten by the hens was determined by the n-alkane method and the 'Adelaide' method. Hen interactions with saltbush were video recorded while hen live weight, feed intake, egg production and egg quality were measured. Layer hens definitely ate the saltbush, it was estimated 5% of their dietary dry matter (DM) intake was saltbush and video footage revealed hens actively pecked at the saltbush. This level of saltbush intake had no influence on the production of the hens.

In the second layer hen trial, the consequences of hens eating increased levels of saltbush were determined. Air-dried saltbush was incorporated into Ridley Barastoc Top Layer Crumbles at the following levels; 0%, 5%, 10%, 15% and 20%. Hy-line Brown layer hens were fed the diets for 28 days (32 – 35 weeks old). There were 15 individually housed hens per diet. The saltbush had no significant impact on egg production, hen live-weight and feed intake. Excreta moisture increased significantly with increased saltbush in the diet. Furthermore, high saltbush eggs (20%) had significantly stronger egg yolk colour and thicker egg shells compared to the control eggs. Very interestingly, consumers had shown a preference for eggs (boiled and scrambled) produced from higher saltbush fed hens.

To investigate whether meat chickens eat saltbush, a series of studies were carried out on a property south of Adelaide during summer/autumn and winter. Fully brooded chickens were raised in moveable enclosures on pasture, whereby they were moved to a fresh section of pasture daily. Saltbush was placed in one of the enclosures. Chickens were videoed and the amount of saltbush removed from the enclosure determined. Meat chickens were found to actively peck and eat saltbush and this was often in preference to pasture plants and weeds. In addition, weather conditions had a large influence on the opportunity for meat chickens to access saltbush. During extremes of weather (e.g. cold/rainy) birds remained in the shelter.

Finally, a study explored the consequences of feeding increased levels of saltbush to meat chickens at day 21 - 28. Air-dried saltbush was incorporated into broiler pellets at 0%, 5%, 10% and 15%. The diets were designed to dilute the normal diet to simulate differing levels of saltbush consumption by chickens out on the range. The 5% saltbush chickens had the greatest weight gain, but this was not significant from the control. Although the highest level of saltbush in the diet did result in the lowest weight gain. Feed conversion ratio (FCR) was lowest for the 5% saltbush and control treatments, with significantly the highest FCR for 10% and 15% saltbush. Excreta moisture showed an increase with higher levels of saltbush but this was not significant.

Under commercial free range conditions it is unlikely that layer hens and meat chickens would be able to eat enough fresh saltbush to impact their production. As such, saltbush would be a valuable addition to the outdoor range area on free range poultry farms to provide shade and shelter. Saltbush also shows promise as a new fed additive for layers in the production of unique eggs. But this will need to be verified on a larger scale.

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1.Introduction

Free range poultry production continues to grow in market share within Australia (47% eggs and 15 % meat, AECL 2013 and ACMF 2011 respectively), but there are many challenges facing the industry. A major challenge is to maintain vegetation on the range area. Poultry are very destructive toward most plants with pecking and scratching activity the most damaging. Nevertheless, free-range accreditation programs stipulate that there must be palatable vegetation on the range at all times. Additionally, there is the consumers' perception of free-range poultry happily foraging amongst green grassy pastures. However, in some poultry production regions of Australia (Western Australia, South Australia, Victoria, northern Tasmania and southern New South Wales) maintaining palatable vegetation on the range will be an even bigger challenge due to low and/or erratic rainfall and poor soils.

The number of forage plant species available for low rainfall areas are not plentiful compared to higher rainfall areas. Yet, recent research on the forages used in free-range poultry is largely based on European and American systems with plant species suited to high rainfall and temperate climates (Breitsameter, et al., 2014; Breitsameter, et al., 2013; Dal Bosco, et al., 2014; Moyle, et al., 2014). The limited research from Australia (Glatz and Ru, 2004; Glatz, et al., 2005) examined the integration of free-range poultry in the medium rainfall (445mm average annual rainfall) sheep-cereal zone of South Australia. Farming systems in the sheep-cereal zone are predominantly based on annual plant types that do not remain green and senesce during the summer months. Singh, et al., (2013) later conducted studies to quantify the amount of grass consumed by poultry, the pasture was Kikuyu (*Pennisetum clandestinum*), a perennial tropical grass species that originated from eastern Africa suited to high rainfall or irrigation. Kikuyu is commonly grown on free range poultry farms in eastern Australia. However, new free-range poultry production enterprises in southern Australia are being developed in marginal agricultural areas. These areas have cheap land prices, are typically low rainfall (250 - 300 mm average annual rainfall), have shallow and poor fertility soils. These soil types and climatic conditions will not sustain the perennial and annual species grown in higher rainfall zones of Australia without the consistent use of irrigation. Irrigation water will be a limited resource and not sustainable during the high evaporative losses during the hot summer months in low rainfall marginal areas. Highly adapted forage species suited to low rainfall conditions need to be considered for free-range poultry farms in marginal areas. A potential group of suitable plants are the saltbushes. Saltbushes are highly regarded by the pastoral grazing industries and they may also play an important role in the free-range poultry industry by providing shade, shelter and possibly forage for chickens.

The term saltbush refers to a large group of plants, approximately 200 species world-wide consisting of many different genera. Australia is rich in the number of saltbush species and saltbushes are the main forage plant found in the pastoral zone. The most widely cultivated species in Australia is oldman saltbush (*Atriplex nummularia*) which is also grown extensively overseas (De Koning and Milthorpe, 2008), as such oldman saltbush will be the main species discussed.

Nutritive value

Generally, nutritive values of leaves are higher than stems, and younger leaves have better nutritive value than older leaves (Barrett-Lennard, et al., 2003). In the review by Ben Salem, et al., (2010), the nutrient content of oldman saltbush was investigated across many studies and countries. The crude protein (CP) in the leaves varied from 12.4% (Chile) to 25.2% (Saudi Arabia) under rain-fed conditions, but was more commonly found above 15%. The authors concluded that variations in CP were probably due to age of plants, the season and differences in edaphic and climatic conditions. Later, as part of the "Enrich" Future Farms CRC project in Australia, oldman saltbush measured 18% CP (Revell, et al., 2013).

Saltbush grows actively during summer and autumn and becomes dormant during the colder months winter/spring (Barrett-Lennard 2003). This is due partly to a temperature response. The nutritive value can be higher during the summer/autumn period when saltbush is actively growing

(Norman, et al., 2002). Later, Norman, et al., (2010) had shown the converse, CP of oldman saltbush was highest in June (greater than 20% of DM) and lowest in March (approx. 12% of DM). However, the later study by Revell at al., (2013) had shown very small differences in seasonal nutritive values from winter and summer samples of 39 Australian shrub species, including many saltbush species. Oldman saltbush can have high levels of the minerals; S, Mg, Ca and P this can have negative or positive influences on ruminant production Ben Salem, et al, (2010). There is also a range of amino acids found in saltbush, in particular methionine and lysine are found at higher levels than those in cereal proteins (Ben Salem, et al., 2010).

Anti-nutritive factors

The main anti-nutritive factors (ANFs) in saltbush are salts, oxalates, saponins, tannins, alkaloids and non-protein nitrogen (nitrates). Any possible adverse effects from ANFs will depend on the chemistry of the ANF, the concentration and the amount consumed (Acamovic and Brooker, 2004).

<u>Salts:</u> Salt in saltbush is potentially the most limiting ANF for poultry. The ash content of saltbush can be high with most in the form of soluble salts such as sodium, potassium and chloride. Norman, et al., (2010) measured 28% to 31% ash in the edible DM of *Atriplex* species, this level of ash was considered high enough to restrict the feed intake and digestibility in ruminants. The salt levels found in saltbush indicate high levels of electrolytes, whether this will have an effect on dietary electrolyte balance in poultry will be largely determined by the amount of saltbush eaten. Higher salt levels are found in saltbush grown on saline soils (De Koning and Milthorpe, 2008). Poultry on high salt diets increase their water consumption. Increased salt in the diet can then increase excreta moisture levels. Barreto, et al., (2012) found meat chickens in their study drank more water with increased levels of saltbush in the diet, furthermore the saltbush in their study was irrigated with brackish water and this would have contributed to high salt content. Therefore, the impact of the salt on bird performance will depend on the proportion of saltbush eaten in the overall diet and whether the saltbush was grown on saline soil or irrigated with brackish water.

<u>Oxalates/Oxalic acid:</u> Oxalic acid is known to interfere with mineral metabolism and decrease availability of calcium, phosphorus, magnesium, zinc and iron (Swick, 1999). Nevertheless, chickens do have some capacity to excrete oxalates. Approximately 26% of the oxalate reaching the kidneys of chickens was excreted in the urine (Tremaine, et al., 1985). Overseas studies have shown 6.20% oxalate in *Atriplex nummularia* (Abu-Zanat, et al., 2003), this was found to vary depending on the season with oxalate levels in *Atriplex* species ranging from 8.29% and 4.92 % in dry weight in spring and autumn respectively. Rahman and Kawamura (2011) found the highest oxalate levels in saltbush were in summer. Oxalate content in forages is influenced by many factors such as fertilisers, type of forage species, harvesting practices and seasonal growth (Rahman and Kawamura, 2011).

