UNIVERSITÉ MONTPELLIER II

Cirad-Département Emvt
Campus de Baillarguet
TA 30/B
34 398 MONTPELLIER Cedex 5

Université Montpellier II
UFR Sciences
Place Eugène Bataillon
34 095 MONTPELLIER Cedex 5

MASTER 2EME ANNEE
BIOLOGIE GEOSCIENCES AGRORESSOURCES
ET ENVIRONNEMENT SPECIALITE
PRODUCTIONS ANIMALES EN REGIONS CHAUDES

SYNTHESE BIBLIOGRAPHIQUE

LES APPROCHES GLOBALES EN ECONOMIE DE LA SANTE : ACE et ACB

par

Agnès WARET

année universitaire 2005-2006

SOMMAIRE

TABLE DES ILLUSTRATIONS

FIGURES

TABLEAU

INTRODUCTION

L'économie de la santé a pris son essor à la fin des années 60 avec la mise en pratique d'analyses de type coût-bénéfice aux Etats-Unis (Beal V.C.Jr, 1983). Pendant les années 70-80, l'école anglaise (Université de Reading) prédomine en économie de la santé animale et les fondements méthodologiques sont posés. En novembre 1972, elle prépare un guide pour la conduite d'études socio-économiques des zoonoses avec l'OMS. Les principes de base de l'analyse coût-bénéfice actuelle, dénommée alors analyse coût/avantages sociaux, y sont exposés (Laval G., 1999).

Les changements socio-économiques des vingt dernières années et leurs impacts sur les décisions relatives aux mesures à prendre en terme de santé animale ont confirmé son importance notamment en tant qu'outil d'aide à la décision.

Ainsi :

- La plupart des maladies épidémiques majeures ont réussi à être contrôlées dans la majorité des pays développés (le bénéfice de leur contrôle était tellement évident qu'une évaluation formelle n'était pas nécessaire) laissant des maladies ayant un impact économique moins évident et une épidémiologie plus complexe à gérer.
- L'autosuffisance pour les produits d'origine animale est moins prioritaire au sein des objectifs nationaux suite à une plus large intégration de marché d'où un affaiblissement des engagements politiques pour le contrôle des maladies au niveau national.
- L'importance de l'agriculture dans l'économie nationale décline lorsque le pays se développe, d'où une compétition plus importante des différents secteurs économiques pour les fonds.
- Enfin, de plus en plus de responsabilités sont transférées du secteur public au secteur privé, qui est plus concerné par un retour visible sur l'investissement.

Il est aujourd'hui incontournable de donner une justification économique des actions visant à améliorer ou protéger la santé animale aux bailleurs de fonds auxquels elles sont proposées (Otte M.J. *et al.*, 2000).

L'économie n'est pas concernée principalement par l'argent mais par le fait de « faire des choix rationnels/ prendre des décisions dans l'attribution de ressources rares afin de réaliser une finalité plutôt qu'une autre (Otte M.J. *et al.*, 2000).

Ainsi sans donner de réponses définitives à certaines questions comme « Quelle est la meilleure option, utiliser un vaccin pour prévenir une maladie ou la soigner quand elle survient ? » ou « Un programme de santé est efficace mais y aurait-il une alternative moins coûteuse ? », l'économie peut permettre aux décideurs d'allouer au mieux les ressources (Toma B. *et al.*, 2001 ; Lefèvre P.C., 2005) ou au moins d'avoir des éléments de hiérarchisation des priorités d'intervention (Faye B., 2001).

L'évaluation économique a deux caractéristiques quels que soient les domaines auxquels elle est appliquée : elle concerne à la fois les coûts et les conséquences des activités mais elle étudie aussi les choix des acteurs et compare plusieurs options. Ainsi on peut la définir comme « l'analyse comparative d'options possibles, sur la base de leurs coûts comme de leurs conséquences » (Drummond M.F. *et al.*, 1998 ; Laval G., 2002).

Lorsqu'une évaluation économique remplit les deux conditions décrites, elle est qualifiée d'évaluation globale ; dans le cas contraire il s'agit d'une évaluation partielle. Les deux caractéristiques de l'analyse économique peuvent être utilisées pour distinguer et nommer les différentes situations d'évaluation en santé comme illustré dans le tableau ci-dessous (Drummond M.F. *et al.*, 1998).

Tableau I : Les caractéristiques de l'évaluation en santé (Drummond M.F. *et al.*, 1998)

<table>
<tr><td colspan="5">Etudie-t-on à la fois les coûts et les conséquences des options envisagées ?</td></tr>
<tr><td rowspan="6">Y a-t-il une comparaison de deux options ou plus ?</td><td></td><td colspan="2">Non</td><td>Oui</td></tr>
<tr><td></td><td>Examen des conséquences seules</td><td>Examen des coûts seuls</td><td></td></tr>
<tr><td rowspan="2">Non</td><td colspan="2"><i>Evaluation partielle</i></td><td><i>Evaluation partielle</i></td></tr>
<tr><td>Description des résultats</td><td>Description des coûts</td><td>Description coût-résultat</td></tr>
<tr><td rowspan="2">Oui</td><td colspan="2"><i>Evaluation partielle</i></td><td><i>Evaluation économique globale</i></td></tr>
<tr><td>Evaluation de l'efficacité pratique ou de l'efficacité théorique</td><td>Analyse des coûts</td><td>Analyse de minimisation des coûts
Analyse coût-efficacité
Analyse coût-utilité
Analyse coût-bénéfice</td></tr>
</table>

Les éléments d'une analyse économique globale et leur application à une étude de type coût-efficacité seront abordés dans une première partie. L'analyse de minimisation des coûts étant une forme particulière d'analyse coût-efficacité, où les conséquences des traitements comparés s'avèrent équivalentes, elle ne sera pas abordée. L'analyse coût-utilité est elle aussi volontairement non traitée car utilisée actuellement uniquement en économie de la santé humaine.

Les étapes supplémentaires pour la réalisation d'une analyse coût-bénéfice seront exposées dans la seconde partie.

Enfin la critique de quatre articles permettra d'avoir des exemples concrets de publications récentes d'application du sujet.

PREMIERE PARTIE : ANALYSE COUT-EFFICACITE, LES PREMIERES ETAPES D'UNE APPROCHE GLOBALE

Les études coût-efficacité sont utilisées pour déterminer la stratégie qui procure l'efficacité maximale à un coût donné, ou à l'inverse un objectif médical au coût le plus faible (Bonnet P., 2003).

La méthode permet la comparaison de plusieurs options ayant le même critère d'efficacité mais ne produisant pas les mêmes conséquences. Le programme le plus intéressant n'est donc pas forcément celui qui coûte le moins cher. On calcule le coût par unité d'effet (Drummond M.F. *et al.*, 1998).

Ainsi, on compare un programme 1, ayant un coût P_1 et provoquant une réduction de la prévalence de X_1 %, avec un programme 2, de coût P_2 et provoquant une réduction de la prévalence de X_2 %.

Ici l'indicateur d'efficacité unique est épidémiologique, le taux de prévalence.

On peut cependant dès à présent noter qu'il est souvent difficile de choisir un indicateur synthétique capable d'être à lui seul le plus représentatif des conséquences multiples des programmes de lutte (Laval G., 1999). On est donc assez vite confronté à l'aspect réducteur de ce type d'approche (Toma B. *et al.*, 2001).

I. Détermination des paramètres initiaux

I.1. Choix du point de vue et du niveau d'analyse

Les projets sur lesquels portent les analyses concernent tout ou partie des agents économiques suivants : l'entrepreneur individuel (éleveur, fermier), l'ensemble ou certains des producteurs (amont de la filière, fabricants de vaccins par exemple, jusqu'à l'aval comme la commercialisation des produits), les consommateurs, l'Etat, la collectivité, le financier et les réalisateurs de l'opération qui peuvent être un ou plusieurs des agents précédents (Tascher G., 2003).

Il est donc nécessaire de déterminer quel point de vue va être considéré. Les objectifs et les conséquences pour les différents acteurs ne sont en effet pas les mêmes et la décision de la « meilleure » répartition des biens est variable. Par exemple, pour un simple fermier la meilleure solution peut être de laisser courir un épisode de fièvre aphteuse dans son cheptel bovin ; alors que du côté gouvernemental, dans l'intérêt des autres paysans, cela peut être au contraire d'insister en faveur de l'abattage total des animaux de l'exploitation pour éviter une dissémination future de la maladie (Mlangwa J.E.D. et Samui K.L., 1996).

De même dans l'évaluation des coûts, l'éleveur est concerné par l'impact de la maladie ou des mesures de contrôle sur la profitabilité de son entreprise – les prix qui l'importent sont les prix du marché auxquels il achète et vend. Mais ces prix peuvent ne pas refléter le véritable coût ou la véritable valeur pour la société dans son ensemble, à cause par exemple des taxes, des subventions ou des contrôles de prix. D'autre part les actions sur sa ferme sont susceptibles d'avoir des effets externes, c'est-à-dire que le contrôle d'une maladie dans un élevage peut améliorer l'environnement sanitaire pour les fermes voisines sans coût pour ces dernières (Renkema J.A., 1980). Ainsi il est important pour n'importe quelle analyse économique de statuer sur le point de vue de qui on s'intéresse (Ott M.J. *et al.*, 2000).

Tout comme le nombre d'agents en cause, les limites du projet peuvent être également très vastes. Elles peuvent aller de l'étude économique des performances d'un animal, à une activité dans une exploitation, à l'ensemble de l'exploitation, à une association d'élevages, à une région, à un pays et même à un continent. Il est donc important, avant de démarrer l'étude, de bien cerner les limites du projet, de savoir si l'on se situe au niveau micro, méso ou macro-économique (Rushton J. *et al.*, 1999 ; Otte M.J. *et al.*, 2000 ; Perry B.D. *et al.*, 2001 ; Tascher G., 2003 ; Lefèvre P.C., 2005).

I.2. Choix de la durée de l'analyse, du pas de temps (horizon temporel)

Il existe plusieurs cadres temporels possibles. Ainsi, l'impact d'un traitement peut être considéré sur la vie entière de l'individu (particulièrement dans le cas des maladies chroniques) ou peut être limité à une période plus courte. Il faut donc décider si l'analyse portera sur une seule année (en prenant comme exemple une année typique, ou une année récemment documentée) ou sur plusieurs années (Toma B. *et al.*, 2001).

Le choix d'une année représentative d'étude est la méthode d'analyse adéquate pour certains problèmes sanitaires dans le cas :

- d'une maladie à incidence stable,
- d'une population animale de taille fixe (ou d'un troupeau de taille typique),
- de mesures de lutte répétées annuellement,
- d'une analyse au niveau d'une exploitation.

Les prix utilisés sont alors ceux de l'année étudiée et il n'est pas nécessaire de prendre en compte des changements de prix dus à l'inflation car il n'y a pas de danger à mélanger coûts et prix de différentes années.

En ce qui concerne les coûts des mesures, le seul problème relatif à la prise en compte du temps est celui du coût des équipements, des outils ou des autres investissements en biens durables (qui serviront pendant plus d'un an). L'option la plus simple est alors de calculer le coût moyen par an de ces investissements (coût d'achat/ années de vie utile).

Dans le cas d'une analyse couvrant plusieurs années, elle peut prendre place soit avant toute intervention, c'est le cas le plus fréquent en santé animale, c'est alors l'évaluation *ex ante* (ou analyse prospective) ; soit après l'intervention pour vérifier ses avantages et ses inconvénients, c'est l'évaluation *ex post* (analyse rétrospective).

L'analyse prospective se fait le plus souvent pour évaluer la rentabilité potentielle d'un programme de lutte collective, portant sur un grand nombre d'élevages dans une zone définie. On doit en général, intégrer des données s'étalant sur plusieurs années, portant souvent sur des coûts plus importants au début du programme de lutte et des avantages qui apparaissent plus tard (Toma B. *et al.*, 2001).

Dans l'analyse rétrospective on distingue trois niveaux : l'évaluation de la réalisation des actions, l'évaluation du degré d'atteinte des objectifs et l'évaluation de l'impact des mesures sur la satisfaction des bénéficiaires. L'appréciation des effets se fait par comparaison à l'image de l'évaluation *ex ante* (Faye B., 2001). Les techniques d'évaluation sont les mêmes dans les deux cas (Putt S.N.H. *et al.*, 1987 ; Msellati L., 1995 ; Ducrot C. et Boisseleau D., 1996 ; Laval G., 2002 ; Tascher G., 2003 ; Lefèvre P.C., 2005).

La durée pendant laquelle on va comparer coûts et bénéfices des situations avec et sans projet varie de 5 à 10, 15 voire 20 ans (Tascher G., 2003).

Même si le cadre temporel est déterminé par l'histoire de la maladie, le choix de celui-ci pour l'étude est souvent limité par les données disponibles (surtout celles d'essais cliniques) (Bonnet P., 2003 ; Lefèvre P.C., 2005).

I.3. Le type de données nécessaires

Les analyses économiques en santé animale nécessitent un certain nombre de données pouvant être classées en quatre types : des données d'épidémiologie sur la maladie (prévalence et incidence), des données sur les conséquences zootechniques de la maladie, des données économiques et des données sur l'effet des programmes de lutte (Bennett R.M., 1992 ; Ducrot C., 1995 ; Mlangwa J.E.D. et Samui K.L., 1996 ; Laval G., 2002).

En matière de démographie et d'épidémiologie descriptive, il s'agit de l'incidence, de la prévalence et du taux de létalité. On dispose ainsi d'informations sur la population animale étudiée (structure, effectifs) et sur la distribution de la maladie dans cette population et son évolution.

Les données épidémiologiques sur les conséquences des maladies permettent d'estimer le coût d'une maladie ou l'évaluation des bénéfices attendus d'une diminution de sa fréquence. Il s'agit de la mortalité, des abattages d'urgence et réformes anticipées, des coûts de traitement et de prévention, des baisses de production (lait, croît, embouche), de la capacité de travail pour les animaux de bât ou de trait, de la qualité des produits ou pertes génétiques, du temps de travail, des baisses des performances de reproduction (avortements, baisse de fertilité).

On doit recueillir enfin, des éléments sur l'efficacité des prophylaxies et des estimations économiques telles que la valeur de certains produits et capitaux.

Toute analyse économique de programme de santé animale requière des données fiables sur l'incidence de la maladie. Cela implique de savoir comment on va collecter ces données de manière efficace et peu coûteuse et quelle sera leur fiabilité. (Ott M.J. *et al.*, 2000 ; Perry B.D. *et al.*, 2001 ; Tascher G., 2003 ; James A., 2005). Le manque d'informations chiffrées est une contrainte majeure, surtout dans les pays en voie de développement (Msellati L., 1995 ; Faye B., 2001).
On peut remarquer de plus que la qualité des données, récoltées de manière passive notamment, a eu tendance à se détériorer concomitamment à la diminution sévère des budgets des services publiques vétérinaires de nombreux pays en voie de développement (Perry B.D. *et al.*, 2001).

L'apparente complexité des analyses économiques ne devrait pas être un frein à leur réalisation. L'accent doit être mis sur la comparaison d'alternatives résultant dans le classement des options plutôt que dans des données précises de coût et de bénéfice (Ott M.J. *et al.*, 2000).

I.4. Un outil qui peut aider : la modélisation

Un modèle est une représentation simplifiée, raisonnée et formalisée d'une situation réelle que l'utilisateur veut évaluer. Les modèles sont utilisés dans des situations trop complexes pour être évaluées directement et où l'information adéquate n'est pas disponible. Ils impliquent la

réduction des situations à leurs composantes primaires et l'isolation de ces composantes des nombreuses influences secondaires qui peuvent s'appliquer (Bonnet P., 2003). Il existe de nombreux types de modèles : les simulations, l'analyse de décision, les méthodes statistiques, la programmation. Ils peuvent être statiques décrivant la situation à un moment donné, ou dynamiques retraçant le comportement d'un système au cours du temps. Ainsi on peut les utiliser pour mesurer l'impact d'un projet de contrôle d'une maladie animale dés son début jusqu'au moment où ses effets à long terme deviennent apparents (Lefèvre P.C., 2005).
Le choix d'une technique dépend de plusieurs facteurs (Dijkhuizen A.A. *et al.*, 1995) : la nature du problème ; les ressources disponibles (temps, financements, outils d'analyse) et la disponibilité des données sur le sujet.

I.4.1. Les modèles de simulation

Ils ont été développés pour étudier les effets à long terme des maladies qui jouent surtout sur les paramètres mortalité et fécondité (Shaw A.P.M., 1995). Les simulations permettent de réaliser des projections dans l'avenir de la propagation d'une maladie (et donc de la composition d'un troupeau suivant le statut des animaux : non-infectés, infectés, immunisés...) en fonction des programmes de lutte engagés si nécessaire.
Les modèles dynamiques sont déterministes ou stochastiques lorsque les variables prennent des valeurs en fonction d'une distribution de probabilités appropriée (Putt S.N.H. *et al.*, 1987 ; Laval G., 1999 ; Waret A., 2003). Les modèles de Markov sont particulièrement bien adaptés pour l'évaluation de traitements médicaux. Ce sont des modèles dynamiques stochastiques qui suivent les changements dans une population par la probabilité de passage dans différents états, qui correspondent à un coût et une mesure d'un état de santé (Bonnet P., 2003). Ils calculent des résultats à partir d'un jeu de variables de départ et en fonction de différents scénarios ou stratégies.

I.4.2. L'analyse de décision

C'est une manière de présenter les résultats d'une analyse économique (ou d'une autre nature) pour faciliter la lecture et la prise de décision par un décideur lorsque le choix est complexe. On construit un arbre de décision, composé de nœuds de décision d'où partent des branches correspondant chacune à un choix avec une probabilité associée. Celle-ci peut être par exemple une probabilité de succès d'un traitement ou de passage d'un état sain à infecté ou de décès.
Toutes les possibilités doivent être représentées dans l'arbre de telle sorte qu'à chaque nœud la somme des probabilités des branches lui correspondant soit égale à 1. Les décisions sont basées sur des critères tels que le coût moyen escompté ou l'utilité attendue (Dijkhuizen A.A., 1988). D'autres techniques existent comme les équations mathématiques et les matrices décision par exemple (Mlangwa J.E.D et Samui K.L., 1996).

I.4.3. Les autres techniques

Les méthodes statistiques : régression linéaire, régression pas à pas, analyse discriminante, analyse de variance, séries chronologiques.
La programmation linéaire et ses variantes : ces modèles sont utiles pour analyser la meilleure allocation possible de ressources limitées dans des situations sous contraintes

multiples (Mlangwa J.E.D et Samui K.L., 1996) ; optimisation de la solution en fonction des objectifs recherchés et des contraintes imposées.
La programmation dynamique (Hall D.C. *et al.*, 1998).

Il faut cependant être prudent dans leur utilisation exclusive d'outil d'aide à la décision. Ainsi, les applications récentes des modèles épidémiologiques ont mis en avant le fait qu'il est difficile voire impossible d'estimer certains de leurs paramètres, surtout ceux qui concernent la fréquence des contacts entre les animaux ou les troupeaux. Dans tous les cas, de tels taux de contacts varient dans le temps en fonction des conditions locales. Les épidémiologistes sont alors forcés d'utiliser des « estimations devinées » de ces paramètres, et le résultat est que le modèle pronostique alors simplement leur propre préconception de la progression de la maladie. Par exemple si celui qui fait le modèle juge que la diffusion à courte distance est plus fréquente qu'à moyenne distance, le modèle va prévoir que des mesures sanitaires telles que la vaccination en anneau ou l'abattage préventif seront relativement efficaces. Cela constitue donc un sérieux manque d'objectivité et les risques sont particulièrement importants quand les décideurs ne comprennent pas la logique de base sur laquelle sont faites les prévisions.
Là où les modèles épidémiologiques ont vraiment une application potentielle importante est dans l'évaluation ex-post de données pour estimer des taux de transmission actuels, et afin d'évaluer les raisons d'augmentation ou de diminution de taux dans le temps et l'espace. En ce sens il est possible d'identifier les mesures sanitaires et les conditions qui influencent apparemment les taux de transmission et de tirer des leçons pour les stratégies futures de contrôle et de prévention. L'application la plus valable des modèles épidémiologiques est donc de clarifier la compréhension des mécanismes de transmission de la maladie et de persistance (James A., 2005).

II. Etablir la liste des types de coûts et des bénéfices dans chacune des situations à comparer

II.1. Coûts variables et coûts fixes

Le coût est la valeur monétaire des ressources utilisées pour produire un bien (Toma B. *et al.*, 2001). Les coûts liés au système de production (intrants et extrants) dans un élevage peuvent être classés par rapport aux divers facteurs de production (travail, capital) et en fonction de leur degré de variabilité (coûts fixes ou variables).
Les *coûts variables* sont les coûts qui varient directement avec la quantité produite dans le court terme, tombant à zéro lorsque la production est égale à zéro. Ils sont proportionnels au nombre d'interventions (diagnostics, vaccins, médicaments, déplacements) (Tascher G., 2003).
Les *coûts fixes* (ou frais généraux) ne varient que dans le long terme et s'imposent même lorsque la production est nulle (Laval G., 1999). Ils sont surtout constitués par les frais de personnel, d'investissement (bâtiments, infrastructures techniques, matériel) et d'étude du projet (Tascher G., 2003).
La distinction est importante dans l'analyse des projets de lutte contre les maladies animales. Généralement une réduction de la mortalité et de la morbidité n'affecte que les coûts variables du producteur, puisque ceux-ci varient avec les niveaux de production et par conséquent, avec

le nombre des animaux. Les coûts variables les plus souvent affectés sont les charges relatives à l'alimentation et surtout aux soins vétérinaires (Laval G., 1999).

On détermine parfois une catégorie de *coûts* dits *intermédiaires*, qui varient avec la production dans le moyen terme (par exemple biens d'équipements).

Enfin certains préfèrent une classification en trois catégories : frais de personnel, d'investissement et frais de fonctionnement. Notons que des investissements (matériel par exemple) peuvent avoir une durée de vie différente de celle pendant laquelle se fera l'étude économique et, dans ce cas, on prend en compte la valeur dite d'usage ou de récupération la dernière année du projet ou de l'étude économique. Elle est alors traitée comme un bénéfice (Tascher G., 2003 ; Tascher G. et Letenneur L., 2003).

II.2. Coûts dus à la maladie

Utilisé de manière correcte le coût dû à la maladie couvre les pertes de production et les pertes en terme de marché ainsi que les effets sur la santé humaine et les montants dépensés pour les traiter et les prévenir. Ainsi c'est la somme de tous les effets négatifs causés par ces maladies (Lefèvre P.C., 2005) que l'on peut classer en coûts directs et coûts indirects.

Plusieurs facteurs déterminent les pertes économiques liées aux maladies animales et leur importance (Renkema J.A., 1983 ; Laval G., 1999 ; Lefèvre P.C., 2005) :

- La forme de la maladie : épizootique ou enzootique
- L'espèce animale : l'impact de la perte est influencé par le rapport normal entre revenu et production brute. Le volume de production dans le secteur concerné au niveau national ou au niveau de l'exploitation est aussi important.
- Le niveau économique concerné

Les sources d'informations en ce qui concerne l'incidence de la maladie au niveau régional ou local sont les recueils de données de terrain des services vétérinaires, les diagnostics des laboratoires participant à des enquêtes de terrain, les enregistrements des services d'inspection dans les abattoirs.
Les données concernant la taille, la répartition et la structure des troupeaux ainsi que les paramètres de production et de productivité sont souvent disponibles ou calculées à partir des recensements et d'enquêtes ponctuelles réalisés par les services commerciaux, les marchés, les associations d'éleveurs, les organisations et coopératives privées de producteurs.

II.2.1. Coûts directs

Les *coûts directs* sont ceux qui peuvent être traduits en termes de pertes de produits animaux. On y inclut donc les coûts liés à la mortalité et ceux liés à la morbidité. Certains auteurs considèrent que le celui des traitements en fait également partie (Tascher G., 2003 ; Lefevre P.C., 2005).

II.2.1.1. Les données nécessaires à l'estimation

- au niveau d'un élevage ou d'un ensemble d'élevages

L'évaluation monétaire de l'impact d'une maladie sur la production de troupeaux individuels est plus difficile qu'à l'échelle nationale, régionale ou de grands troupeaux car les effets aléatoires sont plus importants (Shaw A.P.M., 1995).

Estimation des coûts liés à la mortalité : au niveau de l'élevage, on doit connaître le nombre d'animaux morts de la maladie et leurs caractéristiques (race, âge état d'engraissement pour les animaux à viande si possible) car la valeur économique des animaux en dépend. Au niveau d'un ensemble d'élevages c'est le taux de mortalité par classes d'âge dont on a besoin.

Estimation des coûts liés à la morbidité : au niveau de l'élevage il faut disposer du nombre et des caractéristiques des animaux ayant été atteints par la maladie puis estimer pour chacun la perte de production occasionnée. Si les pertes en production de lait ou de viande s'estiment à peu prés aisément, il est plus difficile d'évaluer le retard de croissance d'un jeune animal par exemple. On transforme ensuite ces évaluations de baisse de production en valeur monétaire, en tenant compte du prix du marché pendant la période de la maladie. Au niveau d'un ensemble d'élevages l'évaluation ne peut être qu'imprécise. Il s'agit d'évaluer une perte moyenne quotidienne par animal malade à partir du taux de morbidité et des connaissances que l'on a des manifestations cliniques de la maladie.

- au niveau national (ou à grande échelle)

Avant d'estimer les coûts, il faut quantifier les pertes physiques. Trois types de données sont alors nécessaires (Laval, 2002) :

- données sur la population animale : il faut les ordonner en une série de tableaux par espèce et système de production indiquant le nombre de troupeaux, selon leur taille et la répartition par âge à l'intérieur des troupeaux.
- Paramètres de productivité normale : les naissances, la mortalité, la croissance et les taux d'exploitation. Ces données peuvent provenir de rapports de routine, d'enquêtes ou de suivis de troupeaux quand ils existent. Elles sont nécessaires pour établir des modèles statiques ou dynamiques et servent de référence pour comparer la productivité avec ou sans la maladie.
- Pertes de production. Elles sont estimées à partir de l'incidence annuelle attendue de la maladie ce qui implique de connaître :
    - la mortalité par classe d'âge,
    - les incidences de la maladie par classe d'age,
    - les pertes de poids par classe d'age,
    - les pertes de production laitière,
    - la baisse de fertilité et les avortements,
    - les autres pertes de production (travail, laine...).

La plupart de ces informations sont des données d'épidémiologie descriptive sur les conséquences de la maladie.

Les données économiques permettent alors d'effectuer la conversion monétaire pour calculer les coûts. Il s'agit des prix du marché pour une estimation micro-économique par exemple.

II.2.1.2. Méthode de calcul en termes physiques et monétaire (Putt S.N.H. *et al.*, 1987)

- *les modèles de production animale*

Ils permettent grâce à des projections sur plusieurs années et après avoir entré les valeurs de paramètres zootechniques, de calculer la différence de la production avec et sans la maladie

(Lefèvre P.C., 2005). Il s'agit d'une évaluation dynamique le plus souvent qui conduit à l'estimation la plus précise des pertes dues aux maladies.

Ce type d'évaluation se fonde sur une connaissance exhaustive du système de production et des effets de la maladie. Elle est particulièrement adaptée à l'estimation des pertes directes à un niveau national ou régional.

- *Les méthodes d'estimation des pertes annuelles*

Cette approche donne pour différentes productions animales des approximations annuelles de l'effet d'une maladie sur certains paramètres de production. On ne tient pas vraiment compte des effets dynamiques qui s'observent par le biais de la diminution de fécondité et de la croissance du troupeau. Deux méthodes :

1) Pertes estimées en tant que fonction de la valeur de l'animal. Se fonde sur le concept d'un prix reflétant le revenu futur attendu d'un animal. Elle utilise le prix moyen estimé par animal dans chaque groupe d'âge/sexe. Les estimations des pertes dues à la mortalité et à la morbidité se font par rapport à ce prix moyen par animal. La mortalité exprimée en pourcentage pour chaque classe permet de calculer le coût de la maladie. Les pertes liées à la morbidité sont estimées approximativement par cette méthode en considérant une perte globale de production égale à un certain pourcentage de la valeur de l'animal atteint.

2) Pertes exprimées par l'effet de la maladie sur la production finale de lait, de viande et de jeunes et sur la puissance de traction. Cette méthode nécessite de connaître précisément les baisses de production entraînées par la maladie. Les pertes dues à la mortalité peuvent être calculées selon la méthode précédente. Pour la morbidité, le calcul prend en considération la diminution de chaque production : lait, œuf, laine, retards de croissance, baisse de poids, troubles de la reproduction par exemple.

La première méthode se prête aux estimations grossières quand on ne dispose pas de données détaillées sur la morbidité et les effets de la maladie.

II.2.2. Coûts indirects

Les *coûts indirects* correspondent pour leur part à toutes les conséquences négatives d'une maladie sur un animal autres que la mortalité et les pertes de production (Msellati L., 1995 ; McCauley E.H., 1990 ; Tascher G., 2003).

