THE PRODUCTION AND FEEDING OF FORMIC ACID PRESERVED POULTRY BYPRODUCT HYDROLYSATE IN DEVELOPING COUNTRIES.

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W-6B.18

SUMMARY

A pilot plant (1t per hour) for the preservation of poultry heads, feet and viscera using a mixture (7:1) of formic and propionic acids has been field tested. The liquid end product, poultry byproduct hydrolysate (PBH), is produced using a two stage mechanical process and autolytic action in order to overcome the problem of handling the initial high viscosity (>140 Pa.s) acidified tissue slurry. Cutting specifications allowed for 95% of the tissue residue to be reduced to a diameter of <4.0 mm after 7 days incubation at ambient temperatures of 25-30°C. Apparent viscosity declined to <30 Pa.s, pH rose from pH 3.3 to 3.8 and up to 70% of the protein was solubilised. Chemical changes continued beyond this point, although at a much slower rate, and would give a product in which >90% of the total nitrogen was in the form of short peptides and free amino acids.

The nutritional performance of PBH stored for 1 and 18 months was assessed in the Bahamas with 36 growing pigs (Large White x Landrace) offered a diet in which PBH provided between 25 and 28% dry matter (approximately 50% of dietary protein nitrogen) intake. Diets and feeding systems were designed to restrict average weight gain to 0.55 kg per day over the 30 to 75 kg pig liveweight growth period. Growth rates in pigs averaged 0.62, 0.55 and 0.54 kg per day for fresh PBH, stored PBH and maize-soya control diets respectively. There were no significant differences in growth rates or carcase quality characteristics between the groups. It was concluded that PBH production represents a practical method of recovery of small quantities of poultry slaughter byproducts; PBH appears to be a useful feed ingredient for pig meat production in developing countries.

Introduction.

Poultry slaughterhouse byproducts can be preserved successfully by the direct addition of organic acids (Machin *et al.*, 1985); small-scale production of poultry byproduct hydrolysate (PBH) for feeding trials relied on simple grinding and mixing technology (e.g. Van Lunen *et al.*, 1990). Larger scale production of PBH presented problems of homogeneous acid distribution within intermediate high viscosity mixtures. A prototype unit for the large scale production of PBH (1 tonne per hour) has been evaluated within a programme of farmer based feeding trials (Hector *et al.*, 1992). Cutting and processing specifications of the unit were designed to produce PBH in which 95% of the mass is reduced below 4 mm in diameter by the combination of mechanical and autolytic action. The high nutritional potential of short-term stored PBH has been demonstrated in growing pigs (Machin *et al.*, 1985). Recent work on acid preserved fish (fish silage) has suggested that extensive storage may result in a loss in nutritional value (Espe *et al.*, 1986). This paper describes some of the physical and chemical changes associated with the industrial preparation of PBH and reports on a short study to compare the effect of long term storage on the nutritional value of PBH.

Materials and methods.

PBH production: All operations were carried out in The Bahamas at ambient temperatures of 25-30°C; raw material temperature ranged from 21 - 23°C. PBH production from raw material at is shown diagrammatically in Figure 1. Poultry heads, feet and viscera were prebroken in a contra-rotating roller cutter (Mono plc, Manchester) into pieces with a maximum diameter of 50 mm. Five hundred kg of the reduced material was suspended directly in 100 kg previously made PBH, followed by the addition of a mixture of formic and propionic acids (in ratio 7:1) at 3.5% weight per weight raw material. The tissue residue of the acidified slurry was reduced to <15 mm in diameter by repeated passage through an immersed sewerage macerator (Mono plc, Manchester).

Combined batches were held within 7t partially closed, shaded, polypropylene tanks for 7 days and mixed on a daily basis. Raw material suspension, acid dispersion, maceration and PBH transfer was made by positive displacement pumps (Mono plc., Manchester) through 100 or 150mm i.d. pipework. Finished product was held in a separate partially closed 7t tank; PBH was delivered to the Agriculture Station or onto farms in 200 litre closed polypropylene drums. PBH for extensive storage (10t) was manufactured using the above procedure and held for 18 months in a partly closed 14t UV stabilised polypropylene tank; it was mixed at monthly intervals.