<u>Saponins:</u> Saponins are found in many plant species and are commonly found in legumes such as alfalfa (Lucerne). Different varieties and plant parts of alfalfa and the season can influence saponin content (Sen, et al., 1998). There are two categories of saponins, steroid and triterpenoid glycosides. The triterpenoids are those mostly found in legumes (Cheeke, 1971). Saponins are such a diverse group of compounds with positive or negative effects on animals (Francis, et al., 2002; Wallace, et al., 2010). High concentrations of saponins in the diets of poultry can reduce feed intake due to their bitter taste. As a result this can lead to poor performance and growth rate of monogastrics with poultry being the most sensitive as reported in the reviews by Cheeke (1971) and Francis at al.(2002). Saponins can also obstruct cholesterol and bile acid absorption and interfere with fat digestibility, this can negatively affect the absorption of the fat soluble vitamins A and E (Jenkins and Atwal, 1994). One study in Tunisia measured 1.4% saponins in the leaves and twigs of oldman saltbush (Ben Salem, et al. 2010).

<u>Tannins</u>

There are two main classes of tannins: hydrolysable tannins and condensed tannins, they are polyphenolic compounds with a range of molecular weights and complexity. Tannins bind with protein to form insoluble complexes. In terms of poultry production tannins can depress feed intake due to their astringency, and they can have a range of adverse effects on poultry including reduced energy digestibility (Jansman, 1993). The level or concentration of tannins can determine the response, for example in the study by Hughes, et al., (2005) the inclusion of the highest rate of condensed tannin sourced from grape seed at 30g/kg did reduce feed intake and growth rate of male Cobb 500 chickens, but no detrimental effect was detected at 2, 5 and 10g/kg rate. Not all plants containing high levels of condensed tannins deter poultry from eating them. The herbaceous leguminous plant *Sericea lespedeza* was eaten by meat chickens despite the high condensed tannin content (Moyle, et al., 2012). Both hydrolysable and condensed tannin are found in oldman saltbush as shown by the many studies summarised by Ben Salem, et al., (2010). Furthermore, seedlings had higher levels of condensed tannins than older plants Abu-Zanat, et al.,2003). It is unlikely that free range broilers will eat enough saltbush to be adversely affected by tannins within the three weeks they have access to the range. However, layers will be different because they are more active than broilers and are under free range production for a longer duration (up to a year or more), this will give them potentially many more opportunities to eat outdoor forages. Hens consuming high tannin feeds have resulted in mottled and green coloured egg yolks (Cunnigham and Sanford, 1974; Fry, et al., 1972; Hughes, 1973; Potter, et al., 1967).

<u>*Alkaloids*</u>
Alkaloids are compounds with great structural diversity and found in many sources such as bacteria, fungi, plants and animals. As with many ANFs, alkaloids can have beneficial or harmful effects. This depends on the type of alkaloid, concentration and the animal species consuming them. For example, the alkaloid betaine is a osmo-protectant found in plants (including saltbush), it can have beneficial effects on poultry such as increased tolerance to heat stress and reduced *Eimeria* parasitic infection (Metzler-Zebeli, et al., 2009; Wallace et al., 2010). However, the pyrrolizidine alkaloids are highly toxic to poultry (McLean, 1970; Pass, et al., 1979). Oldman saltbush leaves contain glycine betaine and coupled with vitamin E this may enhance meat quality in ruminants (Ben Salem, et al., 2010).

<u>*Nitrates*</u>
Much of the nitrogen found in saltbush is in the form of non-protein compounds such as nitrate (Ben Salem, et al., 2010). Dietary nitrates may be an issue as they can cause pink discolouration of cooked meat (Froning, et al., 1969). Nitrates are toxic to poultry, particularly when delivered via water (Mattocks, 2002) with young birds more susceptible than older birds (Carter and Sneed, 1996). Nitrate is converted to nitrite by the microorganisms found in the intestinal tract of the bird (Walker and Gordon, 2003). Nitrite is toxic and can be absorbed into the bloodstream whereby it binds strongly to haemoglobin. This reduces the oxygen carrying capacity of the blood. Chronic nitrate toxicity causes poor growth, anorexia and poor coordination. For example, sodium nitrate fed at 4.2g/kg diet and sodium nitrite at 1.7g/kg retarded growth in cockerels (Atef, et al., 1991). Although Safary and Daneshyar (2012) found dietary sodium nitrate fed to hens at 4.2 g/kg did not affect egg production, shell strength and Haugh unit but it did decrease egg production and egg mass during weeks 30, 31 and 32. Oldman saltbush was measured with 0.25g/kg nitrate by Norman, et al., (2004) This is well below the levels fed in the studies by Atef, et al., (1991) and Safary and Daneshyar (2012). However, nitrate levels found in saltbush are influenced by environmental growth conditions.

Poultry fed saltbush
There is very little information on the performance of poultry fed saltbush. Cilliers, et al., (1999) compared ostriches with cockerels fed oldman saltbush (*Atriplex nummularia*). Ostriches had higher true metabolisable energy (TME_n) values compared to cockerels (7.09 MJ/kg and 4.50 MJ/kg respectively). The saltbush in the trial had a CP of 118 g/kg. It was concluded that ostriches are better at digesting high fibre foodstuffs than cockerels. This outcome is not surprising since cockerels are classified as omnivores and ostriches as herbivores with a gastrointestinal tract able to cope with fibrous diets (Klasing, 2005). In Brazil, Furtado, et al., (2011) examined the prospects of using oldman saltbush as a supplementary source of protein in the diet of naked-neck meat chickens. They had substituted saltbush hay into the basal diet at the levels 0%, 5%, 10% and 15% DM. Chicken meat production was not affected by saltbush levels fed up to 10% saltbush in

the diet. Although at the 15% level there were significant reductions in the overall carcass weight, thigh and breast meat yield. In addition, there was also significantly less abdominal fat. (Barreto, et al., 2012) also explored the prospects of *A. nummularia* in the diet of French free-range meat chickens in Brazil by replacing the cassava hay portion of the basal diet with saltbush at 0%, 35%, 65% and 100%. Fifty percent replacement of cassava with saltbush was the most economical diet combination and produced the heaviest carcass weights.

There is some anecdotal evidence that poultry enjoy ranging around saltbush, but the scientific literature has not revealed any examples of layers eating saltbush *in situ*. Nevertheless, there is a study that did examine the feeding of oldman saltbush leaf meal to Sina laying hens (Abd El-Galil, et al., 2014). Up to 8% oldman leaf meal substitution in the diets of the hens did not adversely affect their physiology and production. It would be very important to determine if layers eat saltbush while ranging, and if they do, will that affect egg quality and cause any undesirable taint or discolouration to the egg yolk. It has been known for some time that certain plant species if eaten by hens can discolour the yolk, for example Shepherd's Purse (*Capsella Bursa-pastoris*) and Penny Cress (*Thlaspi arvense*) can turn egg yolks olive green (Payne, 1927). Yet there may be positive egg attributes from hens eating saltbush such as improved egg yolk colour.

Shade, shelter and enrichment

Encouraging more poultry to go out onto the range has become a significant issue for free-range production. Saltbush could play a vital role in providing shade and shelter on the range thereby attracting more birds to go out and use the range area. For example Dawkins, et al., (2003) had shown a positive correlation with more meat chickens found outside with increased tree cover on the range. Also time of day and season had influenced the number of birds found outside. The size or age of the tree on the range may influence whether chickens go outdoors more. Jones, et al., (2007) found newly planted trees had very little effect on the number of chickens going outdoors, but three year old trees started to have an influence due to shade being created and chickens seeking out shade. In Italy, meat chickens ventured furthest from the poultry house with olive trees on the range compared to no trees (Dal Bosco, et al., 2014). Similar results were shown with Hy-Line layers, where shelter belts were provided on the range, more hens were outside compared to non-shelter belt ranges (Borland, et al., 2010; Nagle and Glatz, 2012). Saltbush plants could provide enough shade and shelter at 18 months old. Grown under ideal conditions oldman saltbush can grow 2-3m tall and can spread 3 – 5 m wide, but it can easily be kept low growing by pruning.

The types of trees and shrubs planted on the range needs careful consideration. It is not desirable to have large trees that flower as they will attract wild bird species. In addition, birds of prey will use large trees as convenient vantage points to observe and attack chickens. Oldman saltbush offers an alternative to larger trees as it can be easily kept to a desirable height by cutting and pruning. Saltbush is a wind pollinated species and produces inconspicuous flowers that are not bird attracting, but wild birds do utilise saltbush for shelter. The number and variety of birds found in saltbush plantations in the southern Murray Mallee region was found to be between that found in remnant vegetation and pasture, with greater numbers occurring in spring than in autumn (Collard, et al., 2011). Saltbush on poultry farms would not be planted at the high densities of plantation blocks found on cereal-livestock farms, therefore the capacity to attract wild birds would not be as high.