La plupart de ces coûts correspondent à des baisses indirectes de productivité dans les activités liées à l'élevage, à une augmentation des coûts de production ou à des conséquences sur la santé humaine.

Dans le cas des zoonoses par exemple, Il s'agit de pertes de revenus liées à l'inactivité d'une personne malade et au coût des soins et traitements. On peut aussi inclure les coûts de la mort et de la souffrance (ou de la qualité de vie). Enfin il y a les pertes liées au refus du producteur d'entreprendre certaines activités de peur de contracter certaines maladies (Putt S.N.H. *et al.*, 1987).

Il est possible de rajouter dans les coûts indirects le coût des interventions et le temps qui leur est consacré (Msellati L., 1995) mais également ceux qui résultent de la fermeture des marchés extérieurs (Ducrot C. et Boisseleau D., 1996). Une estimation peut alors s'effectuer en posant comme hypothèse qu'après la perte initiale d'un marché extérieur, l'exportateur trouvera un autre débouché offrant des prix plus bas (Putt S.N.H. *et al.*, 1987). La fermeture des frontières pendant une certaine période a des effets sur le marché intérieur qu'il faut estimer par les conséquences sur la filière (Ducrot C., 1995).

Les coûts indirects sont donc plus difficiles à estimer et à quantifier mais représentent une part de moins en moins négligeable du coût total imposé par les maladies et doivent être au minimum listés (Harrison S.R., 1996 ; Perry B.D., 2001 ; Toma B. *et al.*, 2001 ; Lefèvre P.C., 2005 ; James A., 2005).

La quantification de tels effets est possible même si elle est difficile. Elle se fonde essentiellement sur l'estimation des revenus supplémentaires des producteurs qui découleraient de l'élimination de la maladie, de l'amélioration éventuelle des systèmes de production existants, ou de l'adoption éventuelle de nouveaux systèmes de production (Putt S.N.H. *et al.*, 1987). Les méthodes du consensus d'experts ou de l'évaluation de contingence peuvent aussi être employées même si elles comportent de nombreux biais. L'évaluation de contingence consiste à enquêter sur ce que les gens seraient prêts à payer en échange d'un bénéfice donné ou pour préserver une situation.

Dans tous les cas il faut éviter les « double compte » en attribuant par exemple une valeur à une perte de poids et en comptant aussi le coût de l'alimentation supplémentaire nécessaire pour lui permettre de retrouver son poids initial (Lefèvre P.C., 2005).

Les coûts indirects sur la santé humaine font l'objet dans les pays développés d'une attention soutenue, alors que dans les pays en développement ils sont beaucoup plus difficiles à appréhender. L'analyse économique, dont l'objectif est le bien-être de l'homme, se doit de les prendre en compte en essayant de les chiffrer (Tascher G., 2003).

II.3. Coûts d'un programme de lutte

Ils correspondent aux moyens financiers mobilisés pour des activités de prévention sanitaire ou des mesures médicales d'éradication (Putt S.N.H. *et al.*, 1987).

Pour la prévention les coûts pris en compte sont ceux des activités quotidiennes des éleveurs (observation des animaux, maintien de la propreté des locaux...), du contrôle des mouvements d'animaux (frontières, clôtures..), des mesures de protection dans les marchés à bestiaux, de la désinfection des véhicules de transport.

Concernant l'éradication, on s'intéresse à la surveillance et au dépistage (diagnostic sérologique ou autre et les enquêtes ainsi que le réseau d'épidémio-surveillance), au traitement de la maladie avec le suivi, à la prophylaxie, aux abattages pour les maladies réglementées, à la lutte contre les vecteurs, à l'utilisation d'animaux résistants à la maladie (expérimentation, sélection, enquêtes, suivis) (Laval G., 1999).

Ces coûts comprennent des charges fixes (fonctionnement et amortissement des véhicules, salaires fixes, administration et bureau) et des charges variables (médicaments et vaccins, petit matériel médical, indemnités de déplacement du personnel) (Putt S.N.H. *et al.*, 1987). Les charges (ou coûts) variables sont proportionnelles au nombre d'interventions réalisées alors qu'au contraire les charges (ou coûts) fixes (ou encore les frais généraux) en sont théoriquement indépendants (Toma B. *et al.*, 2001). En réalité peu de coûts dits fixes le sont réellement, ils progressent par paliers à partir d'un certain niveau d'activité.

Le principal objectif de la distinction est la comparaison de leur part dans le coût total. On veut pouvoir s'assurer que les éléments contribuant aux charges fixes sont utilisés à leur capacité maximale (Putt S.N.H. *et al.*, 1987), les gaspillages étant fréquents. Si les crédits alloués à un projet diminuent, les activités relevant des charges variables sont souvent sacrifiées en premier de sorte que le projet coûte toujours (pour payer les salaires en particulier) alors qu'aucune activité réelle n'existe.

Certains économistes distinguent plutôt trois catégories (Faye B., 2001) : coûts de personnel, coûts d'investissement et de matériel, coûts de fonctionnement (qui correspondent aux coûts variables). Si la lutte dure plusieurs années on calcule un coût général annuel (somme des trois pour toute la durée de la lutte) que l'on multiplie par le nombre d'années.

II.4. Les bénéfices

De manière générale, les avantages d'un programme de lutte correspondent à la différence entre les pertes dues à la maladie « avec » le programme implanté et les pertes « sans » le programme (Tascher G., 2003 ; Lefèvre P.C., 2005). Seuls les coûts de la maladie sont pris en compte, ceux du programme de lutte sont laissés de côté.

Dans une économie de marché, « l'optimum économique » du niveau d'incidence de la maladie et de son contrôle est la résultante de la demande et de l'offre. La demande correspond à la relation entre le prix de marché d'un produit ou d'un service et du nombre de gens qui veulent et qui peuvent acheter, tandis que l'offre est la relation entre le prix du marché et la quantité de producteurs qui veulent et qui sont en mesure de vendre. Il est d'usage de représenter l'offre et la demande sous la forme d'un graphique avec les prix en ordonnée et les quantités en abscisse. La figure 1 montre une hypothétique relation offre/demande (Ott M.J. *et al.*, 2000).

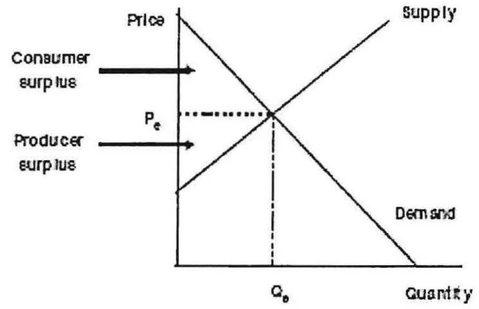
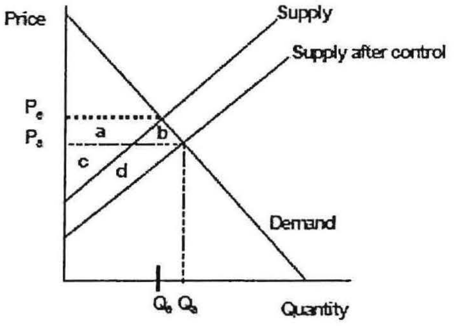


Figure 1 : Courbe de l'offre et de la demande (Ott M.J. *et al.*, 2000)

La courbe de la demande a une pente décroissante - à mesure que le prix baisse le besoin augmente – alors que la courbe de l'offre a une pente croissante – l'offre augmente à mesure que le prix augmente. Les deux droites se coupent au prix d'équilibre : les quantités d'offre et de demande sont en équilibre.
Une mesure de l'effet de la variation de la quantité de la demande et de l'offre selon les prix du marché d'un produit est appelée respectivement élasticité de la demande ou de l'offre. Si une petite variation de prix entraîne une plus grande variation de la demande ou de l'offre, la courbe offre/demande est dite élastique (la courbe a une pente relativement faible). Dans le cas contraire la courbe est dite inélastique et sa pente est forte. Les produits de l'agriculture sont caractérisés par des courbes relativement inélastiques c'est-à-dire que la demande change relativement peu en fonction du prix ce qui par effet miroir implique que de faibles changements de quantités peuvent avoir de gros effets sur les prix.

L'aire entre les courbes d'offre et de demande à la gauche de leur point d'intersection est très importante par rapport à la distribution des bénéfices résultant du contrôle des maladies. Cette surface procure des informations sur le bien fait aux producteurs, aux consommateurs et à la société dans son ensemble. Par exemple, la courbe de l'offre indique que certains producteurs auraient aimé fournir l'offre au marché pour des prix inférieurs à P_e. D'un autre côté, certains consommateurs auraient aimé acquérir le produit à des prix supérieurs à P_e. Ainsi, les consommateurs et les producteurs reçoivent une sorte de surplus, certains consommateurs parce qu'ils obtiennent le produit à un prix inférieur à celui auquel ils étaient prêts à le payer et certains producteurs parce qu'ils reçoivent un prix plus important que celui auquel ils auraient été prêts à produire.



Consumer benefits: a + b   Net benefit: b + d
Producer benefits: d - a

Figure 2 : Courbe de l'offre et de la demande après contrôle

Le contrôle effectif des maladies animales augmente l'efficacité (le rendement) des ressources utilisées dans les populations atteintes, et par conséquent déplace la courbe d'offre pour les produits animaux vers la droite, c'est-à-dire que les éleveurs veulent produire plus quel que soit le prix actuel. Un nouvel équilibre est atteint. Comme on peut le voir sur la figure 2, en résultante de ce nouvel équilibre, le surplus des consommateurs et des producteurs a changé. Plus le produit est vendu à un prix bas, plus le consommateur, qui paie moins, en bénéficie, et plus le producteur, qui en vend plus, en profite aussi. La surface b+d sur la figure 2 représente le bénéfice net pour la société dans son ensemble. La distribution des bénéfices d'un mouvement donné de la courbe de l'offre dépend de l'élasticité de la demande. Plus la demande du consommateur est inélastique, plus le surplus du consommateur sera important, alors que les producteurs profiteront peu de l'augmentation de l'efficience de la production. Les augmentations de l'offre et les conséquences sur les mouvements des prix doivent être considérées quand le contrôle d'une maladie est appliqué à une large proportion d'élevages, c'est-à-dire lors de politiques de contrôle nationales ou de programmes d'éradication (Ott M.J. *et al.*, 2000).

Les bénéfices au sens strict du terme prennent en compte pour leur part ce coût du programme de lutte :
Bénéfice = pertes dues à la maladie sans lutte – (pertes dues à la maladie avec lutte + coût du programme de lutte) (Lefèvre P.C., 2005)

DEUXIEME PARTIE : L'ANALYSE COUT-BENEFICE, PLUS COMPLETE

I. La valeur monétaire des bénéfices

I.1. Passage de l'expression en termes physiques à la valeur monétaire

Souvent, il n'est pas certain que les conséquences des options étudiées soient identiques. De plus il peut être impossible de réduire les résultats attendus à un seul effet commun aux différentes options. On s'intéresse alors soit à des effets qui, tout en étant communs à toutes les options, sont multiples, soit à des effets, uniques ou multiples, qui ne sont pas communs à toutes les options.

Afin de poursuivre l'analyse coût-efficacité, il faudrait alors calculer les ratios coût-efficacité pour ces trois critères. Si une option n'est pas nettement meilleure pour les trois critères à la fois, on peut soit sélectionner (implicitement ou explicitement) un effet principal sur lequel fonder la comparaison, soit trouver une méthode qui agrége les trois effets en un dénominateur commun.

Les analystes tentent alors souvent de dépasser la prise en compte des effets spécifiques eux-mêmes pour mesurer la valeur des effets pris dans leur ensemble. Cette valeur peut-être mesurée dans l'unité monétaire, et les conséquences d'un programme sont alors exprimées par le bénéfice en unité monétaire ce qui facilite la comparaison avec les coûts (Birch S. et Donaldson C., 1987 ; Pauly M.V., 1995). Cela oblige à exprimer en unité monétaire des bénéfices très qualitatifs ce qui n'est pas toujours aisé mais dans certain cas c'est une méthode faisable et adaptée (Drummond *et al.*, 1998). C'est d'ailleurs la méthode la plus utilisée en santé animale (Ducrot C. et Boisseleau D., 1996, Mlangwa J.E.D et Samui K.L., 1996). Elle est également nommée « avantage/coût » ou « coût avantage » par certains auteurs (Laval G., 2002).

C'est une analyse qui se doit d'être méthodique et exhaustive tout comme l'analyse coût efficacité et dont les premières étapes d'inventaire des coûts et bénéfices en termes physiques sont communes, l'étape supplémentaire étant la conversion monétaire. Les résultats des analyses ACB peuvent être présentés sous la forme d'un ratio coût/bénéfice, tous deux exprimés en unité monétaire, soit comme une simple somme (pouvant être négative) représentant le bénéfice net (ou la perte) d'un programme par rapport à un autre (Drummond M.F. *et al.*, 1998).

I.2. L'actualisation

Une même somme d'argent n'a pas la même valeur d'une année sur l'autre, compte tenu des taux d'intérêt. Le principe de l'actualisation est de calculer la valeur actuelle d'une valeur future.

Un sou investi aujourd'hui ne peut donner des résultats que dans un, deux ou trois ans. Quand on place son argent, on obtient des intérêts plus élevés que l'érosion monétaire et ces intérêts sont composés c'est-à-dire que chaque fin d'année l'intérêt s'applique à la somme qui existait sur le compte en début d'année. Si l'on place 100 € à 10%, on recevra 110 € la première année, 121 € la deuxième ou 161 € la cinquième. Le taux d'actualisation correspond exactement à l'inverse de l'intérêt composé. Si dans cinq ans, on s'attend à recevoir 161 €,

aujourd'hui ces 161 € n'ont qu'une valeur actuelle de 100 € si le taux d'actualisation est de 10 p. 100 (Tascher G., 2003 ; Tascher G. et Letenneur L., 2003).
La valeur actuelle d'un coût ou d'un bénéfice à venir, considérant un taux d'actualisation r (p. Cent) et un nombre d'années dans le futur n, est calculée de la manière suivante (Ducrot C. et Boisseleau D., 1996 ; Toma B. *et al.*, 2001) :

$$\text{Valeur actuelle} = \text{valeur future} / (1 + r/ 100)^n$$

Coûts et bénéfices attendus au cours du temps doivent être comparés après l'application d'un taux d'actualisation lors d'une analyse économique (Putt S.N.H. *et al.*, 1987 ; Dijkhuizen A.A. *et al.*, 1995 ; Ducrot C. et Boisseleau D., 1996 ; Toma B. *et al.*, 2001 ; Brent R.J., 1998). Ils doivent être « actualisés » car l'argent perdu ou gagné ultérieurement ne doit pas peser aussi lourd dans la décision que l'argent perdu ou gagné à l'instant présent.
L'inflation n'est généralement pas intégrée dans le taux d'actualisation car les estimations s'effectuent sur la base des prix du moment (Putt S.N.H. *et al.*, 1987 ; Ducrot C. et Boisseleau D., 1996).

I.3. Comparaison des coûts et des bénéfices en utilisant au choix trois indices

I.3.1. la valeur actuelle nette ou le bénéfice net actualisé

La technique de la valeur actuelle est la somme actualisée de la différence entre bénéfices (ou avantages) et coûts de chaque année. Elle suppose que l'on connaisse le taux d'actualisation ou que l'on s'en fixe un arbitrairement. Sa formule mathématique est :

$$VA = \sum_{T=1}^{T=n} (B_t - C_t) / (1 + i)^t \qquad \text{ou} \qquad VAN = VAA - VAC$$

Bt : bénéfices (ou avantages) de l'année t
Ct : coûts de l'année t
t : année 1, 2,...n
n : nombre d'années de l'étude
i : taux d'actualisation

VAN : valeur actuelle nette
VAA : valeur actuelle avantages
VAC : valeur actuelle coûts

Les bénéfices ou les coûts de l'année t représentent en valeur algébrique les bénéfices avec projet diminués des bénéfices sans projet de l'année considérée et il en est de même pour les coûts.
Si la valeur actuelle est positive, le projet peut être accepté (Toma B. *et al.*, 2001 ; Tascher G., 2003).
Cependant, ce critère donne une valeur d'autant plus grande que le projet est important et défavorise les petits projets qui, souvent, ont plus de chances de réussite que des grands projets (Tascher G., 2003 ; Tascher G. et Letenneur L., 2003).

I.3.2. le rapport bénéfices/coûts

C'est le rapport entre la somme des valeurs des bénéfices actualisés (ou des avantages) et la somme des coûts actualisés. Ce critère suppose que l'on connaisse le taux d'actualisation ou que l'on s'en fixe un arbitrairement. Sa formule mathématique est :

$$\hat{}B/\hat{}T = \left(\sum_{T=1}^{T=n} B_t \,/\, (1+i)^t\right) / \left(\sum_{T=1}^{T=n} C_t \,/\, (1+i)^t\right)$$

Si ce rapport bénéfices-coûts est supérieur à 1 le projet peut être accepté.
Les bénéfices ou les coûts de l'année t représentent en valeur algébrique les bénéfices avec projet diminués des bénéfices sans projet de l'année considérée et il en est de même pour les coûts. L'inconvénient de ce critère est qu'il ne dit rien sur la valeur des investissements à entreprendre. (Tascher G., 2003 ; Tascher G. et Letenneur L., 2003).

I.3.3. le taux de rendement interne ou taux de rentabilité interne

Le critère du taux de rentabilité interne est le rapport pour lequel le taux d'actualisation rend nul les bénéfices (ou les avantages) moins les coûts actualisés. Ou bien on peut dire qu'il correspond au taux d'actualisation pour lequel la valeur actuelle des avantages est égale à la valeur actuelle des coûts. Ce critère sous entend que l'on ne connaît pas le taux d'actualisation. Sa formule mathématique est :

$$\sum_{T=1}^{T=n} (B_t - C_t) \,/\, (1+i)^t = 0$$; TRI = tx d'actualisation pour lequel VAA=VAC, donc VAN=0

Où i est le taux de rentabilité interne recherché, la recherche de i se fait en résolvant cette équation par itération. On ne peut en effet pas calculer le TRI directement, il faut le faire par tâtonnement en utilisant différents taux d'actualisation jusqu'à ce qu l'on trouve une VAN très proche de 0 (Toma B. *et al.*, 2001).
Si le taux de rentabilité interne est positif et s'il dépasse le taux d'actualisation courant, le projet peut être accepté. La priorité à donner aux projets commence par ceux qui ont les taux de rentabilité interne les plus élevés.
Ce critère est le plus utilisé notamment par la banque mondiale (Tascher G., 2003 ; Tascher G. et Letenneur L., 2003).

Pour tous ces critères la présentation sous forme de tableau est essentielle, car un chiffre brut comme un taux de rentabilité interne de 15 % peut cacher que certaines années il y aura des difficultés de trésorerie pour l'état, pour le projet ou pour l'éleveur ou que le temps à attendre pour obtenir des bénéfices ou pendant lequel on doit faire des sacrifices n'est pas acceptable.

II. Les critères d'acceptabilité d'un projet et l'analyse de sensibilité

II.1. Les indicateurs d'acceptabilité

Que ce soit en santé humaine ou en santé animale, les indicateurs d'acceptabilité d'un programme sont:

- le bénéfice social net (également dénommé valeur actuelle nette ou bénéfice net actualisé), différence entre les bénéfices et les coûts des programmes comparés,
- le ratio bénéfice/coût,
- le taux de rentabilité interne, défini comme la valeur du marché de l'argent (ou du taux d'actualisation) qui rendrait égaux coûts et bénéfices.

(Putt S.N.H. *et al.*, 1987 ; Drummond M.F. *et al.*, 1998 ; Ducrot C. et Boisseleau D., 1996 ; Toma B. *et al.*, 2001)

Cependant la règle de décision dépendra du contexte de l'évaluation (Pauly M.V., 1995) et en particulier de l'existence ou non d'une contrainte budgétaire (Brent R.J., 1998).

Ce domaine est encore peu développé. En fait, les critères clés sur lesquels sera jugée une stratégie sont plus larges que ceux qu'englobent ces indicateurs économiques. Ainsi on y inclut des paramètres tels que la distribution des bénéfices ou les effets sur l'emploi (Perry B.D., 2001).

II.2. L'analyse de sensibilité

Les analystes doivent identifier les hypothèses méthodologiques critiquables et les zones d'incertitude. Pour ce faire, ils modifient en général l'analyse d'origine (qualitativement ou quantitativement), en utilisant des hypothèses ou des estimations différentes de façon à tester la sensibilité des résultats et des conclusions à ces modifications. Si les résultats sont peu sensibles à des modifications importantes, une plus grande confiance sera accordée aux résultats d'origine. Dans le cas contraire, il faudra s'efforcer de réduire l'incertitude et/ou d'améliorer la connaissance des variables stratégiques. L'analyse de sensibilité est donc un élément majeur d'une évaluation économique sérieuse (Drummond M.F. *et al.*, 1998, Ott M.J. *et al.*, 2000 ; Tascher G. et Letenneur L., 2003).

TROISIEME PARTIE : APPLICATION A L'ETUDE CRITIQUE D'ARTICLES

I. La grille d'analyse selon Drummond

Drummond M.F. *et al.*, 1998 ; Bonnet P., 2003

1. La question de recherche est-elle clairement définie et posée de manière à ce que l'on puisse y répondre ? L'étude permet elle de donner une réponse précise au motif de recherche ?
2. Les options concurrentes du programme à mettre en place ont-elles été décrites de façon exhaustive, explicite et compréhensible ? (i.e. pouvez-vous dire qui ? a fait quoi ? à qui ? où ? et avec quelle fréquence ?)
3. L'efficacité des programmes a-t-elle été établie clairement, y a-t-il assez d'évidences de l'efficience du programme ?
4. Les coûts et les conséquences les plus importants de chaque option ont-ils été identifiés ?
5. Les coûts et les conséquences ont-ils été mesurés correctement, en unités physiques appropriées (nombre d'année de vie sauvées, décroissance du taux de mortalité...) ?
6. Les coûts et les conséquences (avantages) ont-ils été évalués de façon pertinente ?
7. Les coûts et les conséquences ont-ils été ajustés en fonction du temps ?
8. Une analyse différentielle (incrémentielle) des coûts et des conséquences (ratios) des options concurrentes a-t-elle été réalisée ?
9. A-t-on tenu compte de l'incertitude dans l'estimation des coûts et des conséquences et une analyse de sensibilité a-t-elle alors été effectuée?
10. La présentation et la discussion des résultats de l'étude recouvrent-elles toutes les préoccupations des utilisateurs ?

II. Deux articles ACE

II.1. Coût-efficacité de mesures pour prévenir l'introduction de la peste porcine classique en Hollande

DE VOS C.J., SAATKAMP H.W., HUIRNE R.B.M., 2005. Cost-effectiveness of measures to prevent classical swine fever introduction into the Netherlands, *Prev. Vet. Medicine*, **70** : 235-256

L'objectif de l'article est de faire l'analyse coût-efficacité de différentes mesures de prévention de l'introduction de la peste porcine classique en Hollande. Le point de vue semble être celui des décideurs de police sanitaire nationaux qui préconisent actuellement la non-vaccination et l'abattage total des élevages infectés.

Les options concurrentes sont au nombre de six. Il s'agit :

- Du nettoyage et de la désinfection des camions de transport du bétail de retour en Hollande par un personnel certifié dans des centres qui auront été préalablement définis ;
- De la séparation des transports nationaux et internationaux de cochons dans des camions spécifiques avec la mise en place de points de rassemblement pour les cochons destinés à l'export ;
- De l'utilisation de camions de transport à plusieurs containers détachables. Les containers seront déposés vides dans les fermes puis repris un à un sur le trajet de retour une fois pleins ;
- De l'utilisation de routes séparées pour l'approvisionnement et la livraison dans les fermes : existence de barrières physiques entre la partie propre de l'entreprise et les routes de transport bitumées. Une chaîne d'hygiène, pas de véhicule admis dans la partie propre de l'entreprise ;
- D'un apport logistique concernant l'abattage des cochons gras : seront abattus d'abord les porcs hollandais puis les porcs importés. Il ne faut pas de contacts physiques entre les porcs des deux origines. Il y aura un nettoyage et une désinfection supplémentaire de la chaîne et du local pré-abattage après l'approvisionnement en porcs importés ;
- Du test des porcelets et des cochons reproducteurs par un test PCR rapide et fiable. Tous les cochons d'un lot sont testés. Les résultats des tests sont connus dans les 24h.

Les options sont explicitées mais de façon imprécise. On ne dispose pas de détail sur leur déroulement, les acteurs impliqués ou la fréquence de leur mise en œuvre.
Les données utilisées proviennent de diverses sources : publications, consensus d'experts, modèle mathématique.
L'efficacité de chacune des mesures choisies est bien illustrée par l'utilisation d'un modèle de type arbre de décision avec comme indicateur la réduction de la probabilité annuelle d'introduction du virus de la peste porcine classique en Hollande.
C'est au niveau des calculs des coûts que les auteurs regrettent l'obligation d'une estimation grossière par manque de données. Le calcul est approximé par les coûts supplémentaires nécessaires à l'implantation des mesures étudiées par rapport à la situation actuelle, sans que l'on ait beaucoup plus de précisions. On sait par contre qu'ils ont bien été ajustés en fonction du temps en tenant compte de pourcentages de dépréciation annuels par exemple. L'étude de sensibilité réalisée sur les coûts annuels des mesures de prévention, montre que les résultats qui ressortent de l'analyse coût-efficacité sont solides malgré les incertitudes existantes dans le calcul des coûts.

L'article conclut que la mesure la plus efficace est la séparation des transports nationaux et internationaux de cochons avec le transfert des cochons dans des camions spécifiques pour l'international après rassemblement dans des sites pour l'export. C'est aussi la meilleure en terme de coût-efficacité pour la Hollande.

L'étude permet donc l'apport d'éléments précis et importants sur l'efficacité des différentes mesures étudiées dont l'analyse de sensibilité souligne la fiabilité, mais ne saurait se suffire à elle-même lors d'une prise de décision car elle ne recouvre pas toutes les préoccupations des utilisateurs. Par ailleurs, l'approche des coûts nécessiterait un approfondissement par la réalisation d'une étude de la facilité d'implantation des mesures étudiées en fonction notamment de l'investissement nécessaire à leur réalisation, l'étude de la répartition des coûts et des bénéfices entre les différents acteurs impliqués, une étude coût-bénéfice (la mesure vaut elle la peine compte tenu de son prix ?), et enfin une étude du coût imputable à la réduction de la probabilité d'introduction de la maladie.

II.2. L'analyse coût-efficacité en médecine vétérinaire : Illustration par l'étude de la valeur pronostique de l'hématocrite pour les coliques chirurgicales du cheval en Belgique.

DETILLEUX J.C., SERTEYN D., 2005. Cost-Effectiveness Analysis in Veterinary Medicine : Illustration with packed cell value in the Prognosis of horse surgical colic in Belgium. *Intern. J. Appl. Res. Vet. Med*, **3** (4) : 309-318.

Le but de l'étude est l'illustration de l'utilité d'une analyse coût-efficacité dans le cadre de l'exercice de la médecine vétérinaire équine d'urgence. Les auteurs s'appuient sur la valeur pronostic de l'hématocrite pour les coliques équines de nature chirurgicale.
Ils comparent les options « traitement chirurgical de la colique sans test de l'hématocrite » avec « traitement chirurgical après test de l'hématocrite positif et pas de traitement si test de l'hématocrite négatif ». La valeur seuil choisie pour l'hématocrite est 44 % conformément à une étude précédente basée sur des données belges.
Le critère d'efficacité choisi est classique. C'est le nombre d'années de vie gagnées pour le cheval après chirurgie ou « année-cheval ». Les coûts sont d'abord évalués en termes physiques puis en termes monétaires de manière assez rigoureuse.
Le point de vue choisi est celui du propriétaire de l'animal, décideur final pour la chirurgie. Sur ce principe, les auteurs attribuent donc à chaque efficacité une valeur monétaire reflétant la somme maximum que le propriétaire serait prêt à payer pour le résultat.
Le résultat final est exprimé en terme de bénéfice net incrémentiel (INB_K), différence entre les augmentations en efficacité et en coût :

$$INB_K = K \times (E_T - E_N) - (C_T - C_N) \text{ avec :}$$

K : valeur monétaire pour une année-cheval gagnée
E_T : efficacité avec test ; E_N : efficacité sans test
C_T : coût avec test ; C_N : coût sans test

Pour analyser les différents types d'incertitudes plusieurs techniques sont utilisées dont la modélisation et plusieurs représentations : diagrammes, courbe d'acceptabilité coût-efficacité par exemple.

Leur conclusion est que la stratégie « avec test » est moins coûteuse et moins bénéfique que « sans test », quelles que soient la volonté de payer (K) pour une année-cheval, et la limite choisie pour l'hématocrite.