Process monitoring: Change in size of tissue residue was assessed by measuring by the proportion of material that passed through 4.0mm and 1.4mm mesh width sieves. Apparent viscosity (Pa.s) was determined using a Brookfield LVT viscometer at 25°C (standardised on No 4 spindle (surface area 235mm^2) at 0.6 rpm). pH was determined by insertion of a combined glass electrode into a sample aliquot. Nitrogen solubility in 0.45M pH 3.5 buffer was measured by Kjeldahl method; non-protein nitrogen was measured after precipitation of PBH protein with 10% w/v trichloroacetic acid. Proximate analysis of PBH was carried out using standard AOAC (1984) methods for animal feedstuffs. Standard microbiological methods (ICMSF) were used for aerobic count at 25°C, for enumerating coliforms (MPN, 37°C), and detecting Salmonella spp in 25g PBH neutralised with $CaCO_3$.

Pig feeding trial: 36 pigs (Large White x Landrace) from 6 litters were standardised at the Agriculture Station in three groups (6 male castrates/ 6 females) on conventional dry rations to 30 kg average liveweight. PBH stored for 1 month and 18 months was included in dietary formulations at >25% of dry matter in order to meet 50% of the protein requirement of growing pigs (UK Ministry of Agriculture - ADAS, 1978); formulations and calculated analysis are given in Table 1. PBH was mixed with equal weights of a dry balancer ration and water prior to a single daily (mid-morning) feeding; *ad lib* access to water was ensured. Liquid hydrolysate rations were introduced at 1/3, 2/3 and 3/3 grower substitution over a three day period. Animals were weighed individually at two week intervals and intake was adjusted on group average weight according to standard daily feed requirements (ADAS, 1978). Pig groups were fed for 10-12 weeks and slaughtered as groups after overnight resting in the lairage. Carcase assessments were made on the chilled carcase (+3°C at 24 hour post mortem); measurements of the loin (*Mm. longissimus lumborum et thoracis*) were made at the 10th rib. An associated trial, not reported in full here, examined the performance of short term stored PBH 'on farm'.

Results and discussion.

PBH production: Reduction in tissue diameter within a 500 kg batch operation was controlled by two independent operations; cutting specifications were determined on a smaller UK development plant. Mixed raw material was reduced below 50 mm in diameter; 75% of mass must remain critically >1.4 mm in diameter in order to retain a high level of mobility following slurrying with 20% w/w PBH and addition of 3.5% w/w organic acids. The acidified suspension, with an apparent viscosity of between 80 and 140 Pa.s, was reduced further by maceration, reducing tissue diameter below 15 mm but retaining 25% of the mass above 4.0 mm in diameter. This procedure generated a thick pseudoplastic 'liquid', with an apparent viscosity of between 200 and 340 Pa.s. Movement of this product, which exhibits localised shear thinning behaviour, required the use of a controlled throughput (rated at <3.5t per hour) positive displacement pump.

The macerate was incubated at 23-25°C was mixed daily using a combination of cross-mixing (tank to tank) and circulatory (within tank) mixing. The size of the tissue residue declined regularly over the 7 day incubation period (Figure 2), giving a PBH product in which 95% of the mass was below 4.0mm in diameter (75% <1.4 mm in diameter). Tissue residue after 7 days incubation consisted of feathers and tissues with a high elastin content, e.g. shank skin. Particulate material was retained in suspension; addition of feathers increased particle aggregation and appeared to reduce the overall hydrolytic rate. Pieces of feather formed the majority of the residue (6.7% > 1.4 mm in diameter) in PBH stored for 18 months. The cutting specifications allow for the maximum inclusion of 15% per weight of wet feathers in the byproduct mix.

Apparent viscosity reduced rapidly over the first 24 hours (Figure 3), allowing the product to be handled more easily; changes in viscosity thereafter were less rapid. Increase in non-protein nitrogen, indicative of the degradation of protein to short peptides and free amino acids, tended to follow the initial fall in viscosity, which was broadly similar to the findings of Hall et al. (1985) for fish silage. The rate of increase in nitrogen and non-protein nitrogen solubility declined with time; over 70% of total nitrogen was solubilised by day 7 and continued to increase slowly over the 30 day holding period. Non-protein nitrogen increased more slowly, amounting to 45% of total nitrogen (>60% of solubilised nitrogen) by day 7. Hydrolysis of protein continued over time, resulting after

18 months storage in PBH in which >90% of the soluble nitrogen was extensively degraded.