Where saltbush can be grown in relation to poultry production areas

Oldman saltbush naturally occurs in the arid and semi-arid inland areas of Australia (Figure 1). Nonetheless, oldman saltbush has a wide range of adaptation and will grow in other areas. The soil and climatic attributes that favour the growth of oldman saltbush are outlined in Table 1.

Table 1: Soil and climatic attributes for oldman (*Atriplex nummularia*) saltbush in Australia

Attribute	**Description**
Soil Type and texture	Saltbush occurs naturally on heavier soil types but can be grown on a wide range of soil types, including clay loam, heavy clay (greater than 50% clay), medium clay (35- 50% clay) , loam, sandy loam, sandy clay loam and sand. Tolerant of shallow, skeletal soils.
Soil pH	Neutral 6.5 – 7.5, tolerates high alkalinity (greater than 7.5)
Salinity	Highly tolerant of saline soils and salty coastal winds
Waterlogging	Not tolerant of prolonged waterlogging
Mean annual rainfall	230 – 650 mm; rainfall distribution can be uniform, summer or winter dominant
Mean max. temperature for the hottest month	32-37^{o}C
Mean min. temperature for the coldest month	3-7^{o}C
Frost	Relatively frost tolerant (0 to -5^{o}C)
Altitude	0 – 400 m
Drought	Moderately drought tolerant and can tolerate prolonged drought conditions
Fire	Can regrow foliage after fire

Source: from www.florabank.org.au accessed on 18/03/2014

Given that many poultry production areas are located in high rainfall zones along the east coast of Australia (Figure 1); the question maybe asked, will this restrict the usefulness of saltbush? For instance, in New South Wales the recommendation is not to grow saltbush in areas that receive less than 300 mm and higher than 600 mm average annual rainfall (NSW, Agnote DPI – 484, 2004). This recommendation is based on both economic and climatic factors. Below the 300mm rainfall isohyet, saltbush becomes less economic to grow because the cost of establishment for large plantation blocks becomes prohibitive due to higher levels of establishment failure and lower growth rates, unless supplementary irrigation is supplied (Honeysett, et al., 2010). Above the 600mm rainfall isohyet in NSW, this corresponds with 350m altitudes; these areas are normally too cold for saltbush with very acid soils prone to severe waterlogging. The percentage survival of oldman saltbush plants can be relatively high on acidic soils (72% - 91% after three years) but edible biomass was much lower compared to sites with neutral alkaline soils (Emms and Revell, 2014). Lower edible biomass of saltbush is not an issue on poultry farms as shelter and shade aspects would be considered more important than the production of edible forage.

There are still many poultry areas within New South Wales with lower altitudes and mild temperate climates where saltbush has the potential to be grown (e.g. Griffith, Tamworth, Mangrove Mountain, Camden and Hunter Valley). Other Australian localities include; Queensland (e.g. Boodua and Calliope), northern Tasmania, southern Western Australia and Victoria (e.g. Nagambie, Bendigo, Colac). The expansion of the free range poultry industry into the drier regions around Australia is due to cheaper land prices, less population, government incentives and reduced community objections compared to higher rainfall and peri-urban areas around Sydney, Melbourne and Brisbane which are more densely populated. For example, PIRSA (Primary Industries and Regions South Australia) has identified precincts ideal for poultry production in South Australia at Pt Wakefield, Murray Bridge and Blanchetown (www.aginsight.sa.gov.au).

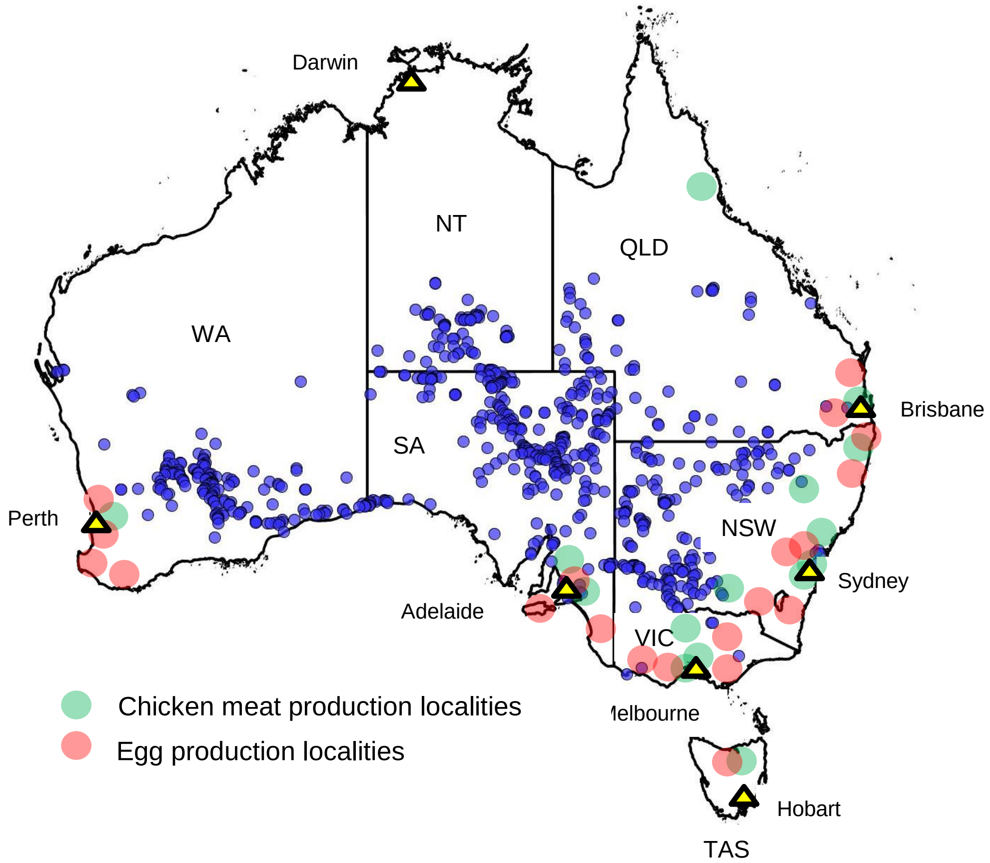

Figure 1: The occurrence of oldman saltbush (blue spots) in relation to the main chicken meat and egg production localities in Australia. Source of map; adapted from ACMF (Australian Chicken Meat Federation map) and ALA (Atlas of Living Australia).

Conclusions

Saltbush could provide many benefits to free range poultry farms, particularly for those farms located in low rainfall or erratic rainfall areas. Those benefits include shade, shelter, range aesthetics and possibly forage. There is potential for saltbush to be grown in many regions across Australia due to the plant's wide adaptation. However, the scientific literature did not provide any evidence of poultry eating saltbush *in situ* on the range. Layers will have the greatest capacity and opportunity to eat saltbush compared to meat chickens because they are more active and have access to the range for at least one year. Positive and maybe negative consequences to poultry production and health may arise from birds eating saltbush planted on the outdoor range, but at this stage we do not know what they are. The impact will be largely determined by the quantity of saltbush eaten by poultry.

2. Objectives
Saltbush could provide shade, shelter and potentially forage on the range of free-range poultry farms in low or unreliable rainfall regions of Australia. However, we do not know the impact saltbush may have on poultry welfare and production. Both meat chickens and layers were examined in this project as their requirements and activity levels on the range are substantially different.

- To determine whether free range meat chickens and layers eat saltbush, and if they do, what are the consequences to production.

- Make recommendations for the management of saltbush used on the range of free range meat chickens and layers.

3. Methodology
The project was divided into two main components, 1.Layers and 2. Meat chickens. For each poultry type, trials were designed to firstly, determine whether birds ate saltbush and secondly, measure the impacts on production.

3.1.0 Do layers eat saltbush?
The trial was conducted at the free range facility at The University of Adelaide, Roseworthy campus, South Australia. Treatments were "with" and "without" saltbush on the range with three replicates of each treatment, this gave a total of six areas. Oldman saltbush (*Atriplex nummularia*) was placed on the "with saltbush" range areas by cutting small saltbush branches 40 – 50cm long and placing them into 2 litre buckets of water. Each saltbush treatment paddock had ten buckets of saltbush with three branches of saltbush in each bucket (a total 30 branches per replicate). Buckets were dug into the soil at ground level and branches of saltbush were pushed through holes in the bucket lid (see Photo 1 and 2). The lids prevented the hens from drinking water from the saltbush buckets. The saltbush buckets were arranged on the range in two rows of five buckets each. Saltbush buckets were 1.5 m apart from one another and placed eight m from the hen house. Fresh saltbush was provided on the range every seven days for the duration of the trial.