Dans l'alternative « pas de test » la chirurgie est faite sur tous les chevaux, alors que dans l'option « test » la chirurgie est faite uniquement sur les animaux à test positif ce qui réduit les coûts.
Cependant puisque la stratégie « test » est aussi moins efficace la question se pose de savoir si l'économie budgétaire réalisée est justifiée.
Cette décision ne peut-être prise que si une valeur critique ou « somme que le propriétaire est prêt à payer » pour une année-cheval a été précisée. Ainsi quand le propriétaire est prêt à

payer au maximum 672€ pour une année-cheval, l'option test (Ht<44 %) est la plus coût-efficace.
Toutefois la courbe d'acceptabilité du critère coût-efficacité montre que le propriétaire prendra la mauvaise décision dans 50 % des cas à cause des variations d'échantillonnage.

Cette étude répond donc explicitement au motif de recherche avec une incertitude forte mais l'évaluation semble pertinente. L'ajustement temporel n'a pas de sens ici puisque l'analyse est directement applicable et se réfère à des valeurs actuelles. On peut cependant se demander si l'on ne se rapproche pas plutôt d'une étude coût-bénéfice, un des critères fondamentaux utilisés étant le bénéfice net incrémentiel et non plus un ratio efficacité/coût.

III. Deux articles ACB

III.1. Analyse coût-bénéfice de la vaccination des vaches laitières contre la paratuberculose

VAN SCHAIK G., KALIS C.H.J., BENEDICTUS G., DIJKHUIZEN A.A., HUIRNE R.B.M., 1996. Cost-benefit analysis of vaccination against paratuberculosis in dairy cattle. *Veterinary Record*, **139** : 624-627

En 1984, un essai de vaccination contre la paratuberculose fut mené par les services de santé animale du nord de la Hollande afin :

- d'étudier l'effet de la vaccination sur le nombre d'animaux ayant la forme clinique ou subclinique de la maladie, et,
- de voir si la vaccination réduit les pertes de production et si les bénéfices de la vaccination surpassent le total des coûts.

Les auteurs se proposent de donner les résultats de la partie analyse coût-bénéfice de l'essai.
Les options concurrentes du programme sont les situations avant et après vaccination, en utilisant un lot vacciné et un groupe témoin. La vaccination est effectuée en une seule fois sur des animaux ayant moins d'un mois à l'aide d'un vaccin tué dans une émulsion huileuse.
Le point de vue choisi est celui de l'éleveur.
Les coûts et les bénéfices de la vaccination sont calculés grâce à la méthode du budget partiel, donc seuls les changements produits par le programme de vaccination sont calculés.
Les pertes par animal à l'échelle de la ferme sont énumérées en termes physiques. Il s'agit de pertes :

- avant que l'éleveur ne réforme l'animal : pertes en termes de production laitière et coût de l'examen vétérinaire et du traitement,
- à la réforme : valeur plus faible à l'abattage et coût des places vides dans l'élevage,
- dues à la réforme : pertes par rapport aux futurs revenus qu'aurait rapportés l'animal.

L'évaluation en terme monétaire est faite à partir des résultats expérimentaux, les prix sont apparemment ceux du moment.
Les chercheurs utilisent aussi la bibliographie et un modèle dynamique pour estimer les manques à gagner futurs en fonction des qualités propres à chaque vache.
Les bénéfices de la vaccination sont la réduction des pertes par la réduction de l'une ou plusieurs de leurs composantes.

La conclusion est que le bénéfice de la vaccination est de 142 $US par vache. La vaccination réduit la fréquence des animaux infectés cliniquement et de manière subclinique. Elle pourrait donc participer à l'élimination de la paratuberculose ce qui serait hautement profitable pour l'éleveur. Les fermes qui vaccinent n'ont pas le droit d'exporter des animaux vivants. Mais pour les auteurs les bénéfices de la vaccination surpasseront en moyenne facilement les pertes causées par ces restrictions à l'export.

La présentation et la discussion des résultats tendent à recouvrir toutes les préoccupations des utilisateurs. Cependant, comme les auteurs eux-mêmes en font mention, on ne peut pas vraiment dire que l'efficacité du programme ait été clairement établie puisqu'ils n'ont pas prouvé que toutes les différences en terme de production laitière et de manque à gagner futur pouvaient être imputées à la paratuberculose. D'autre part on peut regretter que les coûts et les bénéfices se référant à l'étude en 1984 et finie en 1992 n'aient pas été ajustés en fonction du temps et qu'il n'y ait pas d'analyse de sensibilité effectuée.

III.2. Evaluation de différentes stratégies pour la prévention de la maladie de Newcastle au Cambodge

SEN S., SHANE S.M., SCHOLL D.T., HUGH-JONES M.E., GILLESPIE J.M.,1998. Evaluation of alternative strategies to prevent Newcastle disease in Cambodia. *Preventive veterinary Medicine*, **35** : 283-295

Cette étude a été menée pour quantifier l'impact de la maladie de Newcastle à l'échelle d'une ferme commerciale de volailles au Cambodge. Par l'analyse coût-bénéfice, les auteurs veulent aussi évaluer les bénéfices qu'un éleveur peut retirer de différentes stratégies de prévention contre la maladie de Newcastle afin de pouvoir choisir celle qui maximise les profits et le retour sur investissement.

Les différentes stratégies comparées sont :
- ne rien faire (de manière implicite) ;
- la vaccination seule ;
- le renforcement de la sécurité sanitaire seul ;
- l'association de la vaccination et des mesures de police sanitaire.

L'option vaccination est décrite dans le détail. Il s'agit de l'utilisation de vaccins vivants atténués et de vaccins tués dans des émulsions huileuses. Le protocole du programme vaccinal est décrit dans un tableau. La vaccination contre la bursite infectieuse est incluse car il est considéré nécessaire d'avoir une protection contre ce virus pour avoir une réponse correcte en anticorps contre la maladie de Newcastle.
L'efficacité des programmes permet de classer les stratégies alternatives : 70% d'efficacité pour la vaccination, 50% pour la police sanitaire et 95% pour l'association des deux ; l'efficacité étant définie ici comme [1- probabilité d'infection dans un élevage exposé au virus].
La manière d'obtenir ces pourcentages n'est pas très bien explicitée par rapport aux références prises pour le calcul. 70% d'efficacité pour la vaccination semble élevé compte tenu de la difficulté générale de sa mise en place dans les pays en voie de développement. A-t-on pris en compte l'ensemble des conditions sur le terrain ?

Les coûts les plus importants de chaque option semblent avoir été correctement identifiés. Les auteurs en donnent la liste pour chaque option :

- coût de la vaccination :
  - achat et stockage de vaccins fabriqués conformément aux standards internationaux d'efficacité et de sécurité,
  - personnel nécessaire pour l'administration du vaccin
  - provision supplémentaire pour la réalisation d'essais sérologiques afin de confirmer la réponse en anticorps suite au vaccin.
- coût de l'amélioration de la police sanitaire :
  - proportion du coût fixe de mise en place d'une clôture en fer de deux mètres de haut avec des portes sécurisées autour de l'unité de production pour prévenir les intrusions et pour exclure les volailles extérieures à l'élevage,
  - séparation de l'élevage et de la partie accessible par le marchand d'animaux vivants,
  - désinfectants pour la décontamination des locaux et des équipements à la fin de chaque cycle,
  - vêtements et chaussures spécifiques à l'élevage pour le personnel.

S'y ajoute les coûts d'investissement, de fonctionnement et d'équipement pour la réalisation de chacune des options.
Il est difficile d'affirmer que la mesure des coûts est correcte, toutes les données de base des calculs provenant d'enquêtes informelles, même si les prix du marché par exemple sont dits concordants avec ceux du Ministère de l'Agriculture Cambodgien obtenus quatre ans plus tôt.

Par contre le paramètre temps est pris en compte, toutes les valeurs étant ramenées au déroulement d'un cycle de production.
L'analyse différentielle des coûts et des conséquences des options concurrentes est réalisée. Les profits des stratégies de prévention sont calculés en fonction du risque d'exposition variant de 0 à 1 par tranche de 0,1.

Les résultats sont que pour un risque d'exposition supérieur à 0,2, les ratios Bénéfice/Coût des trois stratégies de prévention sont supérieurs à 1.
Pour une probabilité d'exposition supérieure ou égale à 0,3, la combinaison d'une protection sanitaire renforcée et de la vaccination procure le maximum de protection, d'où un maximum de profit pour les producteurs. Lorsqu'elle est comprise entre 0,1et 0,3, l'amélioration des mesures sanitaires toute seule offre le meilleur retour sur investissement. Elle est donc la meilleure stratégie financière pour le producteur.

L'analyse de sensibilité montre pour sa part que l'efficacité de la protection, le coût de l'intrant aliment et les conséquences financières de l'infection affectent de manière non négligeable les ratios coût-bénéfice escomptés.

CONCLUSION

En théorie, l'Analyse Coût-Bénéfice (ACB) fournit une information sur le bénéfice absolu des programmes, en complément de l'information sur leur performance relative. Ainsi, l'ACB donne une estimation de la valeur des ressources consommées par chaque programme, comparée à la valeur des ressources que le programme pourrait épargner ou créer. Cette vision de l'ACB suppose implicitement que chaque programme soit comparé à une alternative « ne rien faire », qui n'occasionne ni coût ni conséquence. Cependant, en pratique, les ACB se résument souvent à une comparaison des coûts et des bénéfices qui peuvent s'exprimer facilement en terme monétaire, et un très petit nombre d'analyses publiées peuvent prétendre à un rôle plus large. De même, rares sont les circonstances où rien n'est fait pour résoudre un problème de santé donné. L'ACE suppose implicitement qu'une telle option n'existe pas, et que l'une des options du programme sera retenue sans considérer son bénéfice net. Bien que cette position puisse être tout à fait réaliste pour un décideur, il faut souligner que l'ACE peut amener à choisir un programme qui ne sera pas « rentable ». Implicitement, l'hypothèse est que l'output, c'est-à-dire l'effet de santé, « vaut la peine » d'être obtenu. La seule question alors est de déterminer la façon la plus efficace de l'obtenir à moindre coût (Drummond M.F. *et al.*, 1998).

D'autre part, ces techniques d'évaluation supposent que les ressources libérées par les programmes choisis ne soient pas gaspillées mais utilisées dans d'autres programmes plus intéressants. Cette hypothèse requiert un examen minutieux. En effet, si les ressources épargnées sont dépensées dans d'autres programmes inefficaces ou non évalués on ne réalisera pas d'économie.

Enfin, toute évaluation est intrinsèquement une activité coûteuse. Aussi l'analyse coût-bénéfice est-elle toujours pertinente ? Il est raisonnable de penser que l'évaluation économique sera des plus utiles dans les cas suivants : les objectifs du programme demandent à être clarifiés, les options concurrentes sont de natures différentes, ou les enjeux financiers sont importants (Drummond M.F. *et al.*, 1998).

BIBLIOGRAPHIE

BEAL V.C.Jr., 1983. L'économie de la santé animale aux Etats-Unis : modélisation mathématique des fluctuations zoo-sanitaires. *In* : Santé animale et économie. *Série technique de l'Office international des épizooties* n°3, 317-329.

BENNETT R.M., 1992. The use of "economic" quantitative modelling techniques in livestock health and disease-control decision making : a review. *Preventive Veterinary Medicine*, **13**, 63-76.

BIRCH S., DONALDSON C., 1987. Applications of cost-benefit analysis to health care : departure from welfare economic theory. *Journal of Health Economics*, **6**, 211-225.

BONNET P. How to appraise the quality of the economic evaluation in Health? Lectures in Animal Health Economics given at University of Addis Ababa Faculty of Veterinary Medicine, Post graduate Master in Public Veterinary Health : Quality and sanitary aspects of Animal production in Ethiopia. February-March 2003, Addis Ababa, Ethiopia.

BRENT R.J., 1998. Cost-benefit analysis for developing countries. Cheltenham, United Kingdom, Edward Elgar, 308 p.

DETILLEUX J.C., SERTEYN D., 2005. Cost-Effectiveness Analysis in Veterinary Medicine : Illustration with packed cell value in the Prognosis of horse surgical colic in Belgium. *Intern. J. Appl. Res. Vet. Med*, **3** (4) : 309-318.

DE VOS C.J., SAATKAMP H.W., HUIRNE R.B.M., 2005. Cost-effectiveness of measures to prevent classical swine fever introduction into The Netherlands. *Preventive Veterinary Medicine,* **70** : 235 – 256.

DIJKHUIZEN A.A., 1988. Modelling to support health programs in modern livestock farming. *Netherlands Journal of Agricultural Science*, **36** : 35-42.

DIJKHUIZEN A.A., HUIRNE R.B.M., JALVINGH A.W., 1995. Economic analysis of animal diseases and their control. *Preventive Veterinary Medicine*, **25** : 135-149.

DRUMMOND M.F., O'BRIEN B.J., STODDART G.L., TORRANCE G.W., 1998. Méthodes d'évaluation économique des programmes de santé. Paris, France, Economica, 331 p.

DUCROT C. Approche économique des prophylaxies – Analyse des méthodes d'approche de l'aspect coûts-bénéfices des maladies faisant l'objet d'un programme officiel de lutte. Clermont-Ferrand : Centre d'Ecopathologie Animale, INRA, 1995. 40 p.

DUCROT C., BOISSELEAU D., 1996. Analyse coûts-bénéfices des prophylaxies : principes, méthodes et illustrations. *Epidémiologie et santé animale*, **30** : 13-19.

FAO (Food and Agriculture Organization of the United Nations), 1990. Cost/benefit analysis for animal health programmes in developing countries. *In* : FAO expert consultation, Rome, Italy. Rome, Italy, FAO, 47 p.

FAYE B., 2001. Economie de la santé animale. Synthèse bibliographique, Diplôme d'études supérieures spécialisées productions animales en régions chaudes, CIRAD – Université Montpellier 2, Montpellier, France, 34 p.

HALL D.C., KAISER H.M., BLAKE R.W., 1998. Modelling the economics of animal health control programs using dynamic programming. *Agricultural Systems*, **56** (1) : 125-144.

HARRISON S.R., 1996. Cost-Benefit Analysis with Applications to Animal Health Programmes : Valuation of Non-Market Costs and Benefits. *In* : Research Papers and Reports in Animal Health Economics, Brisbane, Australia, October 1996. Brisbane, Australia, University of Queensland, 18 p.

JAMES A., 2005. The state of veterinary epidemiology and economics. *Preventive Veterinary Medicine* **67** : 91-99.

LAVAL G., 1999. Les évaluations économiques en santé animale, état des connaissances et application pratique : l'analyse des coûts de la Péripneumonie contagieuse bovine (PPCB) en Ethiopie. Mémoire de DEA , Université Claude Bernard - Lyon I, Lyon, France, 98 p.

LAVAL G., 2002. Analyse coût-bénéfice des méthodes de lutte contre la PPCB. Thèse doct., Université Claude Bernard – Lyon I, Lyon, France, 261 p.

LEFEVRE P.C., 2005. Le coût des maladies animales. Cours de Master PARC, CIRAD, Montpellier, France.

McCAULEY E.H., 1990. Methods of analysis of the indirect losses due to general and specific animal morbidity and mortality. *In* : FAO. Expert consultation on cost/benefit analysis for animal health programmes in developing countries, 10-14 September 1990. FAO, Rome, Italy, n.p.

MLANGWA J.E.D., SAMUI K.L., 1996. The nature of animal health economics in relation to veterinary epidemiology. *Revue Scientifique et Technique de L'Office International des Epizooties*, **15** (3) : 797-812.

MSELLATI L., 1995. Evaluation économique et prise de décision dans le domaine de la santé animale. *Epidémiologie et santé animale*, **28** : 39-45.

OTT M.J., CHILONDA P., 2000. Animal Health Economics : an Introduction. Livestock Information, Sector Analysis and Policy Branch, Animal Production and Health Division (AGA), FAO, Rome, Italy.
[On line]. [2006/02/28].
<URL : http://www.fao.org/ag/againfo/resources/en/publications/agapubs/pproc01.pdf>.

PAULY M.V., 1995. Valuing health care benefits in money terms. *In* : Sloan F.A. ed. : Valuing health care. Cambridge, United Kingdom, Cambridge University Press, p. 99-122.

PERRY B.D., McDERMOTT J., RANDOLPH T., 2001. Can epidemiology and economics make a meaningful contribution to national animal-disease control ? *Preventive Veterinary Medicine*, **48** : 231-260.

PUTT S.N.H., SHAW A.P.M., WOODS A.J., TYLER L., JAMES A.D. 1987. Epidémiologie et économie vétérinaire en Afrique. Manuel à l'usage des planificateurs de la santé animale. Manuel n°3. Addis Ababa, Ethiopie, ILCA, 146 p.

RENKEMA J.A., 1980. Economic aspects of disease in animals, with special reference to the assessment of losses. *Bulletin de l'Office International des Epizooties*, **92** : 5-6.

RENKEMA J.A, 1983. Evaluation économique des pertes causes par les maladies animales. *In* : Santé animale et économie. Série technique de l'Office international des épizooties n°3, 57-74.

RUSHTON J., THORNTON P.K., OTTE M.J., 1999. Methods of economic impact assessment. *Revue Scientifique et Technique de L'Office International des Epizooties*, **18** (2) : 315-342.

SCHAIK G. VAN, KALIS C.H.J., BENEDICTUS G., DIJKHUIZEN A.A., HUIRNE R.B.M., 1996. Cost-benefit analysis of vaccination against paratuberculosis in dairy cattle. *Veterinary Record*, **139** : 624-627.

SEN S., SHANE S.M., SCHOLL D.T., HUGH-JONES M.E., GILLESPIE J.M., 1998. Evaluation of alternative strategies to prevent Newcastle disease in Cambodia. *Preventive Veterinary Medicine*, **35** : 283-295.

SHAW A.P.M., 1995. Evaluation micro-économique. Analyse d'une action au niveau des troupeaux. Epidémiologie et Santé animale, **28** : 27-38.

TASCHER G., 2003. Economie de la santé animale. *In* : Lefèvre P.C., Blancou J., Chermette R. : Principales maladies infectieuses et parasitaires du bétail. Europe et régions chaudes. Tome 1 : Généralités. Maladies virales. Paris, France, Lavoisier, p. 7-21.

TASCHER G., LETENNEUR L., 2003. Manuel d'économie d'élevage en Pays Tropicaux. Montpellier, France, CIRAD, 619 p.

TOMA B., DUFOUR B., SANAA M., BENET J.J., ELLIS P., MOUTOU F., LOUZA A., 2001. Epidémiologie appliquée à la lutte collective contre les maladies animales transmissibles majeures. Maisons-Alfort, France, AEEMA, 571 p.

WARET A., 2003. Enjeux et limites de la vaccination du bétail en Afrique sub-Saharienne. Thèse doct. Vét., ENVT, Toulouse, France, n°4134, 85 p.

ANNEXES

Annexe 1 : DE VOS C.J., SAATKAMP H.W., HUIRNE R.B.M., 2005. Cost-effectiveness of measures to prevent classical swine fever introduction into the Netherlands, *Prev. Vet. Medicine*, **70** : 235-256

Annexe 2 : DETILLEUX J.C., SERTEYN D., 2005. Cost-Effectiveness Analysis in Veterinary Medicine : Illustration with packed cell value in the Prognosis of horse surgical colic in Belgium. *Intern. J. Appl. Res. Vet. Med*, **3** (4) : 309-318.

Annexe 3 : VAN SCHAIK G., KALIS C.H.J., BENEDICTUS G., DIJKHUIZEN A.A., HUIRNE R.B.M., 1996. Cost-benefit analysis of vaccination against paratuberculosis in dairy cattle. *Veterinary Record*, **139** : 624-627

Annexe 4 : SEN S., SHANE S.M., SCHOLL D.T., HUGH-JONES M.E., GILLESPIE J.M.,1998. Evaluation of alternative strategies to prevent Newcastle disease in Cambodia. *Preventive veterinary Medicine*, **35** : 283-295

ANNEXE 1

DE VOS C.J., SAATKAMP H.W., HUIRNE R.B.M., 2005. Cost-effectiveness of measures to prevent classical swine fever introduction into the Netherlands, *Prev. Vet. Medicine*, **70** : 235-256

Available online at www.sciencedirect.com
SCIENCE DIRECT
ELSEVIER
Preventive Veterinary Medicine 70 (2005) 235–256
PREVENTIVE VETERINARY MEDICINE
www.elsevier.com/locate/prevetmed

Cost-effectiveness of measures to prevent classical swine fever introduction into The Netherlands

C.J. De Vos *, H.W. Saatkamp, R.B.M. Huirne

Business Economics, Department of Social Sciences, Wageningen University, Hollandseweg 1,
6706 KN Wageningen, The Netherlands

Received 20 December 2004; accepted 5 April 2005

Abstract

Recent history has demonstrated that classical swine fever (CSF) epidemics can incur high economic losses, especially for exporting countries that have densely populated pig areas and apply a strategy of non-vaccination, such as The Netherlands. Introduction of CSF virus (CSFV) remains a continuing threat to the pig production sector in The Netherlands. Reducing the annual probability of CSFV introduction (P_{CSFV}) by preventive measures is therefore of utmost importance. The choice of preventive measures depends not only on the achieved reduction of the annual P_{CSFV}, but also on the expenditures required for implementing these measures. The objective of this study was to explore the cost-effectiveness of tactical measures aimed at the prevention of CSFV introduction into The Netherlands. For this purpose for each measure (i) model calculations were performed with a scenario tree model for CSFV introduction and (ii) its annual cost was estimated. The cost-effectiveness was then determined as the reduction of the annual P_{CSFV} achieved by each preventive measure (ΔP) divided by the annual cost of implementing that measure (ΔC). The measures analysed reduce the P_{CSFV} caused by import or export of pigs. Results showed that separation of national and international transport of pigs is the most cost-effective measure, especially when risk aversion is assumed. Although testing piglets and breeding pigs by a quick and reliable PCR also had a high cost-effectiveness ratio, this measure is not attractive due to the high cost per pig imported. Besides, implementing such a measure is not allowed under current EU law, as it is trade restrictive.

Keywords: Classical swine fever; Virus introduction; Risk assessment; Prevention; Cost-effectiveness

---

* Corresponding author. Tel.: +31 317 484065; fax: +31 317 482745.
E-mail address: Clazien.deVos@wur.nl (C.J. De Vos).

0167-5877/$ – see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.prevetmed.2005.04.001

1. Introduction

Since the early 1990s, classical swine fever (CSF) control in the European Union (EU) has been based on a strategy of non-vaccination and stamping-out infected herds (CEC, 2001). As a consequence of this policy, the whole EU domestic pig population has become fully susceptible to CSF virus (CSFV). This, combined with the existence of areas with dense pig populations, has occasionally led to large epidemics incurring high economic losses (Vanthemsche, 1996; Elbers et al., 1999; Edwards et al., 2000; Moennig, 2000). The most striking example is a series of epidemics that started at the end of 1996 in Germany due to illegal swill feeding. The virus subsequently spread to several regional pig farms and presumably from Germany to The Netherlands and then to Spain, Italy and Belgium (Elbers et al., 1999). More than 550 confirmed outbreaks could be attributed to these epidemics (Edwards et al., 2000; Moennig, 2000). The costs of these epidemics (i.e., direct costs and consequential losses to farms and related industries) were estimated at US$ 2.3 billion for The Netherlands only (Meuwissen et al., 1999). More recently, sporadic outbreaks of CSF occurred in the domestic pig populations of Germany, Italy, France, Luxembourg, and Spain (OIE, 2004), showing that the introduction of CSF remains a continuing threat to the pig production sector in the EU. In addition, CSF is endemic in wild boar populations in some areas of Germany, France, and Italy (Laddomada, 2000), representing a permanent CSFV reservoir. In recent years infected wild boar were also found in Austria, Belgium and Luxembourg (Artois et al., 2002; OIE, 2004).

In reaction to the CSF epidemic of 1997/1998, in The Netherlands much research has been dedicated to analysing the spread of the disease and determining the optimum control strategy (see, e.g., Jalving et al., 1999; Nielen et al., 1999; Stegeman et al., 1999; Mangen et al., 2001, 2002; Klinkenberg et al., 2003). Furthermore, existing regulations have been amended to reduce the risk of introduction onto and spread from primary farms (LNV, 2004). The emphasis has thus been on control of the disease and not on preventing its re-introduction into the country. A similar tendency was observed after the foot-and-mouth disease (FMD) epidemic in 2001 (Greutink et al., 2002).

Reducing the annual probability of contagious animal disease introduction by preventive actions is, however, another way to reduce losses incurred by epidemics over the long term. In order to use resources optimally for prevention of CSFV introduction, more quantitative insight is needed into the factors which contribute most to the annual probability of CSFV introduction (P_{CSFV}) into The Netherlands. It is, however, impossible to acquire this information by analysing data from recent CSFV introductions. The Netherlands "only" experienced primary CSF outbreaks in 1990, 1992, and 1997 under the non-vaccination strategy (Elbers et al., 1999; De Vos et al., 2000). The number of observations is thus far too low to determine the annual P_{CSFV} or draw conclusions about the main causing risk factors. Therefore, a scenario tree model was constructed that calculates the annual P_{CSFV} into the domestic pig population of The Netherlands and provides information on the relative contribution of risk factors to the annual P_{CSFV} (De Vos et al., 2004). Furthermore, it enables 'experimenting' with preventive strategies, which is impossible in real life.

In the present study this model was used to estimate the effectiveness of tactical measures for preventing the introduction of CSFV into The Netherlands. For decision-makers, however, the cost of implementing these measures is equally important. Therefore, for each of the measures its cost-effectiveness was determined as the ratio between the achieved reduction of the annual P_{CSFV} (ΔP) and the annual cost of achieving this reduction (ΔC) (Belli et al., 2001).

The objective of this paper was to describe the cost-effectiveness analysis of tactical measures aimed at the prevention of CSFV introduction into The Netherlands and to present its main results.

2. Materials and methods

2.1. Scenario tree model for CSFV introduction

2.1.1. Brief introduction to the model

A computer model for CSFV introduction was developed to obtain more quantitative insight into the main risk factors for CSFV introduction into member states of the EU. The risk factors were subdivided into two categories: pathways and countries of origin. Pathways are defined as carriers and mechanisms that can transmit the virus from an infected to a susceptible animal. Pathways included in the model are import of pigs (subdivided into three subgroups: piglets, breeding pigs, and fattening pigs), import of pork products (subdivided into four subgroups: fresh/chilled, frozen, non-heat-treated, and heat-treated), returning livestock trucks, and contacts with wild boar (subdivided into direct and indirect contacts). The countries of origin are the possible sources of CSFV introduction. All 15 EU member states were included as such.[1] The model is constructed such that calculations can be performed for all EU member states if sufficient information is available. In this study model calculations were performed for The Netherlands only. Model calculations result in the annual P_{CSFV}, but the user can select more detailed results by country of origin or by pathway to analyse the risk factors for CSFV introduction. More details on the model can be found in De Vos et al. (2004).

The principles of the scenario pathway approach (Vose, 1997) were used to construct the model for CSFV introduction. Using this approach, the sequence of events that would ultimately lead to CSFV introduction into the domestic pig population of The Netherlands was determined, starting with the event of a pathway-unit (i.e., unit in which a pathway is measured, e.g., a batch of animals, a metric ton of animal products or a returning livestock truck) being infected or contaminated with the virus and ending with the event of an infective viral dose being transmitted to a susceptible pig in The Netherlands. For each pathway in the model these events were ordered in a scenario tree (Miller et al., 1993; Sutmoller et al., 2000). Each event in the scenario trees was assigned a probability of occurrence. To calculate the P_{CSFV} for a certain pathway, all probabilities along its scenario tree were multiplied. Combining the outcome of all scenario tree calculations gave insight into the relative contribution of countries of origin and pathways to the P_{CSFV} into The Netherlands.

---

[1] The research described was carried out before the enlargement of the EU by 10 new member states on 1 May 2004.

The scenario tree model is a stochastic model taking into account the inherent variability of CSF epidemics in the countries of origin. Probability distributions were used for the input parameters describing these epidemics. Model calculations were iterated using Latin hypercube sampling (LHS) (Vose, 2000), resulting in a probability distribution for each output parameter. The model was constructed in Microsoft Excel 97 with the add-in programme @Risk 4.5.2 (Palisade Corporation, 2002).

2.1.2. Model adaptations for the present study

The model used in the present study slightly differs from the previous model version as described by De Vos et al. (2004). Firstly, model input was updated to represent better the current situation in the pig production sector of The Netherlands and the EU. A summary hereof is given in Table 1. Secondly, some changes were made that resulted from an extensive sensitivity analysis. This analysis indicated that four out of the total number of 257 uncertain input parameters in the scenario tree model had significant impact on the ranking of risk factors (De Vos, 2005). To obtain a more precise estimate for the expected number of CSF epidemics in Germany, Belgium, and the UK the observed period was extended from 1990–2001 to 1990–2003 (Table 1). For the uncertain input parameter of the probability of CSFV survival in an empty livestock truck travelling a distance of 0–900 km four experts[2] were consulted who recommended setting its probability value at 0.9 for all distance classes. They also recommended increasing the values for the effectiveness of cleansing and disinfection of returning livestock trucks and decreasing the values for the sensitivity of overall detection of CSFV infection in imported pigs. Values were changed accordingly. Besides, the calculations for separate supply and delivery routes at the primary farm were improved.