Mass pH typically rose from pH 3.3 to 3.65 over the first 24 hr period, increasing to pH 3.8 by day 7 and remained stable in part closed containers over an average two month storage period. *Salmonella* spp and coliforms were absent in 25 g sample; total aerobic count at 25°C ranged from 2.4 to 10^3 to 5.9 x 10^4 cfu per gram. Product stored for 18 months had a pH of 4.3; an additional 0.5% by weight of formic acid was added to retain stability on exposure to air. Long term storage appeared to have resulted in an increase in crude protein and a loss in the nitrogen free extractives fraction (Table 2); similar behaviour is observed in aerobic spoilage of forage silage (McDonald, 1981). The growth of yeasts has been reported to reduce product stability in fermented fish silage (Lindgren and Pleje, 1983).

The pilot PBH was also operated at a daily throughput of <2t per day, i.e. under more aerobic low volume conditions. Rise in bulk volume (through entrapped gas in standing PBH) was increased from the specified maximum of 0.75% per day to levels over 3% per day. This behaviour occurred within 48 hour of manufacture (in PBH at pH 3.7) and could be induced by excessive aeration or low acid strength; both led to product instability and eventual spoilage. Operating procedures at 2t per day include the use of separate PBH for tissue suspension (made in bulk with 20% water and 4% mixed acids (w/w offal)), and limiting mixing to bulk transfer (tank to tank) operations.

Feed performance: Pigs adapted to liquid PBH rations within 4 days of their introduction; no refusals for PBH fed groups were recorded in this or in five associated PBH 'on-farm' trials (all feeding PBH - 1 month at 28% dry matter intake). Diets were targeted to a restricted average weight gain of 0.55 kg per day; average gains of 0.62, 0.55 and 0.54 kg per day were reported for the PBH-1 month, PBH-18 months and pig grower groups respectively. There were no significant ($p>0.05$) differences in gain between groups or sex (Table 3); average gains within the 'on-farm' groups of pigs (n=10) were 0.58 kg per day with males doing marginally better (0.63 kg per day) than females (0.54 kg per day). Overall feed conversion efficiencies (FCE) for PBH-1 month pigs were 2.73 in the trial (average 2.64 'on-farm'). FCE for PBH-18 month fed pigs was marginally poorer. Espe et al., (1991) reported a significant reduction in protein utilisation in rats fed stored (180 days) fish silage as the sole nitrogen source which was attributable in part to fat oxidation. Fat status was not assessed in these PBH products; in UK production trials indicators (e.g. thiobarbituric acid reacting substance value) suggest limited breakdown occurred in lipids over the first 72 hours. PBH takes on a light brown colour over the 7 day processing cycle, evident of the presence of secondary Maillard products; PBH darkened considerably with extensive storage.

Carcase measurements are summarised in Table 3; there was a significant reduction in kill out % in the PBH-18 month fed group which was reflected in higher ($p<0.05$) red offal weights. Carcase backfat thickness over the loin was slightly higher in both groups of PBH fed animals; fat colour and hardness were assessed subjectively and were unaffected in either PBH group. Processor value, based on a standard light cutting pig, was not affected. There were no significant ($p>0.05$) differences in loin (*Mm. longissimus lumborum et thoracis*) muscle area or depth between groups. PBH fed pigs gave higher P1+P3 values (35.4 mm) over the control ration; P1+P3 values for PBH fed 'on-farm' pigs averaged 28.2 mm. Higher sub-cutaneous fat deposition had a more marked effect in the PBH-18 month group, where the muscle depth to fat depth ratio was reduced; this might reduce their comparative retail value. Overall there was no indication that extensive storage or hydrolysis would reduce the feed value of PBH in growing pigs when it provides the equivalent of 50% of dietary 'protein'.

Conclusion.

Preservation using organic acid represents an alternative process to heat preservation for the recovery of poultry byproducts. Production requires a minimum of 3.5% w/w acid (7:1 mixture of formic and propionic acid), good acid dispersal and low aeration mixing; these limitations should be applied vigilantly at all levels of production. PBH can be readily incorporated in to simple liquid feeding systems, although experience with product handling and ration adjustment would suggest that PBH would more suitable for smaller pig keeping facilities. The nutritional value of PBH appeared to be unaffected by length of storage and can provide up to 50% of protein (nitrogen) in a ration for growing pigs. Small-scale PBH production represents a practical method of protein recovery at levels below which heat rendering is uneconomic. Larger scale PBH production may not be cost competitive when considered within the overall chain of pig meat production.

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