Hy-Line Brown pullets (non-beak trimmed) were transferred to the facility at 16 weeks of age on the 15th September 2015 and were randomly allocated to each treatment. A treatment area housed 35 hens giving a total of 210 hens. They remained locked in the hen house for ten days to acclimatise. The pullets were weighed before being allowed access to the range for the first time on the 25th September 2015. The study continued until the hens were 27 weeks old (2nd December 2015). Feed (Barastoc Top Layer Crumbles) and water was provided in the hen house at all times. Unfortunately, the trial was finished one week earlier than planned due to a fox attack when the hens were 26 weeks old, a total of 38 hens were killed. However, enough data had been collected by the time of the fox attack and some measurements were able to be made post fox attack. Egg numbers were recorded daily, egg quality was measured when the hens were 27 weeks old and hen live-weight measured monthly.

The consumption of saltbush was calculated using the Adelaide method (Andrew, et al., 1979) at two times. Furthermore, the *n*-alkane method was also used to estimate saltbush consumption and this was measured when the hens were 23 and 27 weeks of age. Excreta samples for n-alkane were collected by placing drop sheets under the perches in the hen house on the afternoon of the same day when fresh saltbush was placed on the range. Excreta samples were collected the next morning from the drop sheets. Samples of plant species growing on the range were also collected along with feed samples. Some intake components were excluded from the analysis as the number of intake components have to be less than the number of alkanes in the profiles. The odd chained alkanes examined were C27, 29, 31, 33 and 35. The intake components used when the hens were 23 weeks old were; saltbush leaf, saltbush seed, green grass (annual species) and pellet feed. At 27 weeks old the intake components were saltbush leaf, green grass (perennial species), dry grass (annual species) and pellet feed. Final values were obtained by fitting of equations in the EATWHAT program. A non-parametric Wilcoxon Rank Sum Test was used to analyse the pellet component data.

Hen interactions (pecking activity) with saltbush was videoed weekly from 21 weeks of age until 26 weeks of age. Videoing occurred on the day after saltbush had been renewed and the hens were videoed for one hour starting at 9am and again at 4pm on those days. In addition, the numbers of hens on specific areas of the range were recorded morning and afternoon every seven days from 21 weeks until 26 weeks of age.

ANOVA was used to statistically analyse the data for hen weights, interactions with saltbush, percentage flock on range and egg quality measures. The data for interactions with saltbush was log transformed.

3.1.1 Consequences to production when layers eat saltbush

River saltbush (*Atriplex amnicola*) was harvested by Wilson Pastoral, South Australia when it was actively growing and then air-dried and hammer milled. Oldman saltbush was not used as it was not available for harvest at the time of the trial. Saltbush was incorporated into Ridley Barastoc Top Layer Crumbles at the following levels; 5%, 10%, 15% and 20% with a control of no saltbush. The saltbush diets represent the situation where hens may dilute their pellet diet with saltbush they consume while out on the range. Hy-Line Brown pullets were purchased at 16 weeks of age and placed in the layer production facility at Roseworthy campus, South Australia until required for the trial. When the hens had reached 32 weeks of age the trial commenced. A single bird was allocated at random to a cage. Each dietary treatment had 15 individual bird replicates (5 diet treatments x 15 replicates = total 75 hens). Hens were fed the saltbush diets for 28 days (32 – 35 weeks of age). Furthermore, neither yolk colour pigments nor shell grit was added to the diets of the hens for the 28 days. During that time, egg production was recorded. Egg quality was determined after 17 and 18 days on the diets (egg weight, shell weight, shell thickness, Haugh unit and yolk colour). In week 4, all eggs from each diet treatment were collected and set aside for the consumer acceptability trial. At least 70 eggs from each diet were provided. Live-weight of hens was measured at the start and end of the trial. Feed intake throughout the trial was determined and excreta moisture measured on day 28. Analysis of Variance (ANOVA) was conducted on all variates using Analytical Software *Statistix* 8 (Tallahassee FL, USA).

The South Australian Research and Development Institute (SARDI), Food Safety and Innovation group conducted a consumer acceptability trial on the eggs from the five diet treatments, using a panel of 120 untrained consumers. The consumers were a sample of staff located around the University of Adelaide, Waite Campus and were recruited based on two criteria; 1. Enjoyed eating eggs and 2. Consumed boiled and scrambled eggs within the past month. In a blind tasting (consumers were not informed of the source or treatment of eggs), the consumers' rated their liking of specified sensory attributes such as appearance, aroma, flavour, mouthfeel/texture, aftertaste and overall liking, on a 9-point category scale anchored from 1 'dislike extremely' to 9 'like extremely'. Samples of hard-boiled egg (60 people) and scrambled egg (60 people) were presented to consumers using a balanced, randomised presentation order. Consumers were presented with half a boiled egg from each treatment and a 30g sample of scrambled egg. Filtered water was provided for panellists to cleanse their palate between samples. Consumer tasting data was collected and analysed using Compusense Five software (Version 5.6, Compusense Incorporated, Guelph, ON Canada). ANOVA was performed using the individual consumer scores for each sample, to identify whether statistical differences existed between samples for each attribute, where $P \leq 0.05$.

3.2.0 Do meat chickens eat saltbush?

The trial work was conducted on "Nomad Farms", Finniss, South Australia. They produce meat chickens for niche markets by using moveable enclosures. Through the production system utilized on Nomad Farms, it was possible to determine whether the birds actively sought the saltbush in the presence of their regular feed and other pasture species in summer/autumn and during winter.

Summer/autumn - The first batch of chickens for the year started brooding on the 3rd March 2016. Chickens were then placed in two moveable enclosures (each 12 m^2) on the 23rd March, where they had fresh pasture available daily. Measurements were made when the birds were 21 and 42 days old. At d 21 one enclosure had saltbush (67 birds) and the other without saltbush (66 birds). Chickens in the saltbush enclosure had available 435 g of edible fresh saltbush. This was done by placing 30 saltbush branches 30cm long in ten 760ml buckets with water and lids. Both enclosures were videoed for 1 hour in the morning. Saltbush treatment birds had saltbush accessible for one hour, however it was difficult to determine if birds had eaten the saltbush in this timeframe. Therefore one bucket of saltbush was left in the enclosure for the remainder of the day. Excreta samples were taken from each enclosure in the afternoon for alkane analysis. Due to technical issues with alkane analysis, these samples have not been processed at the time of writing this report. Subsequent video footage was taken when the birds were 42 days old. Estimated fresh edible saltbush on offer at this stage was 645g.

Winter - the batch of chickens started brooding on the 19th May 2016. Chickens were then placed in two moveable enclosures (each 12 m^2) on the 9th June, where they had fresh pasture available daily. Measurements were made when the birds were 22, 29 and 36 days old. At d 22 one enclosure had saltbush (67 birds) and the other without saltbush (67 birds). Chickens in the saltbush enclosure had available 510 g of edible fresh saltbush. This was done by placing 30 saltbush branches 30cm long in ten 760ml buckets with water and lids. Both enclosures were videoed for 1 hour in the morning. Saltbush treatment birds had saltbush accessible for one hour whereby nine buckets of saltbush were removed leaving only one bucket of saltbush in the enclosure for the next 24 hours. Subsequent video footage was taken when the birds were 29 and 36 days old. Estimated fresh edible saltbush on offer at this stage was 408 g and 365 g respectively. No excreta samples were taken for alkane analysis.

From the video footage the number of interactions with saltbush, the duration of the interaction and the number of birds interacting with saltbush was recorded. At the same time the interaction with pasture was recorded.

A t-test, two sample with unequal variances was used to analyse interaction times with saltbush and pasture. The null hypothesis was no differences between means.

3.2.1 Consequences to production when meat chickens eat saltbush

River saltbush (*Atriplex amnicola*) was harvested by Wilson Pastoral, South Australia when it was actively growing and then air-dried and hammer milled. Oldman saltbush was not used as it was not available for harvest at the time of the trial. Saltbush was incorporated into pellets at the following levels; 5%, 10% and 15%, with a control of no saltbush (commercial grower pellet for broilers). Diets were designed to dilute the normal pellet diet with saltbush to simulate the situation whereby chickens may dilute their basal diet while they are foraging on the range. Day old male Ross 308 chicks were floor reared at the Roseworthy campus until 22 days of age. Chickens were then transferred to metabolism cages and randomly allocated to one of the four treatments (0, 5, 10 and 15% saltbush in diet). Each treatment had 12 individual bird replicates (4 treatments x 12 replicates = total of 48 chickens). Chickens were fed the diets for one week. The following measurements were taken: excreta moisture at day 6, live-weight gain over 7 days, feed intake and FCR. In addition, the nutritive value of the saltbush being fed was measured.