2.2. Selection of preventive measures

In principal, the annual P_{CSFV} is determined by the number of pathway-units present and the probability of CSFV introduction per pathway-unit. The latter depends on (i) either the CSF situation in the countries of origin or in the Dutch wild boar population and (ii) preventive actions taken to detect or inactivate the virus. In this study the cost-effectiveness of implementing additional preventive actions to the present situation was explored. The results of the default calculations were used to make a first selection of preventive measures. Then eight experts[3] in the field of CSF and/or the Dutch pig production sector were asked for their opinion on how feasible and effective the selected measures would be. This ultimately resulted in six preventive measures for which the cost-effectiveness analysis was performed. Most of the selected measures were directed at mitigating the risk of returning livestock trucks, as previous model calculations indicated that this pathway contributes most to the annual P_{CSFV} into The Netherlands (De Vos et al., 2004). A short description of the measures is given in Table 2.

---

[2] Three experts in epidemiology of CSFV and one expert in virology of CSFV.

[3] The backgrounds of these experts were in epidemiological research (3), veterinary policy (3), and farmers' organisations (2).

Table 1

The expected number of CSF epidemics per year, total number of pig holdings, export of pigs and pork products to The Netherlands per year, and livestock trucks returning to The Netherlands per year for each country of origin in the scenario tree model for CSFV introduction

	Expected number of CSF epidemics per year[a]	Total number of pig holdings[b]	Batches of piglets exported to The Netherlands per year[c]	Batches of breeding pigs exported to The Netherlands per year[c]	Batches of fattening pigs exported to The Netherlands per year[c]	Metric tons of pork products exported to The Netherlands per year[d]	Livestock trucks returning to The Netherlands per year[c]
Germany	7.86	116000	30	65	587	138769	18890
France	0.43	55000	16	46	11	20048	199
Italy	2.36	230000	0	0	0	7164	4003
Belgium	0.29	10000	14	24	953	100827	6702
Luxembourg	0.14	500	0	0	0	332	1
UK	0.21	11000	0	32	0	3673	0
Ireland	0.07	1000	9	0	41	876	0
Denmark	0.07	13000	13	3	78	12050	0
Greece	0.07	23000	0	0	0	0	24
Spain	1.00	69000	0	1	3	10290	3170
Portugal	0.07	121000	0	0	0	11	0
Austria	0.14	76000	0	0	0	424	14
Finland	0.07	4000	0	0	0	120	0
Sweden	0.07	4000	0	0	0	32	0

[a] Based on period 1990–2003; source: EU (2002) and OIE (2004).

[b] Data from 2001; source: EU (2004).

[c] Data from 2003; source: RVV (2004a).

[d] Data from 2003; source: Statistics Netherlands (2004).

Table 2
Overview of tactical measures aimed at preventing the introduction of CSFV into The Netherlands

Abbreviation	Preventive measure	Brief description
LT_C&D	Cleansing and disinfection of all returning livestock trucks	All livestock trucks are cleaned and disinfected at a listed washing point when returning to The Netherlands Disinfection by certified washing point personnel
LT_N&I	Separation of national and international transport of pigs	Livestock trucks are used for either national or international transports only As a consequence, all batches of pigs for export are transferred to an international livestock truck at assembly points for export
LT_CONT	Livestock trucks with detachable containers	Livestock truck brings empty container to primary farm Farmer loads container with pigs Livestock truck returns to pick up full container
PF_S&D	Separate supply and delivery routes on primary farms	Physical barrier between 'clean' part of enterprise and transport routes Paved transport routes Only admittance to 'clean' part of enterprise by hygiene channel No admittance of vehicles at 'clean' part of enterprise
SL_LOG	Logistic supply of fattening pigs at slaughterhouses	First supply of Dutch fattening pigs, then supply of imported fattening pigs No physical contacts between Dutch and imported pigs, also not in the lairage Additional cleaning and disinfection of slaughter line and lairage after supply of imported pigs
IMP_TEST	Testing piglets and breeding pigs by a quick and reliable PCR	All pigs in a batch tested Test results known within 24 h

2.3. Cost-effectiveness of preventive measures

2.3.1. Calculation of effectiveness

The scenario trees of the pathways at which the preventive measures are directed are given in Fig. 1. The events at which the preventive measures intervene are indicated. The values of these input parameters of the scenario tree model were adjusted to mimic the effect of the preventive measures. Four experts[4] were consulted to determine the new values for these parameters. If no substantiated new value could be determined, values were either doubled or halved. In Table 3 an overview of default and new values is given.

The scenario tree model was run for the default scenario and for each preventive measure. The output variables selected were (i) the annual P_{CSFV} into The Netherlands, (ii) the relative contribution of pathways to the annual P_{CSFV}, and (iii) the P_{CSFV} from each country of origin per epidemic and per year. Model calculations were iterated 2500 times and hence did not return a single value for the annual P_{CSFV} but rather a probability distribution (see also Section 2.1.1). Comparing the cumulative distribution function (cdf) for the annual P_{CSFV} of the default scenario and the scenarios with preventive measures

---

[4] Three experts in epidemiology of CSFV and one expert in virology of CSFV.

Table 3
Values of model input parameters for calculating effectiveness of measures aimed at preventing the introduction of CSFV into The Netherlands

Preventive measure	Pathway	Parameter[a]	Default value[b]	New value[b]
LT_C&D	Returning livestock trucks	EFF_{lc}	HRP: 0.25	HRP: 0.9
			PostHRP: 0.9	PostHRP: 0.99
LT_N&I	Returning livestock trucks	CSA[c]	0.5 × RiskDiscrete (0.05, 0.75; 0.39, (1–0.39))	0.01 × RiskDiscrete (0.05, 0.75; 0.39, (1–0.39))
LT_CONT	Returning livestock trucks	CSA[c]	0.5 * RiskDiscrete (0.05, 0.75; 0.39, (1–0.39))	0.5 × RiskDiscrete (0.025, 0.75; 0.9, (1–0.9))
PF_S&D[d]	Returning livestock trucks	CSA[c]	0.5 × RiskDiscrete (0.05, 0.75; 0.39, (1–0.39))	0.5 × RiskDiscrete (0.05, 0.75; 0.78, (1–0.78))
SL_LOG[d]	Import of fattening pigs	ID	HRP: 0.1	HRP: 0.05
			PostHRP: 0.05	PostHRP: 0.025
IMP_TEST	Import of piglets	SE_{tc}	HRP: 0	HRP: 0.9
			PostHRP: 0.5	PostHRP: 0.99
IMP_TEST	Import of breeding pigs	SE_{tc}	HRP: 0	HRP: 0.9
			PostHRP: 0.8	PostHRP: 0.99

[a] See scenario trees of Fig. 1 for an explanation of parameter meaning.

[b] HRP: high risk period, i.e., the period from first infection with virus until first detection of disease; PostHRP: period from first detection of disease until eradication of disease.

[c] The parameter CSA is calculated by multiplying the proportion of returning livestock trucks coming into contact with primary farms by a RiskDiscrete distribution that calculates the probability that a contaminated livestock truck comes into contact with susceptible animals at the primary farm. This RiskDiscrete distribution is defined as RiskDiscrete (probability that contaminated livestock truck comes into contact with susceptible animals if separate supply and delivery routes, probability that contaminated livestock truck comes into contact with susceptible animals if no separate supply and delivery routes; proportion of farms with separate supply and delivery routes (1 – proportion of farms with separate supply and delivery routes)).

[d] For these measures parameter values were either doubled or halved. For all other measures parameter values are based on expert opinion.

gives clear insight into the effectiveness of the measures. To determine the cost-effectiveness of the preventive measures, however, the effectiveness of the measures had to be expressed by a single value. As the uncertainty distribution of the annual P_{CSFV} appeared to be rather skewed (long right tail), the median and 0.95 percentile values of the annual P_{CSFV} were used to calculate the achieved reduction of the annual P_{CSFV} ($\Delta P_{0.50}$ and $\Delta P_{0.95}$).

2.3.2. *Calculation of annual costs*

Implementing the selected preventive measures results in extra costs due to investments and labour. For each preventive measure an estimate was made of the extra annual cost in comparison with the current situation. The annual investment cost was calculated using the annuity method (Van den Tempel and Giessen, 1992). For investments in livestock trucks the depreciation rate was set at 10%, whereas for investments at the primary farm the depreciation rate was set at 6.7%. For all investments maintenance cost was set at 1%, and

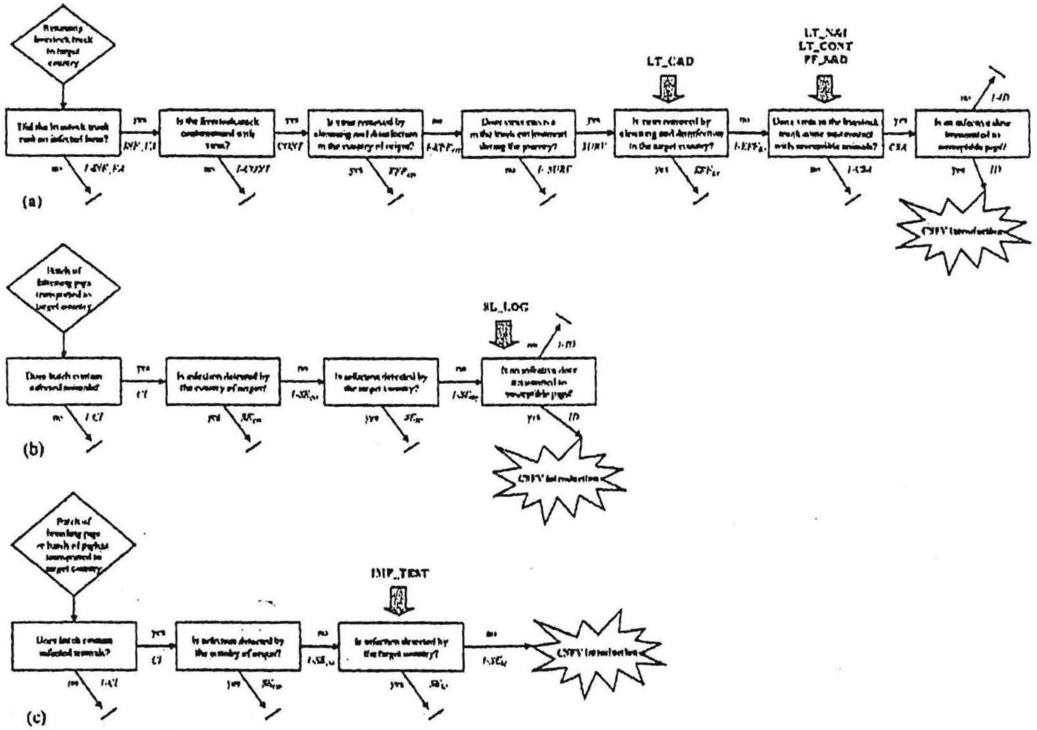


Fig. 1. Scenario trees for the pathways returning livestock trucks (a), import of batch of fattening pigs (b), and import of batch of breeding pigs or batch of piglets (c). Description of parameters used in the scenario trees: INF_FA: probability that a livestock truck visits an infected farm in the country of origin; CONT: probability that a livestock truck gets contaminated with CSFV when visiting an infected farm; EFF_{co}: effectivity of cleansing and disinfection of livestock trucks in the country of origin; SURV: probability that CSFV survives in an empty livestock truck that travels from the country of origin to the target country (here: The Netherlands); EFF_{tc}: effectivity of cleansing and disinfection of livestock trucks in the target country (here: The Netherlands); CSA: probability that a livestock truck comes into contact with susceptible pigs in the target country (here: The Netherlands); ID: probability that an infective dose is transmitted to a susceptible pig; CI: cumulative incidence of the disease at herd level during a CSF epidemic in the country of origin; SE_{co}: sensitivity of overall detection of CSF in the country of origin when pigs are exported; SE_{tc}: sensitivity of overall detection of CSF in the target country (here: The Netherlands) when pigs are imported.

interest rate at 6%. Furthermore, variable costs for extra livestock trucks (insurance, fuel, etc.) were set at 4% of the initial cost. An overview of the annual cost of each preventive measure is given in Table 4. This table also displays the main assumptions and data sources used for the calculations. As there is wide diversity among pig farms, pig transporters, and slaughterhouses with regard to, for example, size, investments already made, working methods, etc., the annual costs calculated for the preventive measures are only a rough estimate. Because of the uncertainties involved in the cost calculations, a sensitivity analysis was performed to test the robustness of the conclusions. In this sensitivity analysis the annual cost of each preventive measure was increased and decreased by 25%.

2.3.3. *Calculation of cost-effectiveness*

To calculate the cost-effectiveness of the preventive measures the reduction of the annual P_{CSFV} achieved by each preventive measure (ΔP) was divided by the annual cost required to implement that measure (ΔC). The cost-effectiveness ratios were calculated for both the median and 0.95 percentile values of the annual P_{CSFV}. In formulae:

$$\mathrm{CE}_{0.50} = \Delta P_{0.50}/\Delta C \tag{1}$$

$$\mathrm{CE}_{0.95} = \Delta P_{0.95}/\Delta C \tag{2}$$

3. Results

3.1. *Probability of CSFV introduction into The Netherlands*

3.1.1. *Default scenario*

Default calculations with the scenario tree model for CSFV introduction show that the annual P_{CSFV} into The Netherlands varies between 6.2×10^{-4} (minimum) and 3.5×10^{-1} (maximum). These differences are mainly due to yearly changes in the occurrence and course of CSF epidemics in the countries of origin. In years with few and small CSF epidemics in the countries of origin, the probability is at its minimum level and in years with many and large CSF epidemics in the countries of origin, the probability is at its maximum level. The median value for the annual P_{CSFV} into The Netherlands is 0.0246, indicating that for 50% of the years the annual P_{CSFV} will be lower than this value. The 0.95 percentile is 0.1279, indicating that – if the current situation remained the same – then the annual P_{CSFV} would only exceeded 12.8% for five years in every century. The mean value for the annual P_{CSFV} is 0.0398, indicating that The Netherlands can expect CSFV introduction on average once every 25 years from the pathways and countries of origin included in the model.

Fig. 2 gives insight into the main countries of origin contributing to the annual P_{CSFV} into The Netherlands. Both the average probability per epidemic and the average probability per year are shown. For some countries of origin, i.e., Portugal, Austria, Finland, and Sweden, the probability that they cause CSFV introduction into The Netherlands is very small (probability per epidemic $<5.0 \times 10^{-6}$) and could not therefore be displayed in the figure. Germany, Belgium, and Spain are the countries of origin that

Table 4
Overview of annual cost of measures aimed at preventing the introduction of CSFV into The Netherlands, main assumptions and sources of information used[a]

Preventive measure	Annual cost (million €)	Assumptions	Sources
LT_C&D	8.46	144 listed washing places need 1 additional employee at € 43 900 per year 20 542 returning livestock trucks to be cleaned and disinfected when returning to The Netherlands at € 25 per livestock truck 17 extra livestock trucks are needed to export the same number of pigs at € 39 962 per year for investment and € 55 200 per year for wages of driver	Scenario tree model calculations; Dijkstra (1995), Lambooij (2002), KWIN (2003), and RVV (2004a, 2004b)
LT_N&I	4.94	46 extra livestock trucks are needed to export the same number of pigs at € 39 962 per year for investment and € 55 200 per year for wages of driver 22 112 livestock trucks need extra cleaning and disinfection at € 25 per livestock truck	Dijkstra (1995), Lambooij (2002), Meuwissen et al. (2002) and RVV (2004a)
LT_CONT	24.82	1400 livestock trucks are replaced by a more expensive livestock truck with detachable container at € 8364 per year for extra investment 127 extra livestock trucks are needed to export the same number of pigs at € 48 326 per year for investment and € 55 200 per year for wages of driver	Dijkstra (1995), Ipema et al. (2002) and Lambooij (2002)
PF_S&D	9.47	80% of pig farms already have separate supply and delivery routes 20% of 1275 multiplier farms have to build two hygiene channels and to pave an area of 700 m^2 at € 5219 per year for investment 20% of 3798 farrow-to-finish farms have to build two hygiene channels and to pave an area of 700 m^2 at € 4383 per year for investment 20% of 6778 finishing farms have to build two hygiene channels and to pave an area of 700 m^2 at € 3547 per year for investment	KWIN (2003) and PVE (2003)
SL_LOG	5.70	14 616 000 pigs slaughtered at € 0 per pig for logistic supply[b] 14 616 000 pigs slaughtered at € 0.39 per pig for additional cleaning at the end of the day	PVE (2003), Van der Gaag (2004) and Van der Gaag et al. (2004)
IMP_TEST	0.84	Blood samples collected for 254 batches of pigs at € 85 per batch (fixed costs) and € 5.67 per pig (variable costs) 17 640 pigs tested at € 27 per test 2.5 extra livestock trucks are needed to import the same number of pigs at € 39 962 per year for investment and € 55 200 per year for wages of driver	Dijkstra (1995), Lambooij (2002), RVV (2004a), and W.L.A. Loeffen (personal communication)

[a] More detailed information on the calculation of costs is available on request from the first author.

[b] Cost of logistic supply was not calculated due to lack of information on input variables.

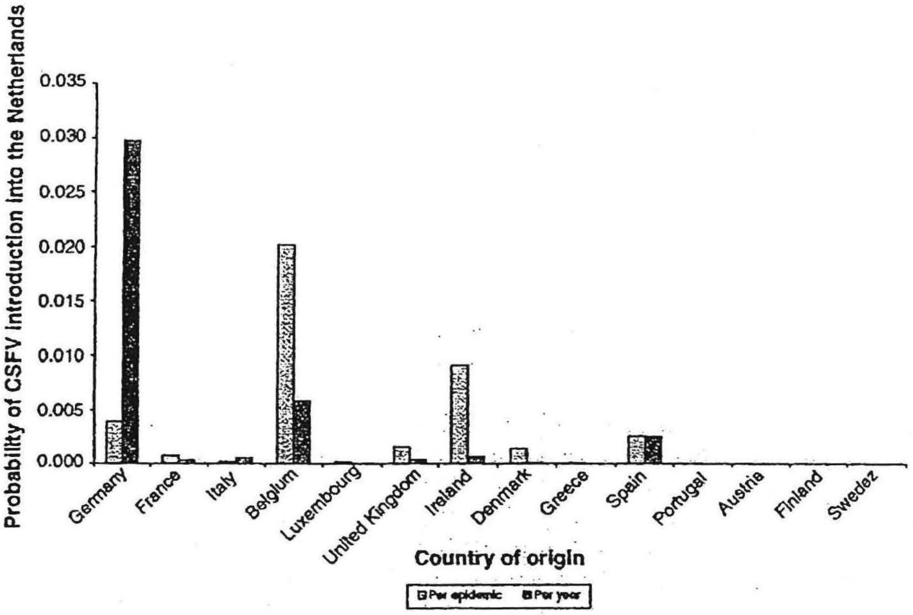


Fig. 2. Probability of CSFV introduction into The Netherlands from each country of origin in the model (all EU member states), both per epidemic in the country of origin and per year.

contribute most to the annual P_{CSFV} into The Netherlands. The P_{CSFV} into The Netherlands during a single epidemic in Germany is much lower than the annual probability, which is explained by the high number of expected epidemics per year in Germany (see Table 1). For Spain the expected number of epidemics is exactly 1 per year, which results in a probability per epidemic equal to the probability per year. For all other countries of origin the expected number of epidemics per year is less than 1, which explains that the probability per year is smaller than the probability per epidemic for those countries. The probability per epidemic is highest for Belgium, indicating that The Netherlands is most at risk for CSFV introduction if CSFV is present in this country of origin. During an epidemic in Ireland the P_{CSFV} into The Netherlands is also quite high. This is explained by the small number of pig farms in Ireland (see Table 1), resulting in a relatively high probability that batches of pigs imported into The Netherlands originate from an infected farm.

The model calculations also provide insight into the relative contribution of pathways to the annual P_{CSFV} into The Netherlands. On average, returning livestock trucks contribute most to P_{CSFV} with 50.1%. This is mainly due to the large number of pathway-units present: The Netherlands is a major exporter of pigs (9.31×10^6 pigs exported versus 3.11×10^5 pigs imported in 2003). Import of fattening pigs contributes next with 22.2%. Although the majority of imported pigs consists of fattening pigs (94% in 2003), these contribute only slightly more than pigs imported for life (breeding pigs 13.8% and piglets 7.2%). This is explained by the P_{CSFV} per pathway-unit, which is highest for pigs imported for life. Import of pork products contributes only 6.6%, and this can be attributed to 96% to the import of fresh/chilled and frozen pork products. Direct and indirect contact with wild boar did not contribute to the annual P_{CSFV} into The Netherlands, as it is very unlikely that CSF infections occurred in Dutch wild boar populations in recent years. Serological surveys of Dutch wild boar shot during the hunting season from 1996 onwards did not result in any positive tests (Elbers and Dekkers, 2000; A.R.W. Elbers, personal communication).

3.1.2. Effect of preventive measures

Table 5 shows the mean, median, 0.95 percentile, and maximum values of the annual P_{CSFV} into The Netherlands for all scenarios. In Fig. 3 the cdf for the annual P_{CSFV} into The Netherlands is shown for the default scenario and when each of the preventive measures is applied. It is evident that the P_{CSFV} is highest for the default scenario, i.e., when no additional preventive measures are applied. Separation of national and international transport of pigs (LT_N&I) appears to be most effective in reducing the annual P_{CSFV}. Cleansing and disinfection of all returning livestock trucks (LT_C&D) and livestock trucks with detachable containers (LT_CONT) are equally effective up till about the 0.85 percentile, but differ in their effectivity with regard to worst-case situations. Applying LT_CONT, the maximum P_{CSFV} is 0.2476, whereas applying LT_C&D the maximum P_{CSFV} is only 0.1394. Comparing these values to the maximum P_{CSFV} in the default scenario, which is 0.3533, it can be concluded that LT_C&D is more effective than LT_CONT. A logistic supply of fattening pigs at slaughterhouses (SL_LOG) and testing piglets and breeding pigs by a quick and reliable PCR (polymerase chain reaction) (IMP_TEST) are equally effective and attain only a small reduction in P_{CSFV} compared with the default scenario.

Fig. 4 shows the average annual P_{CSFV} into The Netherlands from the countries of origin contributing most to the annual P_{CSFV}, i.e., Germany, Belgium, and Spain. LT_N&I is the most effective measure for these countries of origin. For Belgium, the difference in effectiveness of the measures is, however, not as big as for the annual P_{CSFV} into The Netherlands, whereas for Spain the differences are even more emphasised. This is because the pathway returning livestock trucks is the main contributor to the annual probability of CSFV introduction from Spain (98%), whereas for Belgium the import of fattening pigs has a relatively large share in the annual P_{CSFV} (52%). The absolute reduction of the annual P_{CSFV} by applying preventive measures is highest for Germany. Directing preventive

Table 5

Mean, median, 0.95 percentile, and maximum values of the annual probability of CSFV introduction into The Netherlands for the default scenario and when applying six different measures aimed at preventing the introduction of CSFV into The Netherlands

Preventive measure	Mean	Median	0.95 Percentile	Maximum
Default	0.0398	0.0246	0.1279	0.3533
LT_C&D	0.0174	0.0125	0.0502	0.1394
LT_N&I	0.0144	0.0102	0.0412	0.1082
LT_CONT	0.0191	0.0120	0.0566	0.2476
PF_S&D	0.0250	0.0150	0.0826	0.2476
SL_LOG	0.0366	0.0216	0.1224	0.3363
IMP_TEST	0.0353	0.0200	0.1204	0.3353

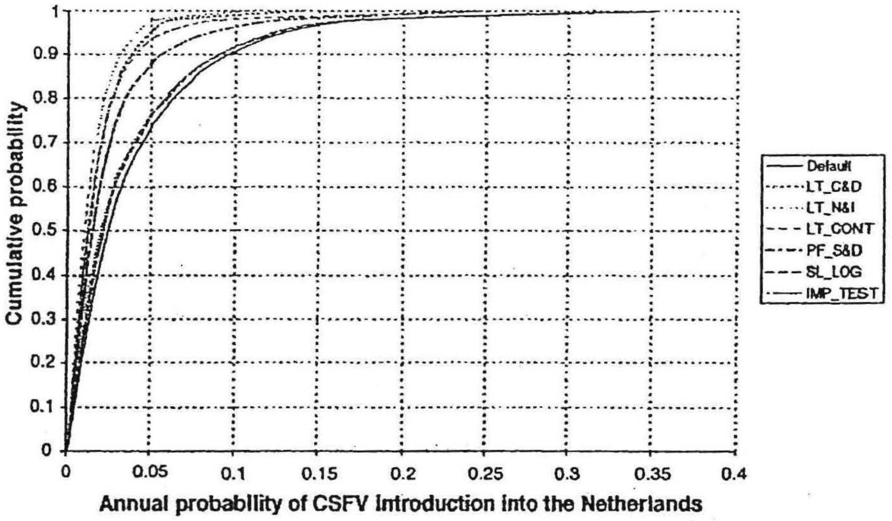


Fig. 3. Cumulative distribution function of the annual probability of CSFV introduction into The Netherlands for the default scenario and when applying six different measures aimed at preventing the introduction of CSFV into the country.

measures at this country of origin alone results in a reduction in the annual P_{CSFV} into The Netherlands of about 55% (SL_LOG) up to about 80% (LT_C&D, LT_N&I, LT_CONT, and PF_S&D) of the reduction achieved when directing preventive measures at all countries of origin.

Fig. 5 shows the relative contribution of pathways to the annual P_{CSFV} into The Netherlands for the default scenario and when each of the preventive measures is applied. The shifts in relative importance are as expected: applying LT_C&D, LT_N&I, LT_CONT, and PF_S&D reduces the relative importance of returning livestock trucks, applying SL_LOG reduces the relative importance of import of fattening pigs, whereas applying IMP_TEST reduces the relative importance of import of breeding pigs and piglets. Again it is clearly shown that LT_N&I is most effective: the relative importance of returning livestock trucks is reduced from 50% in the default scenario to only 5% when applying this measure. Although applying IMP_TEST results in only a slight reduction of the annual P_{CSFV}, it almost eliminates the risk constituted by the import of breeding pigs and piglets. Therefore, it can be concluded that IMP_TEST is a very effective measure in itself, but contributes only slightly to the reduction of the annual P_{CSFV} into The Netherlands, as imports of breeding pigs and piglets are small (see Table 1).

3.2. Cost-effectiveness of preventive measures

Fig. 6 shows a scatter plot with for each preventive measure, its annual cost (ΔC) at the x-axis, and the achieved reduction of the median annual P_{CSFV} ($\Delta P_{0.50}$) at the y-axis. From this graph it is evident that only LT_N&I and IMP_TEST are cost-efficient, i.e.,

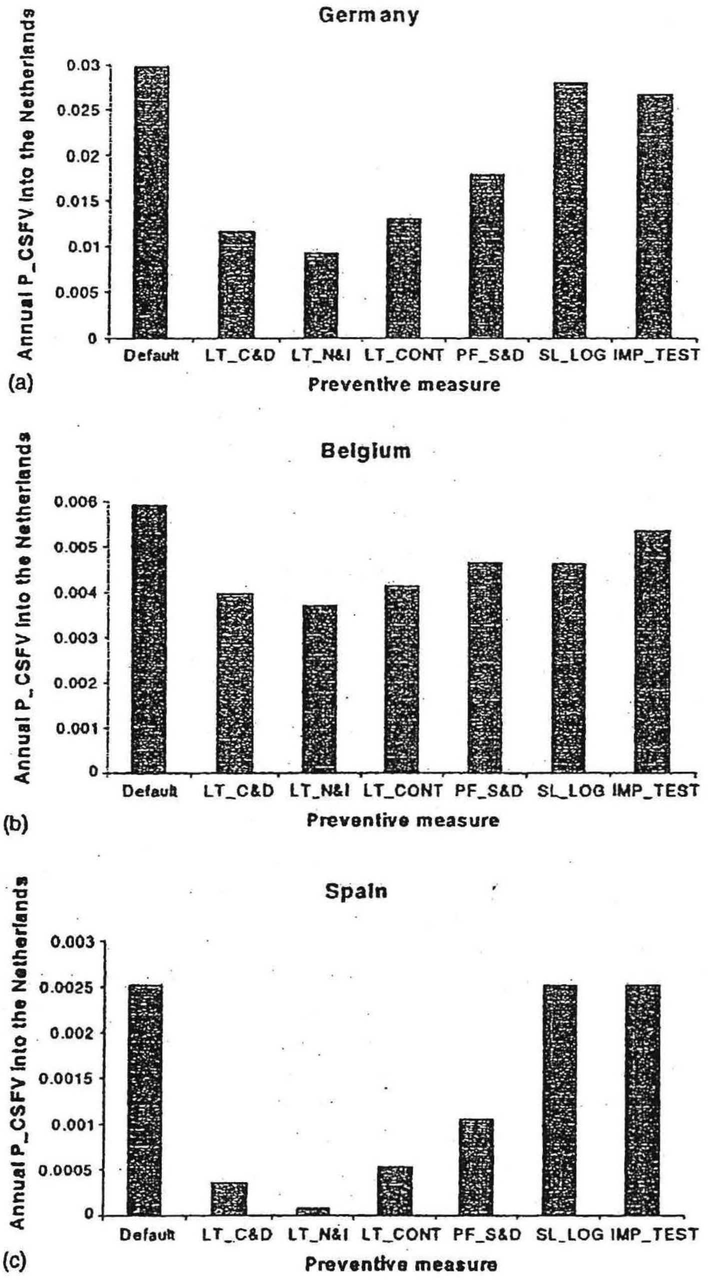


Fig. 4. Annual probability of CSFV introduction into The Netherlands from (a) Germany, (b) Belgium, and (c) Spain for the default scenario and when applying six different measures aimed at preventing the introduction of CSFV.