4. Results

4.1.0 Do Layers eat saltbush?

Free range hens will eat saltbush while outdoors on the range. Over 5% of their DM intake was saltbush in the 24 hours following the provision of fresh saltbush (Table 1). Hens had a preference for saltbush over green grass and the ‘without’ saltbush hens sought out the green grass over the dry grass. Pellet consumption was not significantly different between ‘with’ saltbush and ‘without’ saltbush hens (P = 0.4156). Notably, saltbush seed and saltbush leaf was detected in some ‘without’ saltbush replicates. Some hens from replicate 1 ‘with’ saltbush were found in ‘without’ saltbush replicates 1 and 2 at the time of the alkane measurements at 27 weeks of age.

The highest level of saltbush consumption was estimated at 83% of the total available edible saltbush on offer (using the Adelaide technique). Edible DM was represented by leaves and seed pods. The estimated average amount of saltbush consumed per hen in this trial was not large because the amount on offer each week was not large. Average total edible DM on offer per replicate was 223.5 g/week. This equated to 5.3g edible DM/hen/week. In the later stages of the trial the hens would strip saltbush back to mostly bare twigs and branches within 4 days (see Photo 1 and 2).

The small amount of saltbush that was eaten in this trial had not affected hen live-weight at 17, 21 and 25 weeks of age (P= 0.7594, 0.9964 and 0.7168 respectively, Table 2). Egg production and egg quality were also unaffected (Table 2 and 3). There were no significant differences in feed intake between saltbush and no saltbush hens. Generally, most production measurements were similar to the standard, except for the much lower rate of lay at 22 weeks and the higher kg feed per dozen eggs. A possible explanation is the lower number of daylight hours at that stage of hen development compared to the Hy-Line Brown standard. The standard recommends 16 hours of light for natural ventilated open houses, but based on local sunrise and sunset figures the hens in the trial would have only received 13 hours of natural light. The lower lay rate at 22 weeks later impacted on the kg feed per dozen eggs.

For the first three weeks when the birds were 18 – 20 weeks old they had shown no interest in the saltbush and had stayed very close to the hen house. The hens only began to first peck at the saltbush when they were 21 weeks of age. Interest in saltbush grew with time. This is probably a function of the hens becoming more familiar with their range area as they matured and green pick close to the house had diminished with time. Furthermore, the majority of the plants on the range had senesced by the 4th November 2015 leaving saltbush along with only a few green native perennial grasses. Nevertheless, interactions with saltbush and range use was strongly influenced by weather conditions on particular dates (Table 4 and Table 6). Hot temperatures with strong winds led to less birds outside the hen house on the 18th and 25th November 2015. For example, there were no hen interactions with saltbush on the afternoon of the 18th November 2015 when the maximum daily temperature had reached 41.6^{o}C, hens remained in the house during hot weather. As such, date was a highly significant effect. Saltbush and the time of day did not influence the number of birds out on the range. However, the number of interactions with saltbush and the total time spent pecking at saltbush was significantly higher in the morning compared to the afternoon (Table 5). In addition, the maximum number of birds interacting with saltbush was not influenced by date or time of day.

The saltbush used in the trial (Table 7) had a CP of 21.1% and was high in sodium, chloride, potassium, magnesium and sulphur.

Table 1: Estimated Dry Matter intake (%) based on n-alkanes in the excreta from free range hens aged 23 and 27 weeks provided 'Without' and 'With' saltbush on the range.

Hen age 23 weeks (3rd November 2015)		
Intake component	*'Without' saltbush*	*'With' saltbush*
Saltbush leaf	0.00 (0.00)	5.10 (2.62)
Saltbush seed	0.03 (0.03)	0.00 (0.00)
Green grass (annuals)	0.36 (0.18)	0.00 (0.00)
Pellet	99.60 (0.15)	94.90 (2.62)
Hen age 27 weeks (2nd December 2015)		
Intake component	*'Without' saltbush*	*'With' saltbush*
Saltbush leaf	1.43 (0.76)	5.63 (0.61)
Green grass (perennials)	5.00 (3.40)	0.00 (0.00)
Dry grass (annuals)	0.00 (0.00)	0.00 (0.00)
Pellet	93.50 (2.83)	94.40 (0.62)

SEM shown in brackets

Table 2: Production performance of free range Hy-Line Brown hens with "no saltbush" and with "saltbush" on the range compared to the Hy-Line Brown standards for alternative systems.

Measurement	**No saltbush**	**Saltbush**	**P value (No saltbush vs Saltbush)**	**Hy-Line Brown Standard for alternative systems 2016**
Mortality/culls (%) at 26 weeks (before fox attack)	1.8	0.9	-	0.5
Rate of lay (%) at 22 weeks	21.4	21.6	-	75 - 86
Rate of lay (%) at 26 weeks	84.9	88.0	-	94 - 96
Egg weight (g) at 27 weeks	57.2	57.5	See table 3	58.4 – 60.8
Live weight (kg) at 17 weeks	1.34	1.33	*0.7594*	1.40 – 1.44
Live weight (kg) at 21 weeks	1.63	1.63	*0.9964*	1.67 – 1.77
Live weight (kg) at 25 weeks	1.76	1.77	*0.7168*	1.79 – 1.91
Average pellet consumption (g/hen/day) 16 – 17 weeks	81.4	79.4	-	78 - 83
Average pellet consumption (g/hen/day) 17 – 21 weeks	83.9	81.1	-	79 -106
Average pellet consumption (g/hen/day) 21 – 25 weeks	100.5	99.1	*0.8661* (16 – 25 weeks)	95 -117
kg feed per dozen eggs, 21 – 25 weeks	2.40	2.47	-	1.54 20 – 60 weeks

Table 3: Egg quality traits for free range Hy-Line Brown hens at 27 weeks, with and without access to saltbush on the range.

Quality trait	**No saltbush**	**Saltbush**	***P value (No saltbush vs Saltbush)***
Egg weight (g)	57.2	57.5	*0.8217*
Albumen height (mm)	10.8	10.7	*0.7704*
Yolk colour (Roche fan)	11.3	11.3	*0.9369*
Shell weight (g)	5.68	5.71	*0.8069*
Shell thickness (micron)	385	382	*0.4861*
Haugh unit	103.1	102.7	*0.7908*

Table 4: Hens interacting with saltbush (pecking saltbush) as influenced by date - the number of interactions in 1 hour, the duration of the interaction (seconds), the total time spent interacting with saltbush in the hour and the maximum number of birds interacting with saltbush during an interaction (% of flock).

Date	Hen age (weeks)	Number Interactions (in 1 hour)	Duration of Interaction (seconds)	Total time Interacting (seconds)	Maximum number birds (% of flock)
21.10.15	21	4.27^{b}	71.7^{a}	246.4^{a}	9.1
28.10.15	22	4.27^{b}	36.0^{a}	108.9^{ab}	5.4
04.11.15	23	7.90^{a}	68.6^{a}	651.8^{a}	6.8
11.11.15	24	8.95^{a}	73.0^{a}	446.9^{a}	5.7
18.11.15	25	1.47^{c}	6.1^{b}	7.6^{c}	4.7
25.11.15	26	1.52^{c}	10.5^{ab}	13.6^{bc}	6.8
P value	-	*0.0000*	*0.0214*	*0.0014*	*0.8262*

Different superscript letters in the same column are significant $P \leq 0.05$. Back – transformed (from Log_{10}) data presented in the table.

Table 5: Hens interacting with saltbush as influenced by time of day (morning or afternoon) - the number of interactions in 1 hour, the duration of the interaction (seconds), the total time spent interacting with saltbush in the hour and the maximum number of birds interacting with saltbush during an interaction (% of flock).

Time of day	Number Interactions (in 1 hour)	Duration of Interaction (seconds)	Total time Interacting (seconds)	Maximum number birds (% of flock)
am	5.35^{a}	52.8	203.8^{a}	6.9
pm	2.66^{b}	17.8	45.7^{b}	6.0
P value	*0.0003*	*0.0597*	*0.0389*	*0.7009*

Different superscript letters in the same column are significant $P \leq 0.05$. Back – transformed (from Log_{10}) data presented in the table.

Table 6: The percentage of flock and location of birds out on the range during spring 2015.

Date	Hen age (weeks)	<5 m from house	Shade sail	5- 8 m from house	>8m from house	Total	Weather conditions (Maximum temp.) and Wind rating
21.10	21	37.1 [a]	4.7	4.9 [bc]	5.6 [bc]	52.3 [b]	18.8^{o}C, Calm
28.10	22	38.8 [a]	8.2	8.7 [ab]	4.7 [bc]	60.4 [ab]	29.5^{o}C, Calm
04.11	23	27.1 [ab]	7.0	12.4 [a]	26.6 [a]	73.1 [a]	25.0^{o}C, Calm
11.11	24	20.4 [b]	12.6	6.1 [abc]	10.8 [bc]	49.9 [bc]	30.0^{o}C, Calm
18.11	25	20.2 [b]	11.0	0 [c]	1.2 [c]	32.4 [cd]	41.6^{o}C, Strong wind
25.11	26	19.4 [b]	1.9	0 [c]	0 [c]	21.3 [d]	38.0^{o}C, Strong wind
P value		*0.0148*	*0.1830*	*0.0028*	*0.0000*	*0.0000*	

Different superscript letters in the same column are significant P≤0.05. Back – transformed (from Log_{10}) data presented in the table.