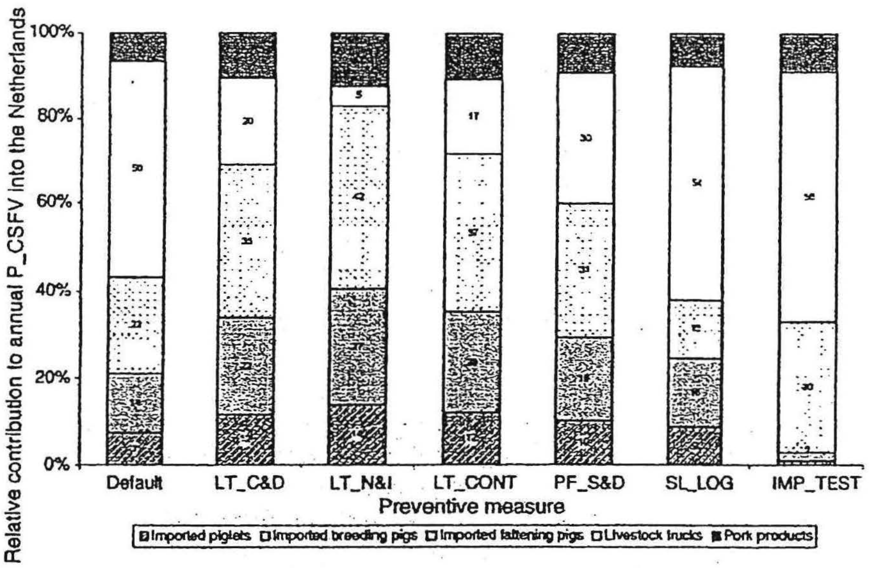


Fig. 5. Relative contribution of pathways in the model to the annual probability of CSFV introduction into The Netherlands for the default scenario and when applying six different measures aimed at preventing the introduction of CSFV into the country.

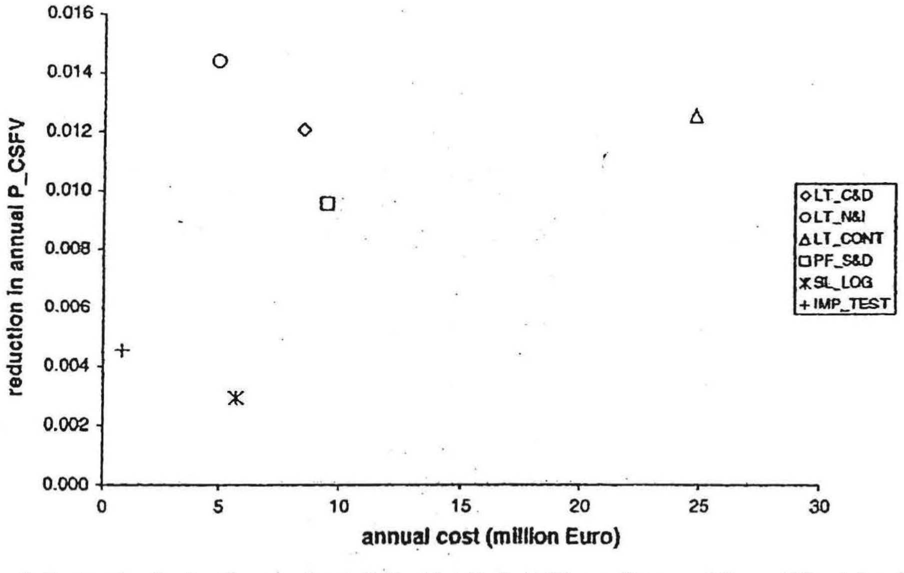


Fig. 6. Scatter plot showing the annual cost (ΔC) and reduction of the median annual P_{CSFV} ($\Delta P_{0.50}$) for six different measures aimed at preventing the introduction of CSFV into the country.

Table 6
Cost-effectiveness ratios for six different measures aimed at preventing the introduction of CSFV into The Netherlands

Preventive measure	Achieved reduction of the annual P_{CSFV}		Annual cost (million €)	Cost-effectiveness ratio ($€^{-1} \times 10^{-10}$)	
	$\Delta P_{0.50}$	$\Delta P_{0.95}$	ΔC	$CE_{0.50}$	$CE_{0.95}$
LT_C&D	0.0121	0.0777	8.46	14	92
LT_N&I	0.0144	0.0867	4.94	29	176
LT_CONT	0.0125	0.0713	24.82	5	29
PF_S&D	0.0096	0.0453	9.47	10	48
SL_LOG	0.0029	0.0054	5.70	5	9
IMP_TEST	0.0046	0.0075	0.84	54	89

implementing the other preventive measures brings higher annual cost whereas the achieved reduction of the annual P_{CSFV} is equal or less. In Table 6 the cost-effectiveness ratios of the preventive measures are given. These values indicate that IMP_TEST is most cost-effective in reducing the annual P_{CSFV} into The Netherlands when considering median values. For 0.95 percentile values, however, LT_N&I is by far the most cost-effective measure. SL_LOG is the least cost-effective for both output values used. The sensitivity analysis of the annual cost of preventive measures by increasing and decreasing values by 25% showed that the results of the cost-effectiveness analysis were robust. The absolute values of the cost-effectiveness ratios changed, but the ranking of measures based on these values did not change.

4. Discussion

4.1. Probability of CSFV introduction into The Netherlands

In Section 3.1.1 a clear overview was presented of the pathways and countries of origin contributing most to the annual P_{CSFV} into The Netherlands in the current situation. These model results were used to select tactical measures aimed at prevention of CSFV introduction. The effectiveness of these measures was calculated as the achieved reduction of the annual P_{CSFV} into The Netherlands (ΔP). For a comparative study like this, the annual P_{CSFV} was an adequate model output parameter, although its absolute value in the default scenario is quite low when compared with expert estimates (Horst et al., 1998; Meuwissen et al., 2000) and recent history (Elbers et al., 1999; De Vos et al., 2000). The model most probably underestimates the annual P_{CSFV} as not all pathways contributing to the P_{CSFV} were included in the model, nor were third countries (see De Vos et al., 2004).

Preventive measures directed at the pig transport sector (i.e., LT_C&D, LT_N&I, and LT_CONT) were most effective in reducing the annual P_{CSFV} into The Netherlands. These measures reduce the contribution of returning livestock trucks to the annual P_{CSFV}. Although separate supply and delivery routes on primary farms (PF_S&D) also affect the probability that CSFV is introduced by returning livestock trucks, this measure was less effective. A logistic supply of fattening pigs at slaughterhouses (SL_LOG) was as effective as testing piglets and breeding pigs by a quick and reliable PCR (IMP_TEST). The total number of batches of fattening pigs imported in 2003 was, however, much higher than the total number of batches of breeding pigs and piglets imported (Table 1). The effectivity per pathway-unit was thus higher for IMP_TEST. This is also illustrated in Fig. 5: SL_LOG reduced the relative contribution of the pathway import of fattening pigs from 22% to 13%, whereas IMP_TEST reduced the relative contribution of the pathways import of breeding pigs and import of piglets from 14% to 2%, and from 7% to 1%, respectively. SL_LOG and IMP_TEST will continue to be less effective than the other preventive measures, as long as The Netherlands is a major exporter of pigs, and imports of pigs are only marginal compared to exports. It should be kept in mind, however, that the conclusions of this study are based on the current situation. Shifts in trade patterns – either pathways or countries of origin, or both – might lead to different conclusions with regard to the effectiveness of the preventive measures.

4.2. *Cost-effectiveness of preventive measures*

Based on effectiveness only, LT_CONT was quite a promising preventive measure (see Fig. 3). Its cost-effectiveness ratio is, however, quite low as implementing this measure incurs high annual cost (Table 6). On the contrary, IMP_TEST only attained a small reduction of the annual P_{CSFV} but had a high cost-effectiveness ratio due to its low annual cost. This is due to the small number of pigs imported for life by The Netherlands (17 640 pigs in 2003). In terms of cost per pig this measure is thus very expensive and despite its high cost-effectiveness ratio not attractive unless heavily subsidised. This illustrates that although the cost-effectiveness ratio provides good insight into the reduction in the annual P_{CSFV} gained per Euro invested, one should not focus only on cost-effectiveness ratios when deciding on preventive measures.

Sensitivity analysis of the annual cost of preventive measures demonstrated that the outcome of the cost-effectiveness analysis was robust, despite uncertainties involved in the cost calculations. This was not surprising given the large differences between the highest and lowest cost-effectiveness ratios (see Table 6). For median values, LT_N&I and IMP_TEST had much higher cost-effectiveness ratios than all other measures, whereas for the 0.95 percentile values LT_N&I was by far the most cost-effective measure. SL_LOG was the least cost-effective for both cost-effectiveness ratios and might even be less cost-effective in reality, as the costs of logistic supply were set at €0 per pig due to lack of information (see Table 4).

The cost-effectiveness ratios based on the median annual P_{CSFV} assume risk neutrality. Risk-averse decision makers will tend to reduce especially the risk of a high annual P_{CSFV}. The cost-effectiveness ratios based on the 0.95 percentiles of the annual P_{CSFV} indicate which preventive measures are most cost-effective in reducing the P_{CSFV} in "bad years", i.e., in years with many large CSF epidemics in the EU. The calculations showed that under a risk-averse policy LT_N&I is by far the most cost-effective measure and that than LT_C&D is preferred over IMP_TEST.

For the 0.95 percentile values of the annual P_{CSFV}, the cost-effectiveness ratios of LT_C&D and IMP_TEST are almost equal. In such a case other criteria are needed to decide which preventive measure is preferred. If the ultimate goal of the preventive actions is to maximally reduce the annual P_{CSFV}, the effectiveness expressed as ΔP is the most important parameter and LT_C&D will be preferred. In case there is a fixed budget that can be spent on prevention of CSFV introduction, the annual cost (ΔC) of implementing the measures is the most important parameter. Then the preventive measure with the highest cost-effectiveness that fits in the budget will be preferred.

4.3. Selection of preventive measures

Preventive actions can either be directed at the number of pathway-units or at the probability of CSFV introduction per pathway-unit. Reducing the number of pathway-units can, however, not be attained by regulations imposed by policymakers. Intra-EU trade of pigs and pork products is no longer hampered by national borders since the establishment of the free internal market in 1993 (Anonymous, 1993). And even imports from outside the EU, although small, can only be prohibited on the basis of sanitary or phytosanitary arguments, i.e., if there is a proved risk that such imports pose a threat to human or animal health (WTO, 1995). Therefore, only the cost-effectiveness of preventive measures aimed at reducing the probability of CSFV introduction per pathway-unit was considered in this study.

Under current EU law testing imported piglets and breeding pigs by a quick and reliable PCR is not allowed either. Nevertheless, this preventive measure was included in the cost-effectiveness analysis to investigate if it is worth considering when the goal is to reduce the annual P_{CSFV} into The Netherlands. Results showed that despite a high cost-effectiveness ratio this measure is not attractive due to its high costs per imported pig. Besides, implementing this measure causes difficulties. To prevent CSFV introduction the pigs should be tested at the border and remain in the lorries until test results are known (i.e., for a maximum period of 24 h). With regard to animal welfare it would, however, be better to test the pigs at the farm in the country of origin before issuing the health certificate.

No preventive actions were directed at the pathways concerning the import of pork products and contacts with wild boar. In the scenario tree model, imported pork products can only result in a CSF infection of susceptible pigs if fed as swill. Although feeding of swill is forbidden in the EU (CEC, 2001), the model contains a small probability of infection by swill feeding to account for illegal practices. The contribution of imported pork products to the annual P_{CSFV} into The Netherlands is thus due to illegal swill feeding only and therefore it was impossible to direct preventive measures at these pathways. Measures to prevent CSFV introduction by direct or indirect contact with wild boar might be very effective if CSFV is present in the wild boar population. Previous model calculations showed that a 10% seroprevalence for CSFV in the Dutch wild boar population would increase the annual P_{CSFV} into The Netherlands by about 60% (De Vos et al., 2004). In the default scenario these pathways did not however contribute to the annual P_{CSFV} into The Netherlands as the Dutch wild boar population is currently free of CSFV. Therefore, it was impossible to calculate the effectiveness of measures directed at these pathways.

A more extensive analysis of the cost-effectiveness of the selected preventive measures was not possible due especially to the lack of information on the costs of measures. Implementing packages of preventive measures might, however, lead to different cost-effectiveness ratios, especially if the measures in a package intervene at the same pathway.

Targeting a preventive measure at only one or a few countries of origin might achieve almost the same reduction of the annual P_{CSFV} at reduced cost. The default calculations showed that Germany contributed most to the annual P_{CSFV}. Targeting preventive measures only at this country of origin would thus result in a considerable reduction of the annual P_{CSFV}. This is, however, only possible for LT_C&D, LT_N&I, and IMP_TEST. Implementing the other preventive measures is only possible for all countries of origin simultaneously. Another option for reducing the expenses of preventive measures is to implement them only when it is known that CSFV is present in the country of origin, i.e., during the PostHRP.[5] For most countries of origin the probability of CSFV introduction is, however, highest during the HRP of an epidemic. The effectiveness of preventive measures will thus also be greatly reduced when applied only during the PostHRP.

In this study only preventive actions directed at the pathways included in the scenario tree model could be analysed. Although the scenario tree model most probably contains those pathways contributing most to the annual P_{CSFV} (De Vos et al., 2004), other pathways such as tourists, illegal imports, and laboratories working with CSFV can also lead to CSFV introduction. The relative importance of these pathways will increase if one or more of the preventive measures of this study are implemented. More insight into the underlying mechanisms of CSFV introduction by pathways not included in the model is then required to further reduce the annual P_{CSFV}.

5. Concluding remarks

The aim of this paper was to explore the cost-effectiveness of tactical measures aimed at prevention of CSFV introduction into The Netherlands. The results showed that, for cost-effectiveness, separation of national and international transport of pigs (LT_N&I) should be preferred. The logistic supply of fattening pigs at slaughterhouses (SL_LOG), on the contrary, is not worth the expense, given both its low effectiveness and low cost-effectiveness ratio. The sensitivity analysis confirmed the robustness of these conclusions. However, cost-effectiveness is not the only criterion when implementing a preventive measure. For a conscious decision the following issues should also be taken into account:

(a) Ease of implementation of the measure, e.g., are small or large investments required, can a measure easily be introduced in the current situation or are significant adaptations required in farm management or the pig transport sector?
(b) Allocation of costs and benefits over different actors, such as primary producers, pig transport sector, slaughterhouses, government, and consumers, i.e., who pays and who gains? LT_C&D, LT_N&I and LT_CONT mainly incur costs for the pig transport sector, PF_S&D and IMP_TEST for primary producers, and SL_LOG for slaughterhouses. Although IMP_TEST has a high cost-effectiveness ratio, this measure is far too expensive for primary producers. Such a measure can only be implemented when

---

[5] HRP: high risk period, i.e., the period from first infection with virus until first detection of disease; PostHRP: period from first detection of disease until eradication of disease.

subsidised. Besides, costs of preventive measures carried out by, for example, the pig transport sector can be partly transferred to primary producers.

(c) Cost-benefit ratio, i.e., is the measure worth its cost anyhow? A rough estimate of the monetary benefits of measures aimed at the prevention of CSFV introduction was obtained by multiplying the achieved reduction of the annual P_{CSFV} by the average cost of a CSF epidemic for The Netherlands (VWA, 2003). This indicated that the annual cost of preventive measures was higher than the expected annual benefits. However, the annual benefits of the preventive measures are most likely largely underestimated for two reasons. Firstly, calculation of benefits was based on the direct cost of an epidemic only, i.e., cost of controlling the epidemic. Indirect losses due to business standstill and especially export bans are in general much higher than the control cost of an epidemic (Mangen, 2002). Secondly, the annual P_{CSFV} calculated by the model is small when compared with recent history and expert estimates. This might result in an underestimation of the reduction in the annual P_{CSFV} by the measures.

(d) Attributable cost, i.e., should all cost of implementing a measure be recovered by the reduction of the annual P_{CSFV} or can side-effects be expected resulting in additional benefits? All measures described in this study, except IMP_TEST, will also reduce the probability of introduction of other contagious pig diseases, such as FMD and African swine fever (ASF). Furthermore, LT_CONT and PF_S&D also reduce possible spread mechanisms during epidemics of contagious pig diseases. It was, however, impossible to quantify these reductions of disease introduction and spread and the accompanying benefits.

Acknowledgements

We thank all experts consulted on relevant measures to prevent CSFV introduction into The Netherlands for their helpful comments. We thank A.R.W. Elbers (CIDC-Lelystad), E.G.M. van Klink (EC-LNV), M. Nielen (Faculty of Veterinary Medicine, Utrecht University), and W.L.A. Loeffen (CIDC-Lelystad) for their comments on input parameters for the scenario tree model. We thank the officials of the RVV for supplying data from the Animal Movement system (ANIMO). The first author acknowledges financial support from the EU Research Project FAIR5-PL97-3566 funded by the European Union.

References

Anonymous, 1993. The EC single market—a new strategy in the field of animal and plant health. Report VI/1526/92-EN-Rev.3. Commission of the European Communities, Directorate-General for Agriculture, Brussels.

Artois, M., Depner, K.R., Guberti, V., Hars, J., Rossi, S., Rutili, D., 2002. Classical swine fever (hog cholera) in wild boar in Europe. Rev. Sci. Tech. Off. Int. Epiz. 21 (2), 287–303.

Belli, P., Anderson, J.R., Barnum, H.N., Dixon, J.A., Tan, J.-P., 2001. Economic Analysis of Investment Operations Analytical Tools and Practical Applications. World Bank Institute, Washington, DC.

Commission of the European Communities (CEC), 2001. Council Directive 2001/89/EC of 23 October 2001 on Community measures for the control of classical swine fever (text with EEA relevance). Off. J. Eur. Commun. L316, 5–35.

De Vos, C.J., 2005. Risk analysis of classical swine fever introduction. Ph.D. Thesis. Wageningen University, Wageningen.

De Vos, C.J., Horst, H.S., Dijkhuizen, A.A., 2000. Risk of animal movements for the introduction of contagious animal diseases into densely populated livestock areas of the European Union. In: Thrusfield, M.V., Goodall, E.A. (Eds.), Proceedings of the Society for Veterinary Epidemiology and Preventive Medicine, University of Edinburgh, March 29–31, 2000, pp. 124–136.

De Vos, C.J., Saatkamp, H.W., Nielen, M., Huirne, R.B.M., 2004. Scenario tree modelling to analyse the probability of classical swine fever virus introduction into member states of the European Union. Risk Anal. 24, 237–253.

Dijkstra, T., 1995. Visie of Fictie. Onderzoek naar de toepassingsmogelijkheden van een POSTILJON- of HETINU-systeem in het internationale vervoer van levende varkens en biggen over de weg. Saveetra, Zoetermeer (in Dutch).

Edwards, S., Fukusho, A., Lefèvre, P.C., Lipowski, A., Pejsak, Z., Roehe, P., Westergaard, J., 2000. Classical swine fever: the global situation. Vet. Microbiol. 73, 103–119.

Elbers, A.R.W., Dekkers, L.J.M., 2000. Sero-surveillance of diseases in wild boar of interest to domestic livestock in The Netherlands 1996–2000. In: Van Nus, A. (Ed.), Proceedings Annual Meeting of the Dutch Society for Veterinary Epidemiology and Economics, Utrecht, The Netherlands, December 13, 2000, pp. 49–54.

Elbers, A.R.W., Stegeman, A., Moser, H., Ekker, H.M., Smak, J.A., Pluimers, F.H., 1999. The classical swine fever epidemic 1997–1998 in The Netherlands: descriptive epidemiology. Prev. Vet. Med. 42, 157–184.

EU, 2002. Unpublished data from the Animal Disease Notification System (ADNS) of the European Union, Brussels.

EU, 2004. Agriculture in the European Union. Statistical and economic information 2003. http://europa.eu.int/comm/agriculture/agrista/2003/table_en/35310.pdf.

Greutink, T., Van Klink, E., Van der Peet, G., Mourits, M., Velthuis, A., 2002. Evaluatie verplaatsingsregelingen MKZ. Rapport EC-LNV nr. 2002/177. Expertisecentrum LNV, Ede (in Dutch).

Horst, H.S., Dijkhuizen, A.A., Huirne, R.B.M., De Leeuw, P.W., 1998. Introduction of contagious animal diseases into The Netherlands: elicitation of expert opinions. Livest. Prod. Sci. 53, 253–264.

Ipema, A.H., Smits, A.C., Hogewerf, P.H., Houwers, W., Van der Walle, K., Velthuis, A.G.J., Hogeveen, H., Hoste, R., Van Wagenberg, C.P.A., Puister-Jansen, L.F., 2002. Haalbaarheidsonderzoek Elektronische Identificatie. IMAG Rapport 2002–07. Research Institute of Agricultural and Environmental Engineering, Wageningen (in Dutch).

Jalving, A.W., Nielen, M., Maurice, H., Stegeman, A.J., Elbers, A.R.W., Dijkhuizen, A.A., 1999. Spatial and stochastic simulation to evaluate the impact of events and control measures on the 1997–1998 classical swine fever epidemic in The Netherlands. I. Description of simulation model. Prev. Vet. Med. 42, 271–295.

Klinkenberg, D., Everts-van der Wind, A., Graat, E.A.M., De Jong, M.C.M., 2003. Quantification of the effect of control strategies on classical swine fever epidemics. Math. Biosci. 186, 145–173.

KWIN, 2003. Kwantitatieve Informatie Veehouderij 2003–2004 (KWIN). Research Institute for Animal Husbandry, Lelystad (in Dutch).

Laddomada, A., 2000. Incidence and control of CSF in wild boar in Europe. Vet. Microbiol. 73, 121–130.

Lambooij, E., 2002. Haalbaarheidsonderzoek container transport varkens. Report 2179. Institute for Animal Science and Health, Department Infectious Diseases and Food Chain Quality, Lelystad (in Dutch).

LNV, 2004. Regeling inzake hygiënevoorschriften besmettelijke dierziekten 2000. Ministerie van landbouw, natuur en voedselkwaliteit, Den Haag (in Dutch). http://wetten.overheid.nl/.

Mangen, M.-J.J., 2002. Economic welfare analysis of simulated control strategies for Classical Swine Fever epidemics. PhD Thesis. Wageningen University, Wageningen.

Mangen, M.-J.J., Jalvingh, A.W., Nielen, M., Mourits, M.C.M., Klinkenberg, D., Dijkhuizen, A.A., 2001. Spatial and stochastic simulation to compare two emergency-vaccination strategies with a marker vaccine in the 1997/1998 Dutch Classical Swine Fever epidemic. Prev. Vet. Med. 48, 177–200.

Mangen, M.-J.J., Nielen, M., Burrel, A.M., 2002. Simulated effect of pig-population density on epidemic size and choice of control strategy for classical swine fever epidemics in The Netherlands. Prev. Vet. Med. 56, 141–163.

Meuwissen, M.P.M., Horst, H.S., Huirne, R.B.M., Dijkhuizen, A.A., 1999. A model to estimate the financial consequences of classical swine fever outbreaks: principles and outcomes. Prev. Vet. Med. 42, 249–270.

Meuwissen, M.P.M., Van Asseldonk, M.A.P.M., Huirne, R.B.M., 2000. The Feasibility of an Insurance for Livestock Epidemics in the Pig Sector. Institute for Risk Management in Agriculture, Wageningen (in Dutch).

Meuwissen, M., Mourits, M., Mangen, M.J., Léon, C., Tomassen, F., Huirne, R., 2002. Differentiatie heffingen Diergezondheidsfonds Varkenshouderij. Institute for Risk Management in Agriculture, Wageningen (in Dutch).

Miller, L., McElvaine, M.D., McDowell, R.M., Ahl, A.S., 1993. Developing a quantitative risk assessment process. Rev. Sci. Tech. Off. Int. Epiz. 12 (4), 1153–1164.

Moennig, V., 2000. Introduction to classical swine fever: virus, disease and control policy. Vet. Microbiol. 73, 93–102.

Nielen, M., Jalvingh, A.W., Meuwissen, M.P.M., Horst, H.S., Dijkhuizen, A.A., 1999. Spatial and stochastic simulation to evaluate the impact of events and control measures on the 1997–1998 classical swine fever epidemic in The Netherlands. II. Comparison of control strategies. Prev. Vet. Med. 42, 297–317.

OIE, 2004. Handistatus II. http://www.oie.int/hs2/report.asp?lang=en.

Palisade Corporation, 2002. Guide to using @Risk. Risk Analysis and Simulation Add-In for Microsoft Excel, Version 4.5. Palisade Corporation, Newfield, NY.

PVE, 2003. Vee, Vlees en Eieren in Nederland 2003. Product boards of Livestock, Meat and Eggs, Zoetermeer (in Dutch). http://bedrijfsnet.pve.agro.nl/pls/pbs/docs/folder/BEDRIJFSNET_US_CA/MARKT/PRIJS_EN_HANDELSINFORMATIE/VVE/VVEN+2003+KLEUREN+VERSIE.PDF.

RVV, 2004a. Unpublished data from the Animal Movement system (ANIMO). National Inspection Service for Livestock and Meat (RVV), Voorburg.

RVV, 2004b. List of Registered Washing Places. National Inspection Service for Livestock and Meat (RVV), Voorburg.

Statistics Netherlands, 2004. Unpublished data from the annual census (2003) of Statistics Netherlands, Voorburg.

Stegeman, A., Elbers, A.R.W., Smak, J., De Jong, M.C.M., 1999. Quantification of the transmission of classical swine fever virus between herds during the 1997–1998 epidemic in The Netherlands. Prev. Vet. Med. 42, 219–234.

Sutmoller, P., Thomson, G.R., Hargreaves, S.K., Foggin, C.M., Anderson, E.C., 2000. The foot-and-mouth disease risk posed by African buffalo within wildlife conservancies to the cattle industry of Zimbabwe. Prev. Vet. Med. 44, 43–60.

Van den Tempel, F.C.A., Giessen, G.W.J., 1992. Inleiding Agrarische bedrijfseconomie. Educaboek BV, Culemborg (in Dutch).

Van der Gaag, M.A., 2004. Epidemiological and economic simulation of Salmonella control in the pork supply chain. PhD Thesis. Wageningen University, Wageningen.

Van der Gaag, M.A., Saatkamp, H.W., Backus, G.B.C., Van Beek, P., Huirne, R.B.M., 2004. Cost-effectiveness of controlling *Salmonella* in the pork chain. Food Contr. 15, 173–180.

Vanthemsche, P., 1996. Classical Swine Fever 1993–1994 Belgium. Pig J. 37, 43–53.

Vose, D.J., 1997. Risk analysis in relation to the importation and exportation of animal products. Rev. Sci. Tech. Off. Int. Epiz. 16 (1), 17–29.

Vose, D.J., 2000. Risk Analysis. A Quantitative Guide, 2nd ed. Wiley, Chichester.

VWA, 2003. Bewaking Klassieke Varkenspest. Food and Consumer Product Safety Authority (VWA), Voorburg (in Dutch).

WTO, 1995. Agreement on the Application of Sanitary and Phytosanitary Measures. World Trade Organization. http://www.wto.org.

ANNEXE 2

DETILLEUX J.C., SERTEYN D., 2005. Cost-Effectiveness Analysis in Veterinary Medicine : Illustration with packed cell value in the Prognosis of horse surgical colic in Belgium. *Intern. J. Appl. Res. Vet. Med*, **3** (4) : 309-318.