Table 7: The proximate chemical analysis report (FEEDTEST, Werribee Victoria) for fresh oldman saltbush (*Atriplex nummularia*) leaf and seed pod used during the free range layer trial.

Test	Fresh leaf	Seed pod
Total Free Sugars (%)	2.60	0.43
Total Starch (% of DM)	2.00	1.10
Fat (dmb)(% of DM)	6.30	4.30
Crude Protein (N x 6.25)(% of DM)	21.1	18.0
Crude Fibre (dmb)(% of DM)	7.2	17.4
Nitrate (mg/kg of DM)	990	4700
Chloride (% of DM)	8.05	9.51
Dietary Cation-Anion Difference ((Na+K)-(Cl+S)) (meq/kg)	1149	846
Aluminium (mg/kg of DM)	72	89
Boron (mg/kg of DM)	11	<0.050
Calcium (mg/kg of DM)	11000	8900
Copper (mg/kg of DM)	2.6	4.0
Iron (mg/kg of DM)	88	78
Potassium (mg/kg of DM)	13000	26000
Magnesium (mg/kg of DM)	6300	4800
Manganese (mg/kg of DM)	36	45
Sodium (mg/kg of DM)	83000	76000
Phosphorus (mg/kg of DM)	1400	1400
Sulphur (mg/kg of DM)	6100	5500
Zinc (mg/kg of DM)	26	28
Ash (dmb)(% of DM)	25.3	26.2

Photo 1: Fresh oldman saltbush placed in a bucket of water on the outdoor range

Photo 2: Oldman saltbush branches with leaves stripped off and eaten by hens within 3 – 4 days after placement on the outdoor range.

4.1.1 Consequences to production when layers eat saltbush

Feeding river saltbush in the diet for 28 days had no significant effect on hen live weight, feed intake and egg production (Table 8). The percentage moisture in the excreta was highly significant with all saltbush diets with greater moisture content than the control. Egg quality measures of egg weight and Haugh unit were not affected by saltbush in the diet (Table 9). However, saltbush eggs at the two highest levels (15% and 20%) had significantly heavier and thicker shells than the control and 5% saltbush egg shells. Yolk colour was also significantly stronger for the higher saltbush diet treatments compared to the control egg yolks.

Similar to the fresh oldman saltbush, the air-dried river saltbush was also found to be high in chloride, sodium and potassium, but was much lower in nitrate and CP (Table 12). Lower CP of the river saltbush is probably due to small stems incorporated into the hammer-milled saltbush.

Table 8: Average live-weight of Hy-Line Brown hens, feed intake, egg production and percentage moisture in excreta for hens at peak lay fed air dried river saltbush at 0%, 5%, 10%, 15% and 20% in a commercial layer pellet diet.

Diet treatment	Live weight (kg) at 32 weeks	Live weight (kg) at 35 weeks	Average feed intake g/hen/day	Rate of lay (%)	% moisture in excreta (day 28)
0% saltbush	1.873	1.900	143.30	99.3	73.69 [c]
5% saltbush	1.841	1.895	142.26	100.0	77.25 [b]
10% saltbush	1.893	1.973	141.31	99.6	78.55 [b]
15% saltbush	1.877	1.947	148.44	98.2	79.97 [ab]
20% saltbush	1.878	1.941	141.99	95.7	81.73 [a]
P- value	*P=0.9411*	*P=0.7285*	*P=0.7534*	*P=0.6182*	*P<0.001**

*Means in the same column with different superscript letters show significant diet effects at P<0.001.

Table 9: Egg quality measures for Hy-Line Brown hens 34 weeks old fed air dried saltbush at 0%, 5%, 10%, 15% and 20% in a commercial layer pellet diet.

Diet treatment	Egg weight (g)	Shell weight (g)	Shell thickness (micron)	Haugh unit	Yolk colour (Roche fan)
0% saltbush	61.130	4.8620 [bc]	318 [c]	107.87	8.10 [c]
5% saltbush	60.663	4.8157 [c]	322 [bc]	107.64	8.20 [bc]
10% saltbush	60.397	5.1573 [ab]	340 [ab]	108.82	9.10 [abc]
15% saltbush	60.990	5.2345 [a]	350 [a]	107.63	9.35 [ab]
20% saltbush	61.195	5.4191 [a]	360 [a]	106.20	10.10 [a]
P - value	*P=0.9710*	*P=0.0016**	*P=0.0004**	*P=0.1501*	*P=0.0057**

* Means in the same column with different superscript letters show significant diet effects at P<0.05.

The results from this trial show no negative consequences to egg production and egg quality from hens eating saltbush. In contrast there was a positive effect on shell thickness and egg yolk colour. However, hens did excrete more moisture in their droppings as a result from eating saltbush and this may impact on litter moisture in the house. Nevertheless, under commercial conditions hens would need to eat substantial amounts of fresh saltbush to reach the higher levels of air–dried saltbush fed in this experiment.

Consumer acceptability trial of saltbush eggs
Boiled egg samples revealed that 20% saltbush eggs were the most preferred across sensory and quality attributes tested and the control egg was the least preferred, except for mouthfeel/texture and overall liking (Table 10). Significant differences for the 20% saltbush egg were identified for appearance and overall liking. Statistical analysis did not find significant differences in aroma, flavour, mouthfeel/texture and aftertaste attributes. Overall, the consumer responses were favourable in regards to all samples, with average scores of 6 or above ('like slightly').

The 20% saltbush scrambled egg was the most preferred across all sensory and quality attributes tested and the 10% saltbush egg was the least preferred, except for appearance (Table 11). Significant differences were found for the appearance, flavour, mouthfeel/texture, aftertaste and overall liking. No significant differences were found for aroma.

Table 10: Average consumer acceptability scores for saltbush eggs - boiled, (scale 1 – 9; where 1 = "dislike extremely" and 9 = "like extremely").

Sample	Appearance	Aroma	Flavour	Mouthfeel/ texture	Aftertaste	Overall liking
Control - boiled	4.97 ^{c}	6.03	6.33	6.43	6.13	6.22 ^{c}
5% saltbush - boiled	5.53 ^{bc}	6.03	6.48	6.43	6.40	6.45 ^{bc}
10% saltbush - boiled	5.67 ^{bc}	6.03	6.67	6.67	6.33	6.52 ^{bc}
15% saltbush - boiled	6.05 ^{ab}	6.18	6.47	6.35	6.13	6.20 ^{c}
20% saltbush - boiled	6.82 ^{a}	6.43	6.80	6.90	6.60	6.90 ^{ab}
P-value	*<0.0001**	*0.1682*	*0.2932*	*0.0965*	*0.2089*	*0.0141**

* Means in the same column with different superscript letters show significance between samples at *P≤ 0.05*.

Table 11: Average consumer acceptability scores for saltbush eggs - scrambled, (scale 1 – 9; where 1 = "dislike extremely" and 9 = "like extremely").

Sample	Appearance	Aroma	Flavour	Mouthfeel/ texture	Aftertaste	Overall liking
Control - boiled	5.93 ^{bc}	6.08	6.22 ^{ab}	6.40 ^{ab}	6.10 ^{ab}	6.12 ^{ab}
5% saltbush - boiled	5.80 ^{c}	6.18	6.48 ^{ab}	6.42 ^{ab}	6.25 ^{ab}	6.37 ^{ab}
10% saltbush - boiled	5.93 ^{bc}	6.08	6.02 ^{b}	5.93 ^{b}	5.78 ^{b}	5.83 ^{b}
15% saltbush - boiled	6.42 ^{b}	6.28	6.32 ^{ab}	6.58 ^{a}	6.25 ^{ab}	6.28 ^{ab}
20% saltbush - boiled	7.32 ^{a}	6.30	6.63 ^{a}	6.82 ^{a}	6.53 ^{a}	6.67 ^{a}
P-value	*<0.0001**	*0.8100*	*0.0441**	*0.0035**	*0.0165**	*0.0042**

* Means in the same column with different superscript letters show significance between samples at *P≤ 0.05*.

Overall, the 20% saltbush egg scored highest for all sensory and quality attributes tested for both boiled and scrambled cooking methods. The enhanced yolk colour of higher saltbush eggs probably contributed to favourable consumer ratings for appearance and this reflects the yolk colour measures made on eggs at 17 and 18 days. The consumers' overall liking for high saltbush eggs (particularly 20%) was unexpected and unexplained. This warrants further investigation, firstly can these results be repeated on a larger scale and then what are the components of saltbush responsible for enhancing yolk colour, improving flavour, mouthfeel/texture and aftertaste.

Table 12: The proximate chemical analysis report (FEEDTEST, Werribee Victoria) of air-dried river saltbush (*Atriplex amnicola*) hammer-milled leaf and small stems used in trials 3.1.2 and 3.2.2.