Cost-Effectiveness Analysis in Veterinary Medicine: Illustration With Packed Cell Value in the Prognosis of Horse Surgical Colic in Belgium

Johann C. Detilleux, DVM, PhD[1]
Didier Serteyn, DVM, PhD[2]

[1]Department of Animal Production
Faculty of Veterinary Medicine
Liège University
Liège, Belgium

[2]Service d'Anesthesiologie Generale et Pathologie Chirurgicale des Grands Animaux
Faculty of Veterinary Medicine
Liège University
Liège, Belgium

KEY WORDS: economy, prognosis, hematocrit, colic, equine

ABSTRACT

Techniques of cost-effectiveness analyses were applied to determine whether or not it is economically efficient to measure the packed cell volume (PCV) on a colic horse before deciding on abdominal surgery. The effects of this decision of uncertainty on the estimated values of the parameters (probability of survival after surgery, surgery costs, PCV positive predictive value, and length of survival after surgery) were considered along with the monetary values of collecting additional information on those parameters. The effects of uncertainty on the incremental net benefits of each alternative were depicted by tornado diagrams, cost-effectiveness acceptability curves, and posterior probability distributions. The worth of additional information was computed as the expected values of perfect and sampling information. Given previously published results, the best PCV cut-off point to distinguish between survivors and non-survivors was at 44%. At this threshold, the most economically effective alternative is to measure PCV before surgery providing the owner is willing to pay less than €672 for each year the horse survives. Uncertainty on probability of survival after surgery largely influenced the decision whether or not to measure the PCV, but one should spend at most €381 in research to reduce this uncertainty. A study of postoperative survival of 500 colic horses would ensure an expected gain of €370 associated with a reduction in uncertainty.

INTRODUCTION

Cost-effectiveness analysis is a tool that enables a decision maker to make informed choices. For the veterinarian, this may consist of choosing to treat or not to treat a sick animal, to perform or not to perform a clinical test before a surgical act, or to decide whether or not to investigate further the basis of an unknown disease. In cost-effectiveness analysis, the costs and benefits of the different alternatives are measured and compared, their relative efficiency is assessed, and the most cost-effective alternative is preferred (assuming the decision maker is rational). Costs are measured in monetary units and benefits are measured in terms of clinical outcome (eg, mortality, morbidity, time for reoccurrence of the disease) to which a monetary value is assigned, value that reflects the decision maker's maximum willingness-to-pay for that clinical outcome. At the end of the analysis, economic results can be summarized in terms of incremental net benefit (INB), that is, the difference in increments in effectiveness and in costs.

For a number of reasons, costs and effects are seldom known with certainty.[1] Uncertainty on the model arises from 2 sources: model development and the values of the parameters.[2] In this article, we concentrated on parameter uncertainty and accepted the model as given. Parameter uncertainty is of first degree when uncertainty is about the true values of the parameters (eg, unobservable values of costs and effects or disagreement among experts). Parameter uncertainty is of second degree when it is associated with sampling variation (eg, limited samples available to estimate the true values of costs and effects). Deterministic analyses, in which costs and effects are varied over their possible range, are often used to take account for the first degree uncertainty while stochastic simulation methods, in which a distribution is specified for each cost and effect, consider the second degree uncertainty.

To reduce uncertainty, the decision maker may gather additional information; however, this means incurring additional time and monetary costs. The question then arises whether gathering this additional information is valuable economically. The expected value of perfect information (EVPI) represents the value of completely eliminating the uncertainty (ie, collecting information with perfect accuracy). It is the upper limit to the amount the decision maker would be willing to pay for any additional information. But obtaining perfect information is nearly impossible. More often, the decision maker will collect more data and compute the expected value of sample information (EVSI) (ie, the additional expected profit possible through knowledge of the sample information).

The goal of the present study was to illustrate cost-effectiveness analyses with an example on the prognostic value of packed cell volume (PCV) in equine surgical colic. The selected alternatives were whether or not to carry out the PCV test before deciding to undertake the surgery, given that the decision to perform surgery involves a trade-off between the immediate expenses posed by the veterinary act and the risk of death. The goal was not to give veterinarians strict indication on the prognosis value of colic surgery based only on PCV pre-surgery values but to illustrate the potentials of cost-effectiveness analyses in urgency veterinary medicine.

MATERIALS AND METHODS

An analysis of costs and effects of surgery for colic of the large intestine in horses was conducted. In this study, the number of years by which life is extended (Y_E) after surgery was used as the measure of effectiveness; costs were associated with surgery (C_S) (ie, cost of surgery and loss of work value) and with the PCV clinical test (C_P). The same value for Y_E was assumed for horses surviving colic surgery and for non-colic horses. The strategy "no test" consisted of surgical treatment of colic without PCV screening. It was compared with the strategy "test," consisting of surgery after a positive PCV screening and no surgery if the PCV result was negative (Figure 1).

In the strategy "no test," survival after surgery was achieved at a probability of p_eff. In the strategy "test," surgery was executed when the test was positive at a probability of p_tp and survival was attained at a probability of p_tp_eff (the test's positive predictive value). Assuming that horses will die without surgery, the effectiveness (E_N) and cost (C_N) associated with the strategy "no test" were:

$$E_N = \text{p\_eff} \times Y_E$$

and

$$C_N = C_S, \text{ respectively.}$$

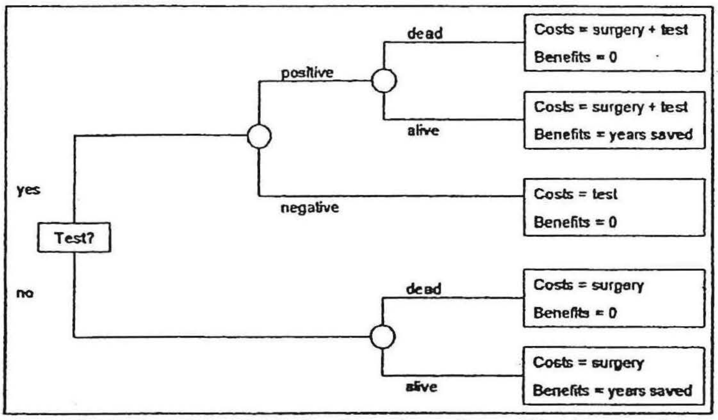


Figure 1. Decision tree displaying the alternatives of the horse colic problem.

For the strategy "test," effectiveness (E_T) and cost (C_T) were:

$$E_T = \text{p\_tp} \times \text{p\_tp\_eff} \times Y_E \text{ and}$$

$$C_T = (\text{p\_tp} \times C_S) + C_P, \text{ respectively.}$$

Baseline Analysis

For each proportion parameter (p_tp, p_eff, and p_tp_eff), a base-value (ie, the reference case) was identified from results of a study of PCV in horses referred at the veterinary hospital of the University of Liège (Belgium) for surgical colic of the large intestine.[3] Base-values were obtained for C_S[4-8] and Y_E[9-13] after a search on Google and Medline on November 22, 2004 (Table 1). Then, values for the incremental net benefit (INB) were computed as:

$$INB_K = K \times (E_T - E_N) - (C_T - C_N),$$

for different values of K, where K is the monetary value for 1 horse-year survived. The most cost-effective alternative was the strategy that led to the highest INB_K.

Analysis of Uncertainty

To analyze the effects of uncertainty on the parameters on the selection of the most cost-effective alternative ("test" or "no test"), 2 analyses were conducted. In the first analysis (first degree of uncertainty), parameter values were varied independently over their possible ranges to obtain highest and lowest INB_K. Maximum and minimum probabilities of survival after surgery were set at 100% and 50%, respectively. The cost of surgery varied from €1,500 to €7,500, and the length of survival after surgery ranged from 2 to 40 years (Table 1). The cost of PCV screening remained fixed at its current value of €10. Tornado diagrams depicted the effects of this type of uncertainty on INB_K.

In the second analysis (second degree of uncertainty), all parameter values were randomly sampled from different prior distributions and the incremental costs and effects were recalculated over 300,000 simulations. For p_eff, p_tp, and p_tp_eff, prior distributions were Beta (α, β) with $\alpha = r_0 + 1$ and $\beta = n_0 - r_0 + 1$, with r_0 = base-value for number of successes and n_0 = base-value for number of trials.[14] The variables $\ln(C_S)$ and $\ln(Y_E)$ were each assumed to be a random sample from a Normal (μ, $1/\tau$) population with prior specifications $\mu \sim$ Normal (μ_0, $1/n_0\tau$) and $\tau \sim$ Gamma (η, δ), with $\eta = 4$ and $\delta = \eta\sigma^2_0$, $\mu_0 = \log(\text{base-value}) - 1/2\sigma^2_0$, and $\sigma^2_0 = \log(1 + [\text{range}/(2 \times 1.98)])^2$, assuming 90% of the values for $\ln(C_S)$ and $\ln(Y_E)$ are within 2 standard deviations from their expected values. Base-values and ranges were from Table 1 and the value for the degrees of belief η was obtained by trial and error. The prior distributions were chosen to compute explicitly the conjugated posterior distributions for INB_K.[15] Uncertainty intervals were estimated from the simulated data

Table 1. Parameters for the Colic Problem: Base Values for Baseline Analysis, Ranges for Analysis of First Degree of Uncertainty, and Distributions for Analysis of Second Degree of Uncertainty.

Parameter	Symbol	Base-Value	Range	Distribution
Surgery costs (€)	C_S	4,000	1,500 to 7,500	logN (4,000, $1,515^2$)
Test cost (€)	C_P	10		
Years of life extended after surgery	Y_E	19	2 to 40	logN (19, 5)
Proportion of horse surviving surgery (%)	p_eff	62	50 to 100	Beta (61, 99)
Proportion of horse with packed cell volume less than (%)	p_tp			
27%		2		Beta (2, 99)
32%		14		Beta (14, 99)
37%		35		Beta (35, 99)
44%		71		Beta (70, 99)
49%		83		Beta (82, 99)
52%		88		Beta (87, 99)
55%		95		Beta (94, 99)
61%		100		Beta (99, 99)
Proportion of surviving horse among those with packed cell volume less than	p_tp_eff			
27%		1.00		Beta (2, 2)
32%		0.79		Beta (11, 14)
37%		0.74		Beta (26, 35)
44%		0.74		Beta (52, 70)
49%		0.72		Beta (58, 82)
52%		0.69		Beta (60, 87)
55%		0.65		Beta (61, 94)
61%		0.62		Beta (61, 99)

by taking the end points of a 95% interval around the average value for INB_K over all iterations. Cost-effectiveness acceptability curves (CEAC) were also constructed in which the probability, based on the available evidence, that INB_K is positive is plotted against K.[16] These probabilities were computed, for each value of K, as the proportion of iterations in which the strategy "test" had positive INB_K.

Value-of-Information Analysis

Finally, the worth of obtaining additional information on the unknown parameters (CS, YE, p_eff, p_tp, and p_tp_eff) was computed as the EVPIK and EVSIK. The algorithm proposed by Ades et al[17] was chosen to get EVPIK and EVSIK.[18] It consists of drawing a sample from the prior distribution of the parameter on which more data are to be collected and a sample from the predictive distribution of the sufficient statistics arising from a new dataset of size n, given the current value of the parameter. The prior distributions were those obtained in the analysis of the second degree of uncertainty. The predictive distributions for CS and YE were log-normal Logn(μ_0, $1/n_0\tau$). The predictive distributions for r_eff, r_tp, and r_tp_eff were binomial: Bin(p_eff, n), Bin(p_tp, n) and Bin(p_tp_eff, n_tp), respectively. Then,

$$EVPI_K = \check{E}(\max INB_K) - \max \check{E}(INB_K),$$

and

$$EVSI_K = \check{E}_D(\max INB_K) - \max \check{E}(INB_K),$$

where $\check{E}(\max INB_K)$ is the expected value under perfect information, $\max \check{E}(INB_K)$ is the expected value under current information, and $\check{E}_D$ is the expected value under imperfect information obtained from data D.

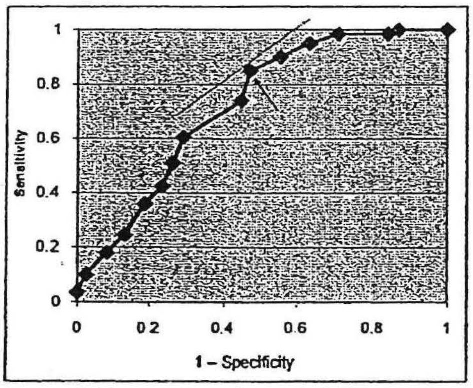


Figure 2. The receiver characteristic curve for packed cell volume as an indicator of survival after surgery for equine colic. The arrow indicates the best cut-off for a packed cell volume of 44%.

RESULTS

In the study of Grulke et al,[3] a horse was classified either as a survivor if it was discharged from the clinics, or as a non-survivor. Average blood PCV was 30.29% (standard deviation [SD] = 6.18) among survivors and 45.03% (SD = 8.77) among non-survivors. Consequently, the PCV test was considered positive when PCV was below some threshold values. A receiver operating curve (ROC) displaying the sensitivity and specificity of the test is shown in Figure 2. The best PCV cut-off point to distinguish between survivors and non-survivors was at PCV = 44%, as determined by the highest Youden index, with 73% of the cases correctly classified and a kappa value of 33%.[19] Therefore, unless stated otherwise, this PCV value was chosen in the analysis.

Baseline Analysis

Whatever the willingness-to-pay (K) for 1 survived year (Y_E) and the PCV limit, the strategy "test" was less costly and less beneficial than the strategy "no test." It was highest at K= €1 with INB_1 = €1,160. This value corresponded to the difference in net benefits between both alternatives, with – €2,819 for the "test" and – €3,979 for the "no test" alternative. The INB_K decreased linearly as K increased and became negative for K > €672.

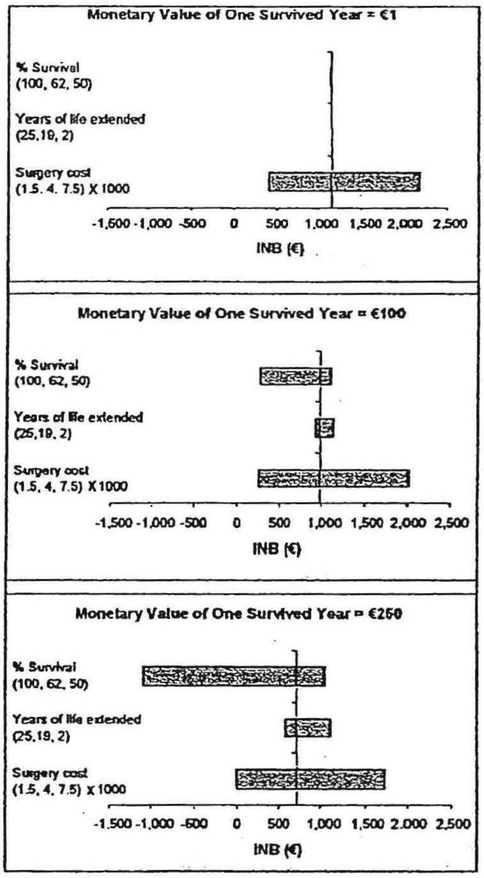


Figure 3. Tornado diagrams for the variation in incremental net benefit (INB) of the strategy "test" over the strategy "no test" given a maximum value for one survived year of €1, €100, and €250. The horizontal axis crossed the vertical axis at the base-value. Surgery costs varied from €1,500 to €7,500 with a base-value of €4,000; years of life extended after surgery varied from 2 to 25 years with a base-value of 19 years; and % of survival with a packed cell volume of 44% varied from 50% to 100%, with a base-value of 62%.

Analysis of the First Degree of Uncertainty

Uncertainty on surgery costs had highest effects on INB^1 for all PCV values (Figure 3). The INB^1 declined to €428 for C_S = €1,500 and increased to €2,185 when C_S = €7,500. The effect of uncertainty on surgery costs remained constant at all K values, but theeffect of uncertainty on YE, p_tp_eff, and p_eff increased as K increased. For

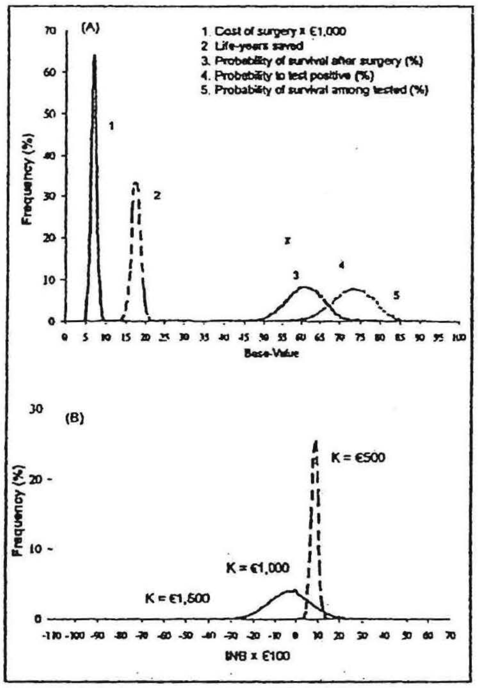


Figure 4. Prior distributions (A) for the parameters of the colic problem and posterior distributions (B) for incremental net benefit (INB) at various monetary values for 1 survived year (K) and for a packed cell volume of 44%.

example, INB_{250} = €1,116 for $Y_E = 2$ years and INB_{250}= €593 for $Y_E = 25$ years; INB_{250} = €1,044 for p_eff = 55% and INB_{500} = –€1,093 for p_eff = 100%.

Analysis of the Second Degree of Uncertainty

Prior distributions for p_eff, p_tp, p_tp_eff, C_S, and Y_E are shown in Figure 4 with the corresponding posterior distributions for INB_K when K = €100, €1,000, and €1,500. Prior averages and 95% confidence intervals (in parentheses) for the proportions were 61.40% (61.38%–61.42%) for p_eff, 70.30% (70.29%–70.32%) for p_tp, 73.60% (73.58%–73.62 %) for p_tp_eff, €3,751 for C_S, and 18.07 (18.06–18.07) years for Y_E. The posterior means for INB_K and their standard errors for PCV = 27%, 38%, 44%, and 52%, and for K = €1, €100, €500, €1,000, and €1,500 are in Table 2. Note that standard errors were lower at low than at high K values. In Figure 5, the CEAC showed that the probability of a positive INB_K was 100% for K ≤ €100 at any PCV values. The probability then decreased. It was close to zero at K = €500 for PCV = 27%, and reached 30% at K = €1,000 for PCV = 44% and 55% at K = €1,000 for PCV = 52%.

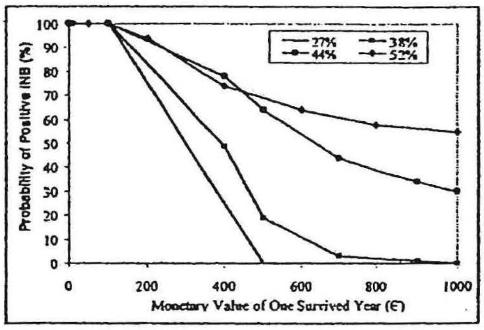


Figure 5. The cost-effectiveness acceptability curves for packed cell volume of 27%, 38%, 44%, and 52%, with incremental net benefit (INB) of the strategy "test" over the strategy "no test." The dotted line represents the 10% significance level for testing the null hypothesis of a negative INB.

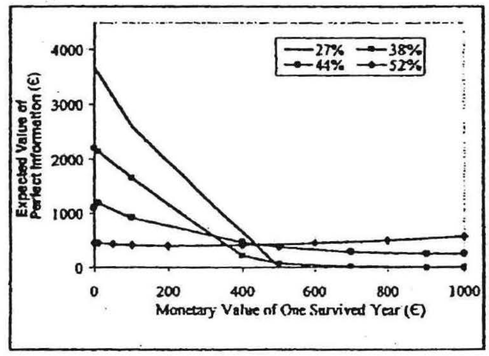


Figure 6. Expected value of perfect information for different monetary value of 1 survived year and for packed cell volume of 27%, 38%, 44%, and 52%.

Value-of-Information Analysis

The values for $EVPI_K$ were higher than €1,000 for K ≤ €100, but they became almost zero at K = €500 for PCV = 27% and at K = €800 for PCV = 38% (Figure 6). From Table 2, it can be seen that INB_K and $EVPI_K$ were identical as long as $pr(INB_K > 0) = 100\%$ and that $EVPI_K$ became greater than INB_K for value of

Table 2. Posterior Means (Standard Errors) for Incremental Net Benefit (INB) of the Strategy "Test" Over the Strategy "No Test," the Expected Value of Perfect Information (EVPI), and the Probability of a Positive INB for Different Monetary Values of 1 Survived Year (K).

	PCV = 27%	PCV = 38%	PCV = 44%	PCV = 52%
K = €1				
EVPI (€)	3667 (0.76)	2189 (0.45)	1091 (0.23)	446 (0.09)
INB (€)	3667 (0.76)	2189 (0.45)	1091 (0.23)	446 (0.09)
pr(INB > 0) (%)	100 (0.00)	100 (0.00)	100 (0.00)	100 (0.00)
K = €100				
EVPI (€)	2606 (0.80)	1644 (0.51)	918 (0.32)	416 (0.24)
INB (€)	2606 (0.80)	1644 (0.51)	918 (0.32	416 (0.24)
pr(INB > 0) (%)	100 (0.00)	100 (0.00)	100 (0.00)	100 (0.00)
K = €500				
EVPI (€)	5.17 (0.11)	81 (0.40)	381 (0.81)	422 (0.83)
INB (€)	−1679 (1.43)	−561 (1.27)	219 (1.18)	293 (1.14)
pr(INB > 0) (%)	1.52 (0.02)	21 (0.07)	64 (0.09)	68 (0.08)
K = €1,000				
EVPI (€)	0 (0)	2.16 (0.07)	243 (0.94)	568 (1.41)
INB (€)	−7036 (2.55)	−3318 (2.42)	−655 (2.32)	141 (2.27)
pr(INB > 0) (%)	0 (0.00)	0.52 (0.01)	30 (0.08)	54.65 (0.09)
K = €1,500				
EVPI (€)	0 (0)	0.42 (0.04)	223 (1.09)	735 (1.98)
INB (€)	−12392 (3.73)	−6075 (3.60)	−1529 (3.47)	−12 (3.40)
pr(INB > 0) (%)	0 (0)	0.08 (0.00)	20.89 (0.07)	49.85 (0.09)

$pr(INB_K > 0) < 100\%$. For all unknown parameters (C_S, Y_B, p_eff, p_tp, and p_tp_eff), the EVSI values were lower than the corresponding EVPI. An example is given in Figure 7, where the expected value of sampling information on p_eff is shown for K = €500 and PCV = 44%: it increased from €300 for a sample size n = 5 to €340 for n = 100, €370 for n = 500, and up to the value of $EVPI_{500}$ at n = 100,000.

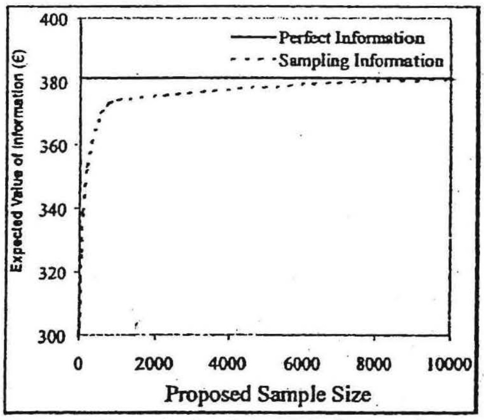


Figure 7. Expected values of perfect and sampling information on the probability of survival, assuming €500 for 1 survived year and a packed cell volume of 44%.

DISCUSSION

The objective of this study was to introduce the techniques of cost-effectiveness analysis in veterinary medicine with an example in surgery for equine colic. Such techniques are important for the clinician working in equine colic referral centers who must present alternatives clearly to their clients. Indeed, colic is a very costly equine disease when surgery is required to avoid death. Studies reported 14% to 41% of horses referred for gastrointestinal colic at veterinary clinics required surgery.[20,21] Colic is also costly because the percentage of surgically treated horses that survive varies with the pathophysiological mechanisms behind the colic syndrome, the physiological status of the animal, the study design and the time frame when surgery was performed.[22]

Different indicators of survival after surgery have been proposed, among which is the preoperative PCV.[3,5,10,23] Based on the

Belgian data,[3] a clinician may recommend surgery when the horse's PCV is below 44% because it is the threshold that best identified survivors and non-survivors, as given by the Youden index and the ROC (Figure 2). This comes at a cost because, in the Belgian study, 26% of the colic horses with PCV $\leq 44\%$ died after surgery ($0.26 \times$ €4,010 = €1,043) and 31% of the colic horses with PCV > 44% survived after surgery ($0.31 \times 19 = 5.9$ years). On the other hand, if surgery is performed on all colic horses without any preoperative testing, a loss of €1,520 ($0.38 \times$ €4,000) will be incurred as a result of the surgery on non-survivors. Given these alternatives, the horse's owner must make the final decision depending on how he/she valued the life-year of the horse. Because it quantifies and compares the economic efficiency of each alternative, cost-effectiveness analysis will help in making decisions that are consistent with maximizing the horse's health gains given the existing information and the owner's available resources.

Baseline Analysis

Given the parameters in Table 1, the strategy "test" is always less costly and less beneficial than the strategy "no test." Indeed, in the "test" alternative, surgery is performed only on animals with a positive test, while in the "no test" alternative, surgery is performed on all horses. Because it is less beneficial than the "no test" alternative, the "test" alternative is said not to dominate[24] and a judgment must be made whether the magnitude of its cost-saving is justified given its reduced effectiveness. This decision cannot be determined unless a cut-of-value, or maximal willingness-to-pay (K) for 1 life-year gained has been specified by the horse's owner.[25] Hence, the "test" strategy at PCV $\leq 44\%$ is the most cost-effective when the horse's owner is not willing to pay more than €672 for 1 life-year gained (to ensure $INB_K > 0$). Note this value is much lower than the maintenance costs of a horse estimated at €1,500 per year.[5,26] If the owner considered only maintenance costs, the surgery should always be performed because $INB_{1,500} < 0$.

Analysis of the First Degree of Uncertainty

Some variables may affect the selection of the best alternative, such as the surgery costs (C_S), the probability of survival after surgery (p_eff), and the number of life-years gained (Y_E). Indeed, costs of colic surgery vary between veterinary clinics, horse value, colic etiology and localization, and existence or not of post-operative complications. In the USA, costs starts generally at €3,000, but can double for more difficult cases.[5] Others reported costs varying from €4,500 to €7,500.[4] In England, costs vary from €3,000 to €7,000, with €4,000 being the average.[7] In France, a study has reported costs from €1,500 to €5,000.[8] Postoperative survival rates fluctuate as well, with values at 21%,[9] 34%,[10] 54%,[12] 65%,[13] and 69.7%,[11] up to 88%.[12] Period of survival after surgery is dependent upon the occurrence of postoperative complication. In a study of 341 horses that recovered from colic surgery, the probability of survival postoperatively decreased to 0.87 by 10 days, 0.82 by 100 days, and declined slowly to 0.75 at 600 days.[6] In this study, all 3 variables affected the value of INB_K at PCV = 44% but at different levels (Figure 3). Uncertainty on C_S was the single most influential parameter as long as K was below €200, but this uncertainty would not alter the choice ofthe "test" alternative as the most cost-effective ($INB_K > 0$ for all K). The influence of uncertainty on p_eff and Y_E increasedwith K, and for K > €200, uncertainty on p_eff had the highest influence on the magnitude and the sign of INB_K. There is atrade-off between the owner's willingness to pay per extended life-year and the post-operative survival. If p_eff isequivalent to the test positive predictive value (p_tp_eff), then the best alternative is to perform the test at any K value ($INB_K > 0$ for all K). If the surgery is 100% effective (p_eff = 1), then the best alternative is not to perform the test, unless the owner is only willing to pay less than €130 per life-year ($INB_K < 0$ for K > €130). Note the impact of uncertainty on the values of CS, Y_B, and p_eff on INB_K is small in regards to the maintenance costs for a horse: at K = €1,500, $INB_K < 0$ and the "no test" alternative is the most cost-effective (unless $Y_E = 2$ years or p_tp_eff = p_eff).

Analysis of the Second Degree of Uncertainty

Prior distributions (Figure 4A) were used to describe the uncertainty on the base-values for C_S, Y_E, p_tp, p_eff, and p_tp_eff, uncertainty linked to the sampling variation. They were chosen compatible with published information on each unknown variables and conjugate to have prior and posterior distributions of the same family. This uncertainty is ricocheted in the spread of the posterior distributions of INB_K (Figure 4B) and the standard errors for the mean INB_K (Table 2). The distributions are widespread and the standard errors high, especially at high K values, making it difficult to draw conclusions or to make recommendations from the available information.

The CEAC are another popular graphical representation of uncertainty (Figure 5). In this study, the CEAC crossed the y-axis at 100%. This is the position at which the horse's owner is unwilling to pay anything for health gain ($K = 0$), in which case he/she should always choose the "test" alternative (given the current base-values). The point where the CEAC reaches equilibrium represents the position at which the horse's owner is willing to pay an infinite amount for each additional gain in life-year. In this study, the equilibrium was at 0% because there was no more heath gain in opting for the"test" alternative when K tended to infinity. Note that the CEAC is equal to $1 - \alpha$ (the 1-sided significance level) for testing the null hypothesis of a negative INB. For example, the null hypothesis is rejected at $a = 10\%$ for $K <$ €320 because, as shown by the dotted line on Figure 5, the probability of obtaining $INB_{320} > 0$ is more than 90%.