Test	Air-dried
Total Free Sugars (%)	0.88
Total Starch (% of DM)	3.0
Fat (dmb)(% of DM)	3.5
Crude Protein (N x 6.25)(% of DM)	7.3
Crude Fibre (dmb)(% of DM)	34.2
Nitrate (mg/kg of DM)	33
Chloride (% of DM)	3.71
Dietary Cation-Anion Difference ((Na+K)-(Cl+S)) (meq/kg)	435
Aluminium (mg/kg of DM)	340
Boron (mg/kg of DM)	<0.050
Calcium (mg/kg of DM)	6400
Copper (mg/kg of DM)	4.5
Iron (mg/kg of DM)	390
Potassium (mg/kg of DM)	10000
Magnesium (mg/kg of DM)	2700
Manganese (mg/kg of DM)	81
Sodium (mg/kg of DM)	32000
Phosphorus (mg/kg of DM)	1000
Sulphur (mg/kg of DM)	2000
Zinc (mg/kg of DM)	26
Ash (dmb)(% of DM)	14.5

4.2.0 Do meat chickens eat saltbush?

Summer/autumn - The video recordings revealed that chickens at both ages showed a strong interest in saltbush, although the novelty of something new (e.g. Saltbush) in the enclosure maybe a factor (Table 13). At d 21 the saltbush had certainly diverted the chickens' attention away from pasture plants with the average interaction time of 299 seconds vs pasture 18 seconds. Over 34 minutes in the hour of video was spent by the chickens pecking at the saltbush and only 3 minutes 22 seconds at the pasture. Those chickens in the enclosure without saltbush had the average interaction time with pasture of 56 seconds and a total of 18 minutes interacting with pasture in the hour. The bucket of saltbush that was left in the enclosure for the day had all the leaves stripped off with no signs of leaf on the ground (approx. 43.5 g fresh saltbush eaten).

Due to dry seasonal conditions pasture in both enclosures was no higher than 2 cm and green herbage coverage was 45%. The species present in the pasture were perennial veldt grass (*Ehrharta calycina*), sheep's sorrel (*Rumex acetosella*), clammy goosefoot (*Chenopodium pumilio*), common purslane (*Portulaca oleracea*) and capeweed (*Arctotheca calendula*). The farmer had noted that chickens appear fond of sheep's sorrel. The same batch of chickens at d 42 were less active and spent much of their time sitting and avoiding the bright sunny warm conditions on the day. Despite this, the older chickens still had numerous interactions with the saltbush with a total of 25 interactions in the hour, but the average interaction duration was only 24 seconds. They had shown no interest in the pasture (30% green coverage). Chickens were also using the saltbush for shade even though the saltbush in buckets were no higher than 35 - 40 cm (Photo 3 and 4). In the no saltbush enclosure the chickens had only two interactions with pasture averaging only 13 seconds in duration.

Table 13: Summer/autumn - The number of interactions, interaction length, total time and average number of birds interacting with saltbush and pasture in a saltbush enclosure vs a control enclosure (without saltbush) during one hour of videoing in the morning.

	Number of Interactions in 1 hour	Average length of interaction (secs)	Average Interaction Length (Probability, two tailed)	Total time (secs)	Average number birds interacting (% flock)	Average number Birds (Probability, two tailed)
Chickens d 21*						
<u>Saltbush enclosure</u>						
• Saltbush (S)	7	299.0	*S vs P P = 0.0322*	2095	3.75	*S vs P P = 0.0925*
• Pasture (P)	11	13.6		193	1.81	
<u>Control enclosure</u> Pasture (CP)	20	53.5	*P vs CP P = 0.0186*	1124	2.18	*P vs CP P = 0.1674*
Chickens d 42+						
<u>Saltbush enclosure</u>						
• Saltbush (S)	25	24.0	-	600	2.00	-
• Pasture (P)	0	0.0		0	0.00	
<u>Control enclosure</u> Pasture (CP)	2	13.0	-	24	1.60	-

* Temperature at time of filming 16^{o}C, overcast, calm
+Temperature at time of filming 22^{o}C, very bright sunny conditions, light breeze

In winter, chickens of all age groups showed a strong interest by pecking at saltbush, mostly in preference to pasture (Table 14). The time spent pecking at saltbush was significantly longer than that for pasture at d 22 and d 36. At d 29 differences were not significant probably due to the small number of interactions in the hour. Rain and cold conditions restricted the birds to their shelter on this occasion. Very little if any foliage was removed and eaten in the hour when the birds were 22 and 29 days old. In addition, d 22 chickens had not removed any foliage from the pot of saltbush left in the enclosure for 24 hours. This is in direct contrast to the batch of chickens in summer/autumn at d 22, whereby they had totally stripped and eaten the saltbush pot left in the enclosure. Saltbush was green and prominent in summer/autumn when very little else was growing in the enclosures due to dry conditions. In the winter study, chickens at d 29 had only eaten approximately 8 grams fresh weight of the saltbush pot left in the enclosure for 24 hours. At d 36, the chickens had removed and eaten some foliage from the saltbush during videoing. It was estimated that 18 g of fresh foliage was removed and eaten in the hour. The enclosures in winter had 90% green herbage coverage and was up to 10cm high. The range of plant species are the same as those in summer/autumn. Despite the abundance of green pick in winter, the cold wet weather during winter would limit the time birds could spend picking at saltbush and pasture. This was shown in this study when the chickens were 29 days old, the chickens had retreated to the shelter section of their enclosure for 80% of the time during the one hour of videoing (Table 14).

Meat chickens will eat saltbush, however very little was eaten during the one hour of exposure to saltbush in this trial. It has been noted that chickens ate the saltbush planted on the range of a commercial farm in South Australia. The chickens on this farm had eaten the saltbush foliage to the height they could reach and then used the shrubs to sit under for shade.

Photo 3: Day 21 chicks pecking at saltbush

Photo 4: Day 42 chicks resting in the little shade cast by saltbush in pots

Table 14: Winter The number of interactions, interaction length, total time and average number of birds interacting with saltbush and pasture in a saltbush enclosure vs a control enclosure (without saltbush) during one hour of videoing in the morning.

	Number of Interactions in 1 hour	Average length of interaction (secs)	Average Interaction Length (Probability, two tailed)	Total time (secs)	Average number birds interacting (% flock)	Average number Birds (Probability, two tailed)
Chickens d 22^						
Saltbush enclosure						
• Saltbush (S)	37	67.1	*S vs P*	2483	3.6	*S vs P*
• Pasture (P)	39	21.0	*P = 0.0025*	819	2.0	*P ≥0.0001*
Control enclosure						
• Pasture (CP)	37	23.1	*P vs CP* *P = 0.5646*	855	2.6	*P vs CP* *P = 0.0385*
Chickens d 29*						
Saltbush enclosure						
• Saltbush (S)	3	221.6	*S vs P*	665	7.0	*S vs P*
• Pasture (P)	6	11.3	*P = 0.1226*	68	2.2	*P = 0.1679*
Control enclosure						
• Pasture (CP)	7	10.3	*P vs CP* *P = 0.6645*	72	2.1	*P vs CP* *P = 0.8778*
Chickens d 36#						
Saltbush enclosure						
• Saltbush (S)	35	36.1	*S vs P*	1263	2.6	*S vs P*
• Pasture (P)	11	13.0	*P = 0.0113*	143	1.8	*P = 0.0136*
Control enclosure						
• Pasture (CP)	33	23.8	*P vs CP* *P = 0.0535*	785	2.8	*P vs CP* *P = 0.0022*

^birds active throughout filming, weather favourable; 15°C, bright sunny, light breeze, no rain.
*all birds retreated to shelter for 48 minutes during filming, rain and cold conditions; temperature at the start of filming 15°C, at the finish temperature dropped to 12°C, overcast, rain
#birds retreated to shelter for 15 minutes during filming due to light rain; 11°C, partly cloudy

4.2.1 Consequences of meat chickens eating saltbush

The results have shown that weight gain and FCR were the only significant variables (Table 15). Excreta moisture did show a slight trend toward higher moisture content in excreta with increased saltbush in the diet, but this was not significant.

Table 15: Feed intake, weight gain, FCR, excreta moisture and AME (as fed) for broiler chickens (d 22 – 29) fed 0%, 5%, 10% and 15% air-dried saltbush in the diet.

	Feed intake (g)	Weight gain (g)	FCR	Excreta moisture content %	AME diet (as fed) MJ
Control	1139	801 [ab]	1.43 [ab]	79.36	13.95 [a]
5% saltbush	1136	818 [a]	1.39 [b]	79.77	13.72 [b]
10% saltbush	1121	763 [bc]	1.48 [a]	80.67	13.58 [bc]
15% saltbush	1114	750 [c]	1.48 [a]	81.12	13.42 [c]
	P= 0.8171	*P = 0.0096*	*P = 0.0209*	*P = 0.2043*	*P = 0.0000*

* Means in the same column with different superscript letters show significance between samples at $P \leq 0.05$.

The 5% saltbush chickens had the greatest weight gain, but this was not significant from the control. Although the highest level of saltbush in the diet did result in the lowest weight gain. FCR was lowest for the 5% saltbush and control treatments, with the highest FCR for 10% and 15% saltbush. Furthermore, the apparent metabolisable energy (AME) of the control diet was significantly higher than the saltbush diets. The CP level of the saltbush was low (Table 12) therefore dilution of the regular broiler diet with 10% and 15% saltbush was likely to result in reduced weight gain. There was also substantial sodium, chloride and potassium in the saltbush that may have impacted on dietary electrolyte balance.

5. Discussion of Results

Saltbush is readily eaten by layer hens and meat chickens although, under commercial conditions the amount of fresh saltbush eaten will not be large. This will in part be due to a lower density of saltbush planted on free range farms when compared to plantation blocks used in ruminant grazing systems. Prevailing weather conditions and the age of the flock will also influence the opportunity birds have to consume saltbush out on the range. For example, fewer birds go outdoors when the weather is extreme (e.g. hot and windy or cold and rainy), therefore less probability of eating saltbush.

Layer hens were not impacted by the consumption of increased levels of saltbush (4.1.1) in terms of their live weight and feed intake. Similarly, Abd-El-Galil, et al., (2014) had found Sina layer hens fed oldman saltbush leaf meal at 0%, 4%, 8% and 12% in their diets had no significant differences in live weight and feed intake. Interestingly, shell thickness was found to increase with higher levels of saltbush in our trial (4.1.1) and likewise with Abd-El-Galil, et al., (2014). In contrast, they had found significant increases in egg number, egg mass, egg weight and FCR with 8% saltbush in the diet the optimal level. Some of these differences may be attributed to the variation in CP and crude fibre between the river saltbush in our trial (4.1.1) and the oldman saltbush leaf meal used by Abd-El-Galil, et al., (2014). River saltbush was lower in CP (river saltbush 7.3% v oldman saltbush 20.13%) and higher in crude fibre (river saltbush 34.2% v oldman saltbush 4.01%). The air-dried river saltbush in our trial had both leaf and fine stems incorporated and this would have reduced the overall CP and increased the crude fibre content.

The fresh oldman saltbush used in the free range trial (4.1.0) was similar in CP and crude fibre to that used by Abd-El-Galil (2014). Hens ate approximately 5% saltbush in DM while ranging outdoors (4.1.0) and had no impact on their production. This level is comparable to the 4% level in the trial conducted by Abd-El-Galil (2014). They also found no differences in the productive performance of the control hens compared with those hens fed 4% air-dried saltbush.

Saltbush fed to hens had no negative impacts on the egg sensory eating qualities. Furthermore, consumers reported a preference for eggs produced from hens fed the highest level of saltbush. Partly, this result was due to the appearance of saltbush egg yolks. Eggs produced from hens fed higher levels of saltbush had stronger yolk colour. In addition, there were other sensory qualities such as mouth feel/texture and flavour that rated high for scrambled saltbush eggs. Saltbush shows promise as a new fed additive for layers in the production of unique eggs. But this will need to be verified on a larger scale.

The meat chicken feeding trial in this project was not designed to evaluate the nutritive value of saltbush, but to simulate the situation whereby free range meat chickens may have diluted their normal diet with saltbush while out on the range. Relatively high levels of saltbush were fed to meat chickens in our trial and they did show reduced growth rate and higher FCR as the level of saltbush increased in the diet (4.2.1). In addition, the AME decreased as saltbush content increased. Similar results were obtained by Furtardo, et al. (2011) even though they had used a slower growing strain of meat chicken and the CP content of their saltbush was higher. Possibly high crude fibre content of saltbush is partly responsible for reduced growth rates, as Cilliers, et al. (1999) had shown cockerels were less efficient in the digestion of high fibre diets compared to ostriches when fed saltbush. Barreto, et al., 2012 had also attributed the higher fibre content of saltbush for reduced weight gain of meat chickens in their trial particularly when saltbush was substituted to levels over 17.7%. The crude fibre in saltbush may partly contribute to reduced growth rates but the AME of the saltbush we used in the trial was likely the most limiting component. But under free range conditions, meat chickens are certain to eat the more palatable leaf material which has less fibre and probably higher AME than stem material. Commercially produced free range meat chickens while outdoors will not eat enough saltbush to impact their production. Firstly, the low number of saltbush plants on the outdoor range will limit their capacity to eat saltbush. Secondly, a meat chicken will not be able to reach much above 30 -40 cm in height, so much of the saltbush foliage will be inaccessible to chickens. Thirdly, meat chickens become less active with age and do not venture far from the house as they grow heavier.

No consumer acceptability trials were conducted on chicken meat produced from birds fed saltbush in this project. Therefore, we do not know whether a relatively small quantity of saltbush in the diet will impact sensory attributes of chicken meat such as appearance, texture, flavour and aroma.

In conclusion, saltbush would be a valuable addition to the outdoor environment on free range poultry farms and may have added benefits if used as a feed ingredient for layer hens.

6. Implications

- Saltbush will be a valuable addition to enrich the outdoor range area on free range poultry farms for shade and shelter.

- Saltbush is palatable to hens and meat chickens and they will eat the foliage while outdoors, but they will not eat enough to impact their production and well-being.

- Air-dried saltbush is a potential new ingredient in the diet of poultry, especially hens.

- Eggs produced from saltbush fed hens may be a unique new product.

7. Recommendations

- Saltbush can be planted on the outdoor range of free range poultry farms to provide shade and shelter.
- Do not plant saltbush too close to the poultry shed (e.g. no closer than 30m from the house on layer farms and no closer than 10 m from the house on chicken meat farms). As such the saltbush will not be in the area of greatest nutrient load or grazing pressure.
- Permanent plantings of saltbush too close to the shed will make it difficult to clean the shed between batches and make it harder to move birds back into the shed.
- It would be best to have artificial shade structures closest to the shed to encourage birds outside and these can be moved further out on the range as the flock matures.
- Saltbush can be planted mid-range and at the edge of the range to help encourage birds further out onto the range.
- Saltbush will need protection from birds until it obtains a growth height of at least 60 cm on meat chicken farms and at least 100 cm on egg layer farms.
- Newly planted saltbush should be protected with tree guards and the roots protected from scratching damage by using large stones or wire mesh placed at the base of the shrub.

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POULTRY CRC

Plain English Compendium Summary

Sub-Project Title:	The role of saltbush on free range poultry farms
Poultry CRC Sub-Project No.:	2-1-16
Researcher:	Dr Carolyn de Koning
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Sub-Project Overview	The project set out to determine whether or not poultry would eat saltbush and secondly, what are the consequences to the welfare and production of birds that eat saltbush? It was shown that layer hens and meat chickens will readily eat the leaf from saltbush plants. To then simulate poultry diluting their commercial feed with saltbush, meat chickens and hens were fed air dried saltbush in their diets ranging from 0% up to 15% for meat chickens and up to 20% for hens. Meat chickens still gained weight on the saltbush diets, but at the higher levels of 10% and 15% the weight gain was significantly less than the control. Hens maintained their live-weight on saltbush diets and continued to lay the same percentage of eggs without any negative effects on egg quality. In fact there was a positive effect with higher saltbush in the diet leading to stronger yolk colour. In addition, high saltbush eggs were preferred by consumers in a blind tasting of hard boiled and scrambled eggs.
Background	There is potential for saltbush to be grown in many poultry regions across Australia due to the plant's wide adaptation. However, the scientific literature did not provide any evidence of poultry eating saltbush *in situ* on the range. Layers will have the greatest capacity and opportunity to eat saltbush compared to meat chickens because they are more active and have access to the range for at least one year. Positive and maybe negative consequences to poultry production and health may arise from birds eating saltbush planted on the outdoor range. The impact will be largely determined by the quantity of saltbush eaten by poultry. Like many plant species, saltbush contains anti nutritive factors and is high in sodium chloride. Therefore it is important to determine if there are negative consequences for poultry that may eat saltbush. The objective of this project was firstly to determine if free range laying hens and meat chickens eat saltbush and secondly what are the effects on production, welfare and product quality should free range laying hens and meat chickens consume saltbush?
Research	Overall the project has shown that both layers and meat chickens will readily eat saltbush without negative consequences to their production.
Sub-Project Progress	All studies were completed.
Implications	• Saltbush will be a valuable addition to enrich the outdoor range area on free range poultry farms for shade and shelter. • Saltbush is palatable to hens and meat chickens and they will eat the foliage while outdoors, but it will not impact their production and well-being. • Air-dried saltbush is a potential new ingredient in the diet of poultry, especially hens. • Eggs produced from saltbush fed hens may be a unique new product.
Publications	De Koning and Singh (in press) Role of saltbush on free range layer farms. APSS 2017 We intend to publish at least two papers in scientific journals