Value of Information Analysis

To reduce the second order uncertainty observed in the baseline analysis, it would be desirable to realize specific research. The upper limit to the value of additional information is $EVPI_K$. In this study, $EVPI_K$ (Figure 6) was important for low values of K, but became negligible as K increased. As a result, there is practically little purpose in further research to determine accurately the values of C_S, Y_E, p_tp, p_eff, and p_tp_eff when the horse's owner valued his/her horse at least at its maintenance costs (€1,500). The $EVSI_K$ for p_eff is shown only as an illustrative purpose (Figure 7) because $EVSI_K$ should always be lower than or equal to $EVPI_K$. Indeed, $EVSI_K$ is concerned with predicting the expected reduction in uncertainty resulting from the collection of data from an additional sample while $EVPI_K$ is concerned with eliminating completely that uncertainty, and this can be achieved only by an infinitely large sample. By comparing the magnitude of $EVSI_K$ to the costs of obtaining the sample, the optimum sample size for a further study on p_eff could be estimated. For example, the cost of collecting information on p_eff on 500 horses should be less than €0.6 per horse ($EVSI_K =$ €300). Figure 7 shows also how EVSI increased with sample size and how even modest study sizes contribute substantially to the decision because of the relatively low precision in the base value for p_eff.

CONCLUSION

In conclusion, comprehensive cost-effectiveness analysis provides an explicit, coherent, and flexible framework to help a decision maker in identifying the intervention with the greatest expected net benefit if he/she wishes to maximize health outcome subject to a budget constraint. By considering the expected value of information, he/she may also decide whether further research is required and to set priorities for collecting additional information. In our colic example, the base-analysis showed that a horse's owner should prefer the "test" alternative for a horse with PCV = 44%, as long as he/she is willing to pay less than €672 each year the horse survives. However, due to sampling variation, he/she will make the wrong decision almost 50% of the time, as shown by the CEAC (Figure 5) and the posterior distributions of $INB_{1,000}$ (Figure 4). At a willingness-to-pay of €500, the probability of postoperative survival was influencing most the choice of the testing as the best alternative (Figure 3) but one should spent at most €381 (Table 2; $EVPI_{500}$) in research to reduce the second order uncertainty on the probability of survival. Finally, a study of postoperative survival of 500 colic horses would ensure an expected gain of €370 associated with a reduction in uncertainty.

ACKNOWLEDGEMENTS

The author would like to thank the scientists from the Department of Equine Surgery at the Faculty of Veterinary Medicine, University of Liège, Belgium, for conducting the surveys and collecting the data.

REFERENCES

1. Doubilet P, Weinstein MC, McNeil BJ: Use and misuse of the term "cost-effective" in medicine. *N Engl J Med* 1986;314:253–256.
2. Johnson-Masotti AP, Laud PW, Hoffmann RG, Hayat MJ, Pinkerton SD: Probabilistic cost-effectiveness analysis of HIV prevention: comparing a Bayesian approach with traditional deterministic sensitivity analysis. *Eval Rev* 2001;25:474–502.
3. Grulke S, Olle E, Detilleux J, Gangl M, Caudron I, Serteyn D: Determination of a gravity and shock score for prognosis in equine surgical colic. *J Vet Med A Physiol Pathol Clin Med* 2001;48:465–473.
4. Compton A, Hoffman A: *Should You Insure Your Horse?* Available at: http://www.petplace.netscape.com/articles/artShow.asp?artID=1207. 2004.
5. Freeman DW, Walker OL, Johnson BJ: "First time" horse ownership: selecting horses and budgeting horse interests. *Oklahoma Extension Fact Sheets* 2004;F-4004:1–4.
6. Proudman CJ, Smith JE, Edwards GB, French NP: Long-term survival of equine surgical colic cases. Part 1: patterns of mortality and morbidity. *Equine Vet J* 2002;34:432–437.
7. Royal Veterinary College of London: *Colic Fact Sheet*. Available at: http://www.rvc.ac.uk/Hospitals/SEH/Fact_Sheets/Colic.cfm. 2000.
8. Thoulon F: *Les Coliques*. Available at: http://users.skynet.be/bs715830/cavaliers/dos_col.htm. 2004.
9. Furr MO, Lessard P, White NA: Development of a colic severity score for predicting the outcome of equine colic. *Vet Surg* 1995;24:97–101.
10. McCarthy RN, Hutchins DR: Survival rates and post-operative complications after equine colic surgery. *Aust Vet J* 1988;65:40–43.
11. Puotunen-Reinert A, Huskamp B: Acute postoperative diarrhoea in colic horses. *J S Afr Vet Assoc* 1986;57:5–11.
12. van der Linden MA, Laffont CM, Sloet van Oldruitenborgh-Oosterbaan MM: Prognosis in equine medical and surgical colic. *J Vet Intern Med* 2003;17:343–348.
13. Wiemer P, Bergman HJ, van der Veen H, Pruissen L: Colic surgery in the horse: a retrospective study of 272 patients. *Tijdschr Diergeneeskd* 2002;15:682–686.
14. Vose D: *Quantitative Risk Analysis: A Guide to Monte Carlo Simulation Modelling*. John Wiley & Sons: New York; 1996.
15. Miconnet N, Cornu M, Beaufort A, Rosso L, Denis J-B: Uncertainty distribution associated with estimating a proportion in microbial risk assessment. *Risk Anal* 2005;25:39–48.
16. Stevens JW, O'Hagan A, Miller P: Case study in the Bayesian analysis of a cost-effectiveness trial in the evaluation of health care technologies: depression. *Pharm Stat* 2003;2:51–68.
17. Ades AE, Lu G, Claxton K: Expected value of sample information calculations in medical decision modeling. *Med Decis Making* 2004;24:207–227.
18. Tappenden P, Chilcott J, Eggington S, Oakley J, McCabe C: Methods for expected value of information analysis in complex health economic models: developments on the health economics of beta interferon and glatiramer acetate for multiple sclerosis. *Health Technol Assess* 2004;8:1–78.
19. Altman DG: *Practical Statistics for Medical Research*. Chapman and Hall: London; 1991.
21. Thoefner MB, Ersbøll AK, Jansson N, Hesselholt M: Diagnostic decision rule for support in clinical assessment of the need for surgical intervention with acute abdominal pain. *Can J Vet Res* 2003;67:20–29.
22. Kaneene JB, Miller R, Ross WA, Gallagher K, Marteniuk J, Rook J: Risk factors for colic in the Michigan (USA) equine population. *Prev Vet Med* 1997;30:23–36.
23. Thoefner MB, Ersbøll AK, Jensen AL, Hesselholt M: Factor analysis of the interrelationships between clinical variables in horses with colic. *Prev Vet Med* 2001;48:201–214.
24. O'Brien B, Drummond M, Labelle R, Willan A: In search of power and significance: issues in the design and analysis of stochastic cost-effectiveness studies in health care. *Med Care* 1994;32:150–163.
25. Karlsson G, Johannesson M: The decision rules of cost-effectiveness analysis. *Pharmacoeconomics* 1996;9:113–120.
26. Viaene J, Gellynck X, De Belder T: Het economisch beland van de paardensector. *Vakgroep Landbouweconomie in opdracht van de Belgische Confederatie van het Paard, Gent.* 2003.

ANNEXE 3

VAN SCHAIK G., KALIS C.H.J., BENEDICTUS G., DIJKHUIZEN A.A., HUIRNE R.B.M., 1996. Cost-benefit analysis of vaccination against paratuberculosis in dairy cattle. *Veterinary Record*, **139** : 624-627

SCHMALOHR, D. & LINKE, D. B. (1988) *Electromyography and Clinical Neurophysiology* **28,** 233
SHAHANI, B. T. & YOUNG, R. R. (1972) *Neurology* **22,** 149
SHAHANI, B. T. & YOUNG, R. R. (1973) New Developments in Electromyography and Clinical Neurophysiology. Vol 3. Ed J. E. Desmedt. Basel, Karger. p 641
SOLIVEN, B., MEER, J., UNCINI, A., PETAJAN, J. & LOVELACE, R. (1988) *Muscle and Nerve* **11,** 848
TAKADA, M., ITOH, K., YASUI, Y., MITANI, A., NOMURA, S. & MIZUNO, N. (1984) *Neuroscience Letters* **50,** 251
TAMAI, Y., IWAMOTO, M. & TSUJIMOTO, T. (1986) *Brain Research* **380,** 19
TRONTELJ, M. A. & TRONTELJ, J. V. (1978) *Journal of Neurology, Neurosurgery and Psychiatry* **41,** 538
WHALEN, L. R. (1985) *American Journal of Veterinary Research* **46,** 229

Cost-benefit analysis of vaccination against paratuberculosis in dairy cattle

G. van Schaik, C. H. J. Kalis, G. Benedictus, A. A. Dijkhuizen, R. B. M. Huirne

Veterinary Record (1996) **139,** 624-627

Paratuberculosis is an infectious and incurable disease which causes considerable economic losses in dairy cattle, due mainly to premature disposal and losses of milk production. In 1984 the Animal Health Service North-Netherlands started a vaccination trial in which young calves were vaccinated once, to test whether vaccination reduced the production losses and whether the overall costs of vaccination were outweighed by the benefits. Vaccination against paratuberculosis reduced the number of clinically infected animals by almost 90 per cent. It also reduced the numbers of subclinically infected animals and animals with a positive histological and/or bacteriological test result. Although vaccination did not prevent losses in milk production, it reduced the infection pressure and the clinical signs of the disease. Partial budgeting showed that vaccination against paratuberculosis was highly profitable. The costs of vaccination were US$15 per cow and the benefits (total returns minus costs) were US$142 per cow.

PARATUBERCULOSIS is an infectious and incurable disease which particularly affects cattle, sheep and goats. The bacterium *Mycobacterium paratuberculosis* causes a thickening of the intestinal lining which reduces the efficiency of feed absorption. In the clinical form, paratuberculosis causes a considerable loss in milk production and the cows lose weight in spite of the fact that their appetite remains good. The disease manifests itself most often in cows which are between four and five years old (Benedictus 1985).

The animals most susceptible to the infection are young calves, which can be infected by contact with manure or milk, or in utero (Benedictus 1985). The severity of the infection depends primarily on the age of the animal and the concentration of the pathogen present. The older the animals and the lower the infection pressure, the less often an infection will cause clinical signs of paratuberculosis (Benedictus 1985). When *M paratuberculosis* is present on a farm, all the animals will usually come into contact with it (Benedictus 1985).

Paratuberculosis causes considerable economic losses which are due mainly to premature disposal and a reduction in milk production. In dairy cattle, reductions in milk production were reported to range from about 5 per cent in cows with subclinical forms of the disease to 20 per cent in clinically affected cows. Moreover, affected cows were culled earlier and had a reduced slaughter value. The average losses per animal culled were found to be US$1250 and US$1000 for clinically and subclinically infected animals respectively (Benedictus and others 1987).

In the Netherlands, an eradication programme based on the voluntary disposal of infected cows was ineffective, and the number of cases of paratuberculosis did not decline over the years. In 1984 the Animal Health Service North-Netherlands started a field vaccination trial in which young calves were vaccinated once (Kalis and others 1991). The goals of the trial were to investigate the effect of vaccination on the numbers of animals with the clinical or subclinical form of paratuberculosis, and to test whether vaccination reduced the production losses and whether the benefits of vaccination outweighed the overall costs. This article gives the results of the cost-benefit analysis of the trial. A comparison was made between the situation before and after vaccination, taking into account a vaccinated and a control group.

Materials and methods

Data

The vaccination trial was conducted on 12 farms in the northern part of the Netherlands, where more than 5 per cent of cows were culled anually as a result of paratuberculosis. The unvaccinated cows which were culled between 1982 and 1984 were tested for paratuberculosis. In 1984 the vaccination trial started and all the calves on the farms were vaccinated once before one month of age with a heat-killed water-in-oil emulsion vaccine. The vaccinated animals left the farms between 1984 and 1992 and all those which were culled were examined by the Animal Health Service for clinical signs of paratuberculosis. Material from the intestines was collected for histological, bacteriological and cultural tests to check whether an animal was infected. The histological tests used staining techniques and the material from the intestine was cultured to investigate whether *M paratuberculosis* was present. The presence of *M paratuberculosis* was tested microscopically in the animals which were positive in the histological or bacteriological test and if the organism was identified the animals were considered to be subclinically infected. *M paratuberculosis* was often not identified microscopically in animals with a positive cultural test result and these animals were considered to be latently infected. After five years the rate of disposal of animals because of the clinical form of paratuberculosis was reduced from 11 per cent in 1984 to less than 1 per cent in 1989. However, the subclinical form of the disease was still present to a considerable extent (Kalis and others 1991).

Data on 652 cows were available for economic analysis. Data on 573 cows, 304 of which were vaccinated and 269 of which were unvaccinated controls, could be used to calculate the reduction in milk production. The cows from the vaccinated and control

---

G. van Schaik, MSc Agric, **A. A. Dijkhuizen,** MSc Agric, PhD, **R. B. M. Huirne,** MSc Agric, PhD, Department of Farm Management, Wageningen Agricultural University, Hollandseweg 1, 6706 KN Wageningen, The Netherlands
C. H. J. Kalis, DVM, **G. Benedictus,** DVM, PhD, Animal Health Service North-Netherlands, PO Box 361, 9200 AJ Drachten, The Netherlands

groups were subdivided into the following four groups on the basis of clinical and laboratory tests:

(a) healthy, uninfected animals in which no bacteria were found;
(b) subclinically infected animals which tested positive for paratuberculosis in the bacteriological and/or histological test, but which had no clinical signs;
(c) animals with clinical signs of paratuberculosis which were confirmed by laboratory tests and were culled;
(d) latently infected animals which were positive only in the cultural tests, and which were free of clinical signs.

In the vaccinated group the numbers of animals in groups a, b, c and d were 162, 27, 18 and 97 respectively, and in the unvaccinated group the numbers were 124, 45, 50 and 50.

The empirical data were evaluated statistically with Statistix 4.0 (Siegel 1992) and tested for significance by the least significant difference method, with $P<0{\cdot}05$.

Cost-benefit analysis

The possible benefits of vaccination for the farmer would be reduced culling and lower losses in production. However, the farmer must meet higher costs for vaccination and sampling.

The costs and benefits of vaccination were calculated by partial budgeting, which meant that only the changes produced by the vaccination programme were calculated. The economic losses for each animal consisted of the following components (Dijkhuizen and others 1991): first, the losses before disposal, which consist of the reduction in milk production and the costs of examination and treatment; secondly, the losses at disposal, which consist of the lower slaughter value and the costs of open places; and thirdly, the loss due to disposal, which is the loss of future income.

The sum of these components gives the total losses per animal at farm level. The benefits of vaccination will be the reduction in the losses due to one or more of these components.

Results

Losses before disposal

The production of milk, fat and protein in the cows' last lactation before disposal and in their first (heifer) lactation were compared, after adjustment for differences in age, season, year and length of lactation (Wilmink 1987). This calculation gave the loss or gain in milk production for a cow in its last lactation compared with its expected milk production capacity as a heifer. The percentage reduction in milk production multiplied by the average production of heifers of the corresponding subgroup gives the absolute reduction in kg of milk, fat and protein. The results for the subgroups are summarised in Table 1.

In the subgroup of uninfected animals the vaccinated animals had a greater reduction in milk production than the unvaccinated animals, 316 kg compared with 28 kg of milk. In the subgroups of subclinically and latently infected animals the vaccinated animals also had a greater reduction in milk production, respectively 706 – 199 = 507 kg and 382 – (–248) = 630 kg. However, the vaccinated clinically infected animals had a smaller reduction in milk production, 1089 – 631 = 458 kg milk, than the unvaccinated animals. In each group, similar trends were apparent for the reduction in the production of fat and protein.

The costs of examination and treatments included the visit by a veterinarian at a rate of about US$20 and possible faeces and blood tests costing about US$5. Some animals were also treated for scour at an average cost of US$3. The total costs were estimated to be US$25 per clinically infected cow. The costs of vaccination were US$15 per animal.

Losses at disposal

Clinically infected animals had a lower slaughter value at disposal, owing to weight losses, which was estimated at about 30 per cent. Considering a normal slaughter value of US$1085 per culled cow, this loss was US$325 per clinically infected cow. According to Benedictus and others (1987), replacement animals will not always be available immediately, and a cost of US$47 was therefore assumed for two weeks of open places per culled cow.

Losses due to disposal

The economic losses due to premature disposal can be defined as the difference between the income a particular animal could earn during its remaining expected life, and the expected income over the same period of a replacement animal. These losses vary, particularly with the productive quality of the cow and her age at disposal, and were taken from the dynamic programming model of Houben and others (1994). The cows in the various subgroups produced on average 6·5 per cent above herd level in their first lactation and were culled on average after 3·3 lactations. The losses due to disposal averaged US$815 per case, and ranged from US$614 for vaccinated, latently infected cows to US$919 for unvaccinated, clinically infected cows (Table 2).

Profitability of vaccination

The profitability of vaccination is the difference in costs before, at and due to disposal, compared with the unvaccinated group. The total costs for the vaccinated and unvaccinated groups were determined by multiplying the frequency of uninfected, subclinically, clinically and latently infected animals in each group by the costs at each stage. The costs of disposal of an average cow from the unvaccinated and vaccinated group are the standard of comparison. It was assumed that the total rate of disposal at farm level remained the same. The total losses calculated for the periods before, at, and due to disposal are summarised in Table 2.

As might be expected the total losses were highest for clinically infected cows. Vaccination reduced the losses for these animals by US$106 per cow. For subclinically and latently infected cows the opposite occurred; in the case of subclinically infected cows, mainly because of a high lost future income, and in the case of latently infected cows because of a greater reduction in milk production before disposal. The total losses for uninfected animals were lower, despite a greater reduction in milk production,

TABLE 1: Reductions in milk, fat and protein production (% and kg)

	Uninfected		Subclinically infected		Clinically infected		Latently infected	
	unvaccinated	vaccinated	unvaccinated	vaccinated	unvaccinated	vaccinated	unvaccinated	vaccinated
Number of cattle	124	162	45	27	50	18	50	97
Milk								
(%)	0·5	5·7	3·9	13·1	20·6	13·1	–4·5	7·0
(kg)	28	316	199	706	1089	631	–248	382
Fat								
(%)	0·6	4·9	2·0	13·5	13·2	14·2	–4·1	7·9
(kg)	1·5	12·2	4·5	32·7	29·7	32·4	–10·1	19·5
Protein								
(%)	–1·2	4·2	2·0	13·5	21·8	13·6	–5·3	5·3
(kg)	–2·3	7·9	3·4	25·0	33·4	23·3	–9·8	9·9

TABLE 2: Total losses (US$) before, at, and due to disposal per subgroup

	Uninfected		Subclinically infected		Clinically infected		Latently infected	
	unvaccinated	vaccinated	unvaccinated	vaccinated	unvaccinated	vaccinated	unvaccinated	vaccinated
Number of cattle	124	162	45	27	50	18	50	97
Before disposal (%)	–14	42	44	352	407	363	–96	139
At disposal	47	47	47	47	47	47	47	47
Due to disposal	831	624	831	907	919	857	768	614
Total	864	713	922	1306	1698	1592	719	800

because of a smaller lost future income. Clinically infected animals had a smaller reduction in milk production and a smaller lost future income, which also resulted in smaller losses for clinically infected animals in the vaccinated group.

In Table 3 the costs per subgroup have been multiplied by the number of animals in the unvaccinated and vaccinated groups. Vaccination against paratuberculosis decreased the frequency of subclinically and clinically infected animals. In the unvaccinated group 26 per cent and 11 per cent of the animals were subclinically and clinically infected, respectively, whereas in the vaccinated group the percentages were 11 per cent and 0·8 per cent, respectively. This means a reduction of 86 per cent in the numbers of clinically infected animals. The number of latently infected animals increased considerably from 15 to 26 per cent. However, the number of uninfected animals increased after vaccination from 48 to 62 per cent.

Taking into account the frequency distribution shown in Table 3, the total losses were US$949 per cow in the unvaccinated group and US$807 in the vaccinated group. The benefits of vaccination, that is the total returns minus the costs, were on average US$142 per culled cow. It is true that the costs for the uninfected and latently infected cows were higher in the vaccinated group (US$444 and US$210 respectively versus US$410 and US$111 in the unvaccinated group), but the frequency of subclinically and clinically infected animals was considerably lower in the vaccinated group, which is the major reason that vaccination was profitable.

Discussion

Paratuberculosis is difficult to diagnose in the various stages of the disease (Sprangler and others 1992) and a combination of tests was used to increase the reliability of detection.

The unvaccinated and vaccinated groups were made comparable for age, calving season, month of lactation, and lactation length by correcting the lactations by factors derived from the Dutch Cattle Syndicate (NRS) (Wilmink 1987). Nevertheless it has not been proved that all the differences in milk production and lost future income could be explained by an infection with paratuberculosis. Among the uninfected animals there were differences in costs between the unvaccinated and vaccinated group; the losses due to lost future income should be interpreted with caution.

Benedictus and others (1987) observed a reduction in milk production of 16 per cent in subclinically infected animals whereas, in this investigation, the reduction was only 4 per cent in the unvaccinated group and 13 per cent in the vaccinated group. One explanation might be that the subclinically infected animals used by Benedictus and others (1987) were at a later, almost clinical, stage of the disease. The 20·5 per cent reduction in milk production for the clinically infected animals was similar to the 19·5 per cent observed by Benedictus and others (1987). The 13 per cent reduction in the milk production of the vaccinated clinically infected animals may not have been due entirely to the vaccination. These animals were culled, on average, before their third lactation, that is before the influence of paratuberculosis on milk production reaches its maximum (Collins and Nordlund 1991).

The vaccination of the uninfected and latently infected animals appeared to reduce their milk production by 5·7 per cent and 7·0 per cent, respectively, whereas there was hardly any reduction in the uninfected (0·6 per cent) and latently infected (–4·5 per cent) cows in the unvaccinated group. The reduction in milk production in the vaccinated group may have been due to the fact that older animals, like heifers, can still experience an infection with *M paratuberculosis* without getting the clinical form when they are older (Rossiter and others 1994). The vaccinated heifers which were infected may not have had any difficulty in resolving the infection and remaining uninfected or becoming latently infected, unlike the unvaccinated heifers, which may have had more difficulty in resolving an infection, and suffered a reduction in milk production. As a result, the vaccinated heifers had a higher milk production than the unvaccinated heifers (C. H. J. Kalis, personal communication). The correction of the last lactation of a vaccinated, uninfected or latently infected cow in relation to its lactation as a heifer thus seems to result in a greater reduction in milk production in the vaccinated group.

Vaccination did not seem to reduce the incidence of infection with *M paratuberculosis*, as was shown by the large number of latently infected animals in the vaccinated group. However, vaccination did reduce the incidence of severe clinical infections. Subclinically and clinically infected animals had much higher costs than latently infected animals, US$203 and US$979 respectively, in the unvaccinated group, and US$506 and US$792 respectively, in the vaccinated group. Since vaccination reduced the incidence of subclinically and clinically infected animals considerably, the eradication of paratuberculosis would be highly profitable, and vaccination could contribute to the process.

On the farms used in this investigation 11 per cent of the animals were clinically infected before vaccination. Even if the level of infection had been only 5 per cent, the benefits of vaccination would still have been US$83 per head.

Farms that vaccinate are not allowed to export live animals. The calculated benefits of vaccination will, however, on average easily outweigh the potential losses from such a restriction. For example, if 10 per cent of the heifers were exported at an average price of US$1390, then the US$142 benefit from vaccination would outweigh the losses from the export restrictions.

TABLE 3: Costs per average culled animal

	Cows per subgroup (%)	Total costs per cow (US$) (see Table 2)	Average costs within group (US$)
Unvaccinated			
uninfected	47·5	864	410
subclinically infected	26·1	922	241
clinically infected	11·0	1698	187
latently infected	15·4	719	111
total	100		949
Vaccinated			
uninfected	62·3	713	444
subclinically infected	10·7	1306	140
clinically infected	0·8	1592	13
latently infected	26·2	800	210
total	100		807

References

BENEDICTUS, G. (1985) PhD thesis, University of Utrecht

BENEDICTUS, G., DIJKHUIZEN, A. A. & STELWAGEN, J. (1987) *Veterinary Record* **121**, 142

COLLINS, M. T. & NORDLUND, K. (1991) Proceedings of the International Colloquium on Paratuberculosis 1991, Orlando. p 402

DIJKHUIZEN, A. A., RENKEMA, J. A. & STELWAGEN, J. (1991) *Agricultural Economics* **5**, 263

HOUBEN, E. H. P., HUIRNE, R. B. M., DIJKHUIZEN, A. A. & KRISTENSEN, A. R. (1994) *Journal of Dairy Science* **77,** 2975
KALIS, C. H. J., BENEDICTUS, G., VAN WEERING, H. J., FLAMAND, F. & HAAGSMA, J. (1991) Proceedings of the International Colloquium on Paratuberculosis 1991, Orlando. p 484
ROSSITER, C. A., SANG, J. S., JACOBSON, R. H., SCHAFLER, D. H. & LEIN, D. H. (1994) Proceedings of the 4th International Colloquium on Paratuberculosis 1994, Cambridge. p125
SIEGEL, J. (1992) Statistix 4.0, User's Manual. Analytical Software. 319 pp
SPRANGLER, E., BECH-NIELSEN, S. & HEIDER, L. E. (1992) *Preventive Veterinary Medicine* **13,** 185
WILMINK, H. (1987) PhD thesis, Wageningen Agricultural University

ANNEXE 4

SEN S., SHANE S.M., SCHOLL D.T., HUGH-JONES M.E., GILLESPIE J.M.,1998. Evaluation of alternative strategies to prevent Newcastle disease in Cambodia. *Preventive veterinary Medicine*, **35** : 283-295

ELSEVIER Preventive Veterinary Medicine 35 (1998) 283–295

PREVENTIVE
VETERINARY
MEDICINE

Evaluation of alternative strategies to prevent Newcastle disease in Cambodia

S. Sen[a], S.M. Shane[a,*], D.T. Scholl[a],
M.E. Hugh-Jones[a], J.M. Gillespie[b]

[a] *Department of Epidemiology and Community Health, School of Veterinary Medicine, Louisiana State University, Baton Rouge, LA 70803, USA*
[b] *Department of Agricultural Economics and Agribusiness, Louisiana State University, Baton Rouge, LA 70803, USA*

Accepted 6 February 1998

Abstract

Velogenic viscerotropic Newcastle disease (vvNCD), which is endemic in Cambodia, can be prevented in theory by a combination of biosecurity and immunization of broiler flocks. The relative contribution of appropriate biosecurity and effective vaccination was quantified at the farm level, applying realistic projections for capital investment, fixed and variable production costs and losses following infection. Non-protected broiler flocks generate a loss when the probability of vvNCD infection exceeds 0.4. Applying both biosecurity and effective vaccination would sustain profitability up to a probability of exposure of 1.0. The benefit to cost ratios for alternative strategies were evaluated for a range of probabilities of exposure to vvNCD extending from 0.1 to 1.0. The benefit-to-cost ratio for biosecurity exceeded unity at a risk of exposure exceeding 0.1, and 0.2 for vaccination and the combination of vaccination and biosecurity respectively. A sensitivity analysis demonstrated that the efficiency of protection, feed cost, and financial consequences of infection markedly affected the projected benefit-to-cost ratios associated with alternative methods of prevention. © 1998 Elsevier Science B.V.

Keywords: Chicken-microbiological diseases; Cost–benefit analysis; Newcastle disease; Vaccination biosecurity; Cambodia

1. Introduction

Effective control of endemic velogenic viscerotropic Newcastle disease (vvNCD) in tropical countries is critical to the profitable production of commercial chickens. Direct

---

* Corresponding author. Tel.: +1 504 346 3335; fax: +1 504 346 3331; e-mail: smshane@vt8200.vetmed.lsu.edu

PII S0167-5877(98)00065-8

and indirect contact with backyard flocks (which serve as reservoirs of the virus) results in infection of the broilers, replacement breeding stock and egg-production pullets. Newcastle disease (NCD) is a major restraint to attaining acceptable production levels in privately owned commercial enterprises and cooperative village units (Sinurat et al., 1993). Under practical conditions in rural and peri-urban areas in Southeast Asia, options for control of vvNCD include vaccination (Spradbrow, 1994), biosecurity (Wahid, 1981), or their combination (Rusdi and Sumardi, 1981).

The development of an appropriate prevention strategy requires an analysis of relevant costs and benefits (Dijkhuizen et al., 1995) and a projection of gains derived from preventive action (Power and Harris, 1973). Previous studies analyzing the economics of disease control have used partial budgeting, gross marginal analysis, and welfare economics. Partial budgeting can be applied to measure changes in income and expenditure associated with a production plan (Boehlje and Eidman, 1984). Gross margin analysis allows comparison of different strategies within a given time period with defined probabilities of exposure to disease (Martin et al., 1987). Costs affecting the revenue of individual farms are relatively easy to calculate or predict (McInerney and Turner, 1989). In contrast, the social costs of disease including expenditure by the public sector on control (Putt et al., 1988) and escalation in purchase price to the consumer are more difficult to determine (McInerney et al., 1992). Analysis of benefit-to-cost ratios associated with alternative approaches to disease control can be used to guide the allocation of resources and to define policy (Miller et al., 1996). The social benefit of controlling poultry disease in a country such as Cambodia may be analyzed using techniques of welfare economics which quantify how changes in programs affect producers, consumers and public well-being. Welfare economics can relate endemic vvNCD to the increase in the selling price to consumers following a reduction in the supply of poultry. The demand for live broilers and eggs in Cambodia may be regarded as relatively elastic in the short term. Infections such as vvNCD and highly pathogenic infectious bursal disease (vvIBD) impose additional costs to consumers and reduce the per capita intake of protein.

In a country with endemic vvNCD, effective prevention reduces direct losses to producers and generates potential opportunity benefits. Reduction in supply to urban markets as a result of seasonal outbreaks of vvNCD increases the unit selling price of eggs and live birds. Producers with effective disease control procedures benefit from enhanced revenue at the expense of farmers who experience flock losses. A simulation study on the economic impact of the potential introduction of vvNCD into Australia demonstrated that effective control and preventive measures could justify importation of poultry meat (Hafi et al., 1994). This conclusion was based on the value of total consumer and producer surplus, which exceeded the cost of eradicating and controlling possible limited outbreaks of vvNCD.

Agriculture is the most important sector of the economy of Cambodia representing 47% of 1991 real gross domestic product and 85% of total employment (Food and Agriculture Organization, 1994). Statistics processed by the central government (Department of Animal Production and Health (1995), Cambodia, 1995) confirm stagnation in chicken population which remained at 10 million birds during the period 1987 to 1993. The disparity between the 4.4% annual population growth rate and lack of expansion in poultry production has led to a shortage of adequate dietary protein of animal origin. A study conducted by an international agency concluded that vvNCD was principally responsible for up to 80% mortality in immature backyard and cooperative village-owned, confined flocks in Cambodia (Food and Agriculture Organization, 1994).

Comprehensive control measures are required to suppress vvNCD. These include extension activities at the village level and implementation of biosecurity and vaccination, especially in the small-scale commercial units being established by entrepreneurs and cooperatives. This study was undertaken to quantify the financial impact of vvNCD on commercial broiler farms and to apply benefit–cost analyses to predict the outcome of alternative prevention strategies including vaccination and biosecurity.

The objective of this study, applying partial budgeting and benefit–cost analysis, was to determine vvNCD prevention strategies that maximize expected profits and returns per dollar of investment for limited-scale, commercial broiler units in Cambodia.

2. Materials and Methods

2.1. *Assumptions*

Production parameters (including stocking density, feed conversion and growth rates and age at live sale) were ascertained for a typical 2000 broiler unit in Cambodia, based on an informal survey carried out by a representative of an international aid agency assigned to the country (pers. comm., C. Bartels, 1994). Assumed values for mortality and degradation of performance in flocks infected with vvNCD are based on the experience of the first two authors in Southeast Asia and Southern Africa respectively. These values and the corresponding performance for uninfected farms are shown in Table 1.

Table 1
Assumed production parameters for a cooperative broiler growing farm in Cambodia, producing at a level of 2000 birds/batch, used in modelling the benefit-to-cost ratio of 5 competing velogenic viscerotropic Newcastle disease (vvNCD) prevention strategies

Characteristic	vvNCD-uninfected	vvNCD-infected
Allowance for culls and mortality (%)	10	70
Maximum age at sale (days)	50	50
Inter-cycle period (days)	10	10
Total length of production cycle (days)	60	60
Number of cycles per annum	6	6
Stocking density (birds/m^2)	12	12
Cumulative feed conversion efficiency at 50 days of age	2	2.5
Live-weight at sale (kg)	1.5	1.2
Average birds produced per cycle	2000	660
Chick cost ($US)	0.3	0.3
Feed cost ($US/ton)	200	200
Live-weight revenue ($US/kg)	1.5	1.5

Table 2
Vaccination program for broilers at high risk of vvNCD[a] and vvIBD[b] in Cambodia

Vaccine	Age	Route
Attenuated NCD Vaccine (Hitchner of V4 strain) and inactivated NCD oil emulsion	Day old	Eye drop Subcutaneous at hatchery or delivery
Attenuated intermediate strain IBD, and inactivated IBD oil emulsion	8 days	Eye drop Subcutaneous at farm
Attenuated NCD vaccine (Hitchner strain)	20, 30, 40 days	Coarse spray

[a] vvNCD = Velogenic, viscerptropic Newcastle disease.
[b] vvIBD = Very virulent infectious bursal disease.

Capital and operating costs and the selling price for live broilers were obtained from personal contact with farmers by the senior author and were consistent with a 1994 United Nations survey of Cambodian agriculture (Food and Agriculture Organization, 1994). Input costs and market prices assume an exchange rate of 2500 Riels (Cambodian currency) to $US 1. The benefits associated with reduced risk of vvNCD infection were projected for hypothetical situations before and after initiating preventive programs. Strategies to prevent or suppress vvNCD comprised vaccination (Table 2) and biosecurity alone and their combination. Preventive strategies were classified according to three levels of intensity, each with corresponding levels of protection efficiency (Table 3). This was defined as one minus the probability of infection in flock exposed to vvNCD virus. The assumed costs of implementing each of the vvNCD prevention strategies for each broiler cycle are presented in Table 3.

The cost of comprehensive vaccination ($330/cycle) includes purchase and storage of both attenuated and inactivated commercial vaccines manufactured according to international standards of efficacy and safety, labor required for administration and a provision for limited serologic assay to confirm the antibody response to vaccines. The cost of enhanced biosecurity ($103/cycle) represented the per cycle proportion of the fixed costs of erecting a 2 m high wire fence with secured gates around the production unit to prevent trespass and to exclude backyard poultry. The farm operator would purchase a supply of coops to obviate entry within the fenced area by live bird traders. In addition, the biosecurity provision incorporates expenditure on disinfectants to

Table 3
Alternative strategies for preventing vvNCD[a] and their associated protection efficiencies[b] and costs to a cooperative broiler-growing farm in Cambodia, producing 2000 5 birds/cycle in the absence of vvNCD

Alternative strategy	Assumed protection efficiency	Assumed cost per cost per cycle ($US)
No protection	0	0
Vaccination	70%	330
Biosecurity	50%	103
Combination of vaccination and biosecurity	95%	433

[a] vvNCD = Velogenic, viscertoropic Newcastle disease.
[b] One minus the probability of disease, expressed as a %, folowing exposure to vvNCD virus.

Table 4
Assumed capital and fixed costs of a cooperative broiler growing farm in Cambodia, producing 2000 birds/batch

Category	Total value ($US)	Annual depreciation		Annual interest[b] at 12% ($US)
		Rate (%)	Cost ($US)	
Housing	8400	10	840	1008
Equipment	610	20	122	73
Site improvements	312	10	31	37
Installations	1500	20	300	180
Total	10822		1293	1298

[a] Depreciation = (total value−salvage)÷functional life (years); Salvage=0.
[b] Annual interest=(total value)×0.12.

decontaminate the premises and equipment at the end of each cycle and to provide protective clothing and footwear for farm workers.

2.2. *Capital cost*

Capital costs (including housing, equipment, site improvements, and transportation) required for operation of a broiler farm in Cambodia are shown in Table 4. An annual interest rate of 12% (based on the bank rate in 1994) was incorporated into the calculations. The functional life of broiler houses and associated installations was assumed to be 10 years and is reflected in an annual depreciation rate of 10%. Equipment and installations were assumed to have a functional life of 5 years, and an annual depreciation rate of 20% was applied.

2.3. *Simulation of operating costs and revenue*

Operating costs (including both fixed and variable components) were projected for each scenario (Table 5). Fixed costs comprised administrative overhead, annual interest, depreciation, and working capital. Variable costs included chickens, feed, labor, vaccines, medication, disinfectants, utilities, and fuel required to grow broilers.

The loss incurred following vvNCD infection was projected in relation to the risk of exposure and the efficiency of protection. The following calculations quantified the average projected income or loss associated with vvNCD exposure:

> [1] Average profit per cycle (NCD-uninfected) at a specific probability of exposure=profit per cycle in which the flock remains uninfected ×{1−[(probability of exposure) ×(1−protective efficiency)]}.
> [2] Average loss per cycle (NCD-infected) at a specific probability of exposure=loss per cycle for a flock becomes infected × probability of exposure × (1−protective efficiency).
> [3] Expected profit (loss) per cycle=[1] + [2].

The expected profit or loss from broiler flocks subjected to each hypothetical situation was calculated by applying relevant values for the probability of exposure and level of

Table 5
Operating costs, revenue and profit (loss) with and without vvNCD[a] infection for a cooperative broiler growing farm in Cambodia, producing 2000 birds/ batch without vvNCD

Category	Cost per production cycle ($US)	
	NCD-uninfected	NCD-infected
Fixed operating cost		
Administration overhead	$100	$100
Annual interest	216	216
Annual depreciation	216	216
Working capital	332	332
Subtotal	864	864
Variable operating cost		
Chick cost	660	660
Feed cos	1242	784
Labor cost	300	300
Vaccine	66	0
Medication	50	150
Disinfectant	84	118
Utilities and fuel	50	50
Subtotal	2452	2062
Total operating cost	3316	2926
Total revenue	$4550	$1188
Profit (loss)	$1234	($1738)
Live-weight produced (kg):	3000	792
Unit live-weight costs:	41.11	$3.69
Unit live-weight profit (loss)	$0.39	($2.19)

[a] vvNCD = Velogenic viscerotropic Newcastle disease.

protection as provided by each of the three alternative preventive strategies (vaccination, biosecurity, or their combination).

2.4. Benefit-to-cost ratios

The benefit-to-cost ratio for each of the three protection strategies was calculated to evaluate the contribution of each of the alternative programs. These values comprised the ratio of projected income accruing from each preventive strategy compared to non-protected flocks divided by the incremental costs incurred by the specific level of protection.

The benefit to cost ratios were derived using the following calculations:

> [4] Benefit attributed to a given level of protection = expected profit derived from applying the level of protection (less cost of protection (Table 3), minus the expected revenue from non-vaccinated flocks with conventional management omitting protection against vvNCD.

[5] Benefit to cost ratio for a given level of protection = [4] ÷ by the additional cost incurred by the specific protection strategy (Table 3).

2.5. *Sensitivity analysis*

A series of calculations was performed to determine the effect of changes in assumed costs of feed inputs, level of mortality resulting from infection and efficiency of the protection levels on the financial outcome from each of the alternative prevention strategies.

3. Results

3.1. *Financial impact of Newcastle disease on broiler production*

The production costs for uninfected and vvNCD-infected broiler flocks were applied to quantify the change in average variable costs as a result of mortality and other effects of exposure to vvNCD. The reduction in production volume in infected flocks raised the estimated average cost per kg produced although fixed costs remained unchanged. Total variable costs decreased in infected flocks because of the reduction in total feed consumed as a result of vvNCD mortality, which usually occurs at 2 to 3 weeks of age in the production environment in Cambodia. Table 5 depicts the operating costs and expected loss following vvNCD infection of a broiler flock. Mortality and depression in live-weight of survivors has a substantial impact on revenue and profit. The expected profit per cycle associated with increased risk of exposure to vvNCD (Table 6) ranges from $1234/cycle without infection to a loss of $1738 following exposure in the absence of a prevention program which was assumed to always result in infection of the flock.

3.2. *Effect of alternative preventive strategies*

The expected profit derived from each of the three protection strategies was calculated in relation to the risk of vvNCD exposure of broiler flocks ranging from zero to 1.0 in increments of 0.1. Without protection, loss occurred when the probability of exposure exceeded 0.4 (Fig. 1). Implementing prevention procedures would extend the break-even point, allowing farmers to earn a profit despite the increased probability of exposure. Protective strategies (including vaccination or biosecurity alone or their combination) sustained profitability up to a probability of exposure between 0.7 and 1.0, depending on the selected strategy.

The benefit-to-cost ratios for the relevant preventive strategies are shown graphically in Fig. 2. At a risk of exposure greater than 0.2, the benefit-to-cost ratio of all three alternative strategies exceeded unity. The benefit-to-cost ratio of enhanced biosecurity exceeded unity with a probability of exposure above 0.1. The value of biosecurity relative to vaccination in terms of benefit-to-cost ratios is indicated by the approximately equivalent ratios for vaccination and combined vaccination and biosecurity and the improved ratios estimated for enhanced biosecurity alone.

Table 6
Benefit–cost ratios of three alternative vvNCD[a] prevention strategies for a cooperative broiler growing farm in Cambodia, producing at a level of 2000 birds/batch

Protection	Probability of exposure	0	0.1	0.2	0.3	0.5	0.7	0.9
No	Average profit[b,c]	$1234	$1111	$987	$684	$617	$370	$123
Protection	Average NCD loss[c]	0	(174)	(348)	(521)	(869)	(1217)	(1564)
	Expected profit (loss)[c]	1234	937	639	343	(252)	(847)	(1441)
Vaccination	Expected profit (loss)[d]	$904	$815	$726	$637	$458	$4890	$102
	Expected benefit[e]	0	208	416	624	1040	1456	1872
	Benefit–cost ratio[f]	0	0.63	1.26	1.89	3.15	4.41	5.67
Biosecurity	Expected profit (loss)	$1131	$982	$834	$685	$388	$91	($206)
	Expected benefit	0	149	297	226	743	1040	1337
	Benefit–cost ratio	0	1.11	2.88	4.33	7.21	10.10	12.98
	Expected profit (loss)	$801	$786	$771	$756	$727	$697	$667
	Expected benefit	0	282	565	847	1412	1976	2541
Vaccination and biosecurity	Benefit–cost ratio	0	0.65	1.30	1.96	3.26	4.56	5.87

[a] vvNCD = Velogenic viscerotropic Newcastle disease.
[b] All monetary values are $US per production cycle.
[c] Calculated as defined in the text.
[d] net of control cost.
[e] Expected benefit=expected profit at specified protection level + cost−expected profit at protection level 0.
[f] With respect to Protection Level 0.

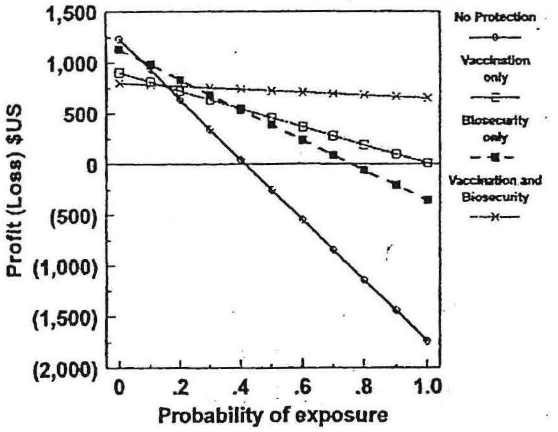


Fig. 1. Expected net profit (loss) in $US for 2000-bird/batch commercial broiler-growing farm in Cambodia at probabilities of exposure to velogenic viscerotropic Newcastle disease ranging from 0 to 1.0. Profit (loss) curves are shown for a farm applying one of four levels of disease prevention: none; effective vaccination only; appropriate biosecurity only; or a combination of vaccination and enhanced biosecurity.

3.3. Sensitivity analysis

Fig. 3 shows the effect of changing feed price (ranging from $US 180 to $US 220/ton) and broiler mortality (ranging from 60% to 80%) on the probability of exposure without

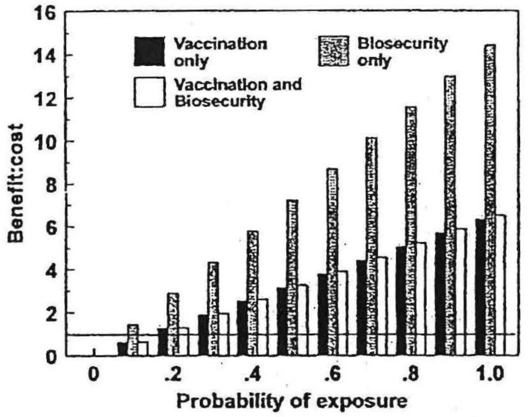


Fig. 2. Estimated benefit-to-cost ratios for a 2000-bird/batch commercial broiler growing farm in Cambodia at probabilities of exposure to velogenic viscerotropic Newcastle disease ranging from 0 to 1.0. Ratios are shown for farms employing one of three levels of disease prevention relative to no additional disease prevention: effective vaccination only; enhanced biosecurity only; or a combination of vaccination and enhanced biosecurity.

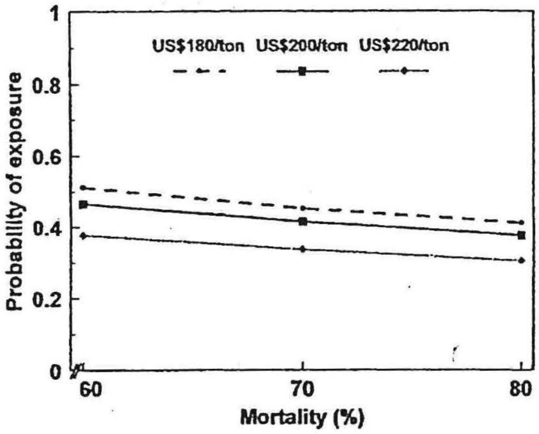


Fig. 3. Probability of exposure to velogenic viscerotropic Newcastle disease corresponding to the break-even point for a 2000-bird/batch commercial broiler growing farm in Cambodia with various feed costs and mortality in a flock exposed to vvNCD.

protection, as measured by the break-even risk of exposure. Both escalation in feed cost and elevation in vvNCD mortality reduced the probability of infection associated with the break-even point, but cost of feed was comparatively more important. At a feed cost of $US 180/ton, and 70% mortality, a 0.45 probability of exposure resulted in a break-even situation. An increase in feed cost to $US 220/ton reduced the probability of exposure at break-even to 0.34. Similarly, increasing the flock mortality due to vvNCD from 60% to 80% at any given feed cost reduced the break-even probability of exposure. The impact of

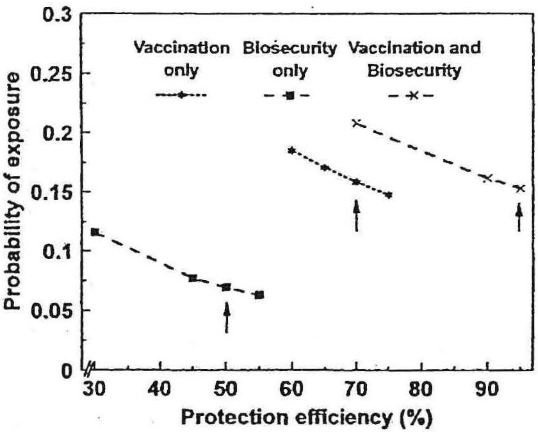


Fig. 4. Probability of exposure to velogenic viscerotropic Newcastle disease corresponding to a benefit-to-cost ratio of unity for a 2000-bird/batch commercial broiler growing farm in Cambodia under a range of assumed protection efficiencies for each of three disease prevention strategies relative to no disease prevention; effective vaccination only; appropriate biosecurity only; combination of vaccination and enhanced biosecurity. Arrows indicate the protection efficiency initially modelled.

vvNCD on the broiler enterprise in Cambodia was only moderately sensitive to input costs and the level of mortality resulting from outbreak.

The probability of exposure which generated a benefit-to-cost ratio of unity for the four different protection efficiencies was calculated for each of the prevention alternatives (Fig. 4). The probability of exposure associated with a benefit-to-cost ratio of unity is inversely proportional to the efficiency of any preventive strategy. However, the probability of exposure when the benefit-to-cost ratio equals unity was only moderately influenced by downward revision of the assumed efficiency of protection for each of the three prevention strategies.

4. Discussion

Newcastle disease is the most important infection of chickens in Southeast Asia, especially among non-confined village flocks and backyard birds (Spradbrow, 1994). Since control of vvNCD in these populations with vaccination is difficult to achieve, there is constant spread of virus from reservoirs to commercial chicken flocks. Reducing contact between commercial flocks and village chickens through enhanced biosecurity lowers the risk of lateral infection. The techniques evaluated in this study quantify the efficiency of alternative approaches including combinations of biosecurity and vaccination to control vvNCD in broiler farms in Cambodia. The value of \$330/cycle for effective vaccination (Table 3) include purchase of 4 doses of attenuated NCD vaccine, one dose each of inactivated NCD and IBD vaccines and a single dose of attenuated intermediate strain IBD vaccine. It is considered necessary in the countries of Southeast Asia to provide comprehensive protection against the highly immunosuppressive and pathogenic vvIBD virus to achieve a satisfactory antibody response NCD vaccination. The combination of live attenuated and inactivated oil emulsion vaccines, as shown in Table 2, although expensive and requiring manual labor for administration, is highly effective in protecting flocks from the two catastrophic diseases which are endemic in the region. For the purpose of the simulation an attenuated Hitchner B1 strain NCD vaccine was selected, based on availability, quality, and efficacy when purchased from a supplier manufacturing in accordance with USDA or EC standards. The heat-stable V4 strain (Spradbrow, 1994) could be substituted but the differential in cost using a product derived from a reputable supplier would be minimal in relation to the expenditure on Hitchner B1 NCD. The V4 vaccine has been shown to be highly effective in reducing losses due to vvNCD in free-ranging and village flocks in developing countries. This is due to the tolerance of the NCD mutant to heat and the ease of administering the vaccine by the oral route in a feed pellet.

Expenditure on prevention of NCD must be considered in relation to the risks and consequences of disease exposure (Gifford et al., 1987). The provisional projections of the financial impact of vvNCD and the increase in revenue from alternative prevention programs define the limits of expenditure to achieve acceptable benefit-to-cost ratios.

The combination of enhanced biosecurity and improved vaccination provided the maximum protection and hence profit to producers at probabilities of exposure ≥ 0.3 compared to the two other preventive strategies. At probabilities of exposure <0.30, enhanced biosecurity alone offered maximum profit to producers. Biosecurity alone was the most financially efficient strategy resulting in the highest benefit-to-cost ratio at a probability of exposure ≥ 0.1. This is because costs associated with this level of protection were lower than those associated with the alternatives. The benefit-to-cost ratios relating to efficient vaccination, biosecurity, and the combination of vaccination and biosecurity were all directly and positively influenced by risk (probability) of exposure. The incremental revenue values serve as a guide to select a model program to prevent vvNCD. Any change in the market price of broilers or in production costs resulting from macro- economic factors or variation in production parameters would modify the benefit-to-cost values associated with prevention programs.

It is unlikely that small shifts in the probability of exposure can be reliably estimated under field conditions. These results are insensitive to deviations in feed cost and vvNCD mortality within the ranges selected in this analysis. It naturally follows that expected profits and benefit-to-cost ratios associated with the three alternative protection levels will follow these results proportionately.

Projections confirmed the inverse relationship between protection efficiency afforded by the alternative strategies and the level of exposure which justifies implementing the prevention strategy. Qualitatively, the shifts in assumed protection efficiency would not alter decisions with respect to the implementation of enhanced biosecurity. Protection provided by vaccination alone or vaccination in combination with biosecurity may alter the relative benefits, depending on the assumed efficiency of protection provided by each component. The return from effective prevention of vvNCD on individual broiler farms could be enhanced by obtaining increased revenue for broilers following regional or national outbreaks of disease which disturb the supply–demand equilibrium. Paucity of data (input costs, selling prices of competing products, inflation, and quantity of chickens consumed during the past 5 years in Cambodia) has precluded a specific analysis of opportunity benefits resulting from an efficient vvNCD prevention program for commercial broiler farms.

Welfare analysis relating to the impact of vvNCD on chicken production requires an estimation of demand and supply functions and prices for eggs, poultry meat, and competing items. Projection of demand based on consumption data in Cambodia over five consecutive years is unavailable. This study was, therefore, confined to financial values relating to farm production and did not incorporate the economic cost of vvNCD associated with the public sector or the losses to society.

5. Conclusion

The results of this analysis contribute to an understanding of the financial impact of vvNCD in the broiler, egg and duck industries of developing nations. The structured evaluation of alternative prevention strategies as presented, can be used to select appropriate combinations of vaccination and biosecurity under a wide range of probabilities of exposure and for different situations relating to production cost and income. Based on the assumptions made in the foregoing analyses, expected profit is maximized by the implementation of a combination of enhanced biosecurity and vaccination. The greatest return on investment is potentially realized by enhancing biosecurity. A combination of vaccination and biosecurity is the most appropriate vvNCD preventive strategy for cooperative and entrepreneurial-owned commercial broiler farms in Cambodia and Southeast Asia.

References

Boehlje, M.D., Eidman, V.R., 1984. Farm Management. Wiley, New York, pp. 86–262.

Department of Animal Production and Health, 1995. An Annual Report on Animal Production. Phnom Penh, Cambodia.

Dijkhuizen, A.A., Huirne, R.B.M., Jalvingh, A.W., 1995. Economic analysis of animal diseases and their control. Prev. Vet. Med. 25, 135–149.

Food and Agriculture Organization/United Nations Development Programme, Cambodia, 1994. Agricultural Development Options Review (Phase I), Report No. 42/94 UNDP-CMB 1 SR. Investment Center, FAO, Rome, pp. 94–95.

Gifford, D.H., Shane, S.M., Hugh-Jones, M.E., Weigler, B.J., 1987. Evaluation of biosecurity in broiler breeders. Avian Dis. 31, 339–344.

Hafi, A., Reynolds, R., Oliver, M., 1994. Economic impact of Newcastle disease on the Australian poultry industry. ABARE Research Report No. 94.7, Commonwealth of Australian Bureau of Agricultural and Resource Economics. Canberra, Australia, pp. 23–48.

Martin, S.W., Meek, A.H., Willeberg, P., 1987. Veterinary Epidemiology, Principles and Methods. Iowa State University Press, Ames, IA, pp. 245–258.

McInerney, J.P., Howe, K.S., Schepers, J.A., 1992. A framework for the economic analysis of disease in farm livestock. Prev. Vet. Med. 13, 137–154.

McInerney, J.P., Turner, M.M., 1989. Assessing the economic effects of mastitis control at herd level using farm accounts data. Proc. Soc. Vet. Epidemiol. and Preventive Med. Exeter, pp. 46–59.

Miller, G.Y., Tsai, J.-S., Forster, D.L., 1996. Benefit–cost analysis of the national pseudorabies virus eradication program. J. Am. Vet. Med. Assoc. 208, 208–213.

Power, A.P., Harris, S.A., 1973. A cost benefit evaluation of alternative control policies for foot and mouth disease in Great Britain. J. Agr. Econ. 24, 572–600.

Putt, S.N.H., Shaw, A.P.M., Woods, A.J., Tyler, L., James, A.D. 1988. In: Veterinary Epidemiology and Economics in Africa. 2nd edn., University of Reading, Reading, Berkshire, England, pp. 83–102.

Rusdi, U.D., Sumardi, T.W. 1981. Newcastle disease (Tetelo) in Indonesia. In: Shortridge, K.F. (Ed.), Newcastle Disease and its Control in Southeast Asia. Hong Kong University Press, Hong Kong, pp. 45–47.

Sinurat, P.A., Gilchrist, P., Hamid, H., Basuno, E., 1993. Diseases of village poultry. In: Proc. Inter. Congress, World Vet. Poult. Assoc. Sydney, pp. 19–25.

Spradbrow, P.B., 1994. Newcastle disease in village chickens. Poult. Sci. Rev. 5, 57–96.

Wahid, R.A., 1981. Malaysia – Country report. In: Shortridge, K.F. (Ed.), Newcastle Disease and its Control in Southeast Asia. Hong Kong University Press, Hong Kong, pp. 51–58.

RESUME ET MOTS-CLES

RESUME :

Après avoir restreint l'étude des approches globales en économie de la santé à ses deux composantes principales en médecine vétérinaire : l'analyse coût-efficacité et l'analyse coût-bénéfice, l'auteur expose les étapes méthodologiques de leur réalisation.

Le détail des paramètres initiaux ainsi que celui de la liste des coûts et bénéfices à établir préalablement à tout calcul est exposé. Les techniques économiques permettant le passage à la valeur monétaire et l'évaluation de l'acceptabilité d'un projet sont aussi revues.

L'étude critique de quatre articles permet ensuite d'en illustrer les applications actuelles mais aussi les limites dans leur mise en œuvre pratique et dans le domaine de la recherche.

MOTS-CLES : économie, santé animale, analyse coût-efficacité, analyse coût-bénéfice, programme de lutte.