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BEHAVIOR PERSISTENCE: A COMPARISON OF TWO BINOMIAL PROPORTIONS

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ABSTRACT

We studied the persistence of the traditional method of Attiéké processing in two communes, Adzopé and Alépé, of the Attié ethnic group in Southern Ivory Coast. We considered three statistical methods, the Pearson Chi square test and the asymptotically equivalent likelihood ratio Chi square; the logistic regression method; and the risk ratio method in our approach to comparing the proportions of persons who exhibited consistent behavior with respect to the traditional technology of Attiéké processing in the two communities. We found that higher proportions of women ($\hat{p}_1$ = 0.891 and $\hat{p}_2$ = 0.858, respectively for the communes of Adzopé and Alépé) followed tradition and consistently used the traditional method of Attiéké processing that is characteristic to the Attié ethnic group. With all three statistical methods of analysis, we concluded that the consistent behavior equally developed and persisted in the two communes. We inferred that the need to conform to tradition for acceptance and survival in the communities, and the pragmatic reason to satisfy the local consumers, indigenous to the communes, were the primary reasons for the persistence of that behavioral trait.

Key words : *Behavior, Binomial, Chi-square, likelihood ratio, risk ratio*

RÉSUMÉ

La Persistance du comportement : une comparaison de deux proportions binomiales

Nous avons étudié la persistance de la méthode traditionnelle de production d'Attiéké dans deux communes, Adzopé et Alépé, du groupe ethnique Attié,

au sud de la Cote d'Ivoire. Notre approche consistait à comparer la proportion de dames qui utilisaient et persistaient la procédure. Nous avons considéré trois méthodes statistiques, le test khi-deux de Pearson et son équivalent asymptotique khi-deux du rapport de vraisemblance ; la méthode de régression logistique ; et la méthode du rapport de risques. Nous avons observe des proportions élevées de femmes ($\hat{p}_1$ = 0.891 et $\hat{p}_2$ = 0.858, respectivement, pour les communes d'Adzopé et Alépé) qui suivaient la tradition et utilisaient la méthode traditionnelle de production d'Attiéké caractéristique au groupe ethnique Attié. Chacune des trois méthodes statistiques de notre analyse ont permis de conclure que la méthode traditionnelle de production d'Attiéké a persisté avec consistance dans les deux communes, et toute altération de cette méthode a été jusque là très négligeable. Nous avons déduit que le besoin de se conformer à la tradition dans chaque commune, et la raison pragmatique de satisfaire les consommateurs, indigènes aux deux communes, sont les raisons fondamentales de la persistance des traits de comportement par rapport à la production traditionnelle de l'Attiéké.

Mots Clés : *Comportement, Binomial, khi-deux, rapport de vraisemblance, rapport de risques*

I - INTRODUCTION

Behavior is a very complex character that is determined by both genetics and environment. All the genetic material that would later be expressed to affect behavior is laid out during prenatal development. And many different genes are expressed at a given age during the lifetime of the individual. The temporal expression of those genes greatly affects our behavior. For example, gene encoding for the secretion of pituitary growth hormone determines postnatal growth of bone and soft tissues [1], and increases immunity [2]. The rate of growth hormone from the pituitary is highest around puberty, declines progressively thereafter, and correlates with insulin-like growth factor-1 [2 - 4].

The reduced expression of growth hormone gene is associated with aging [5] and is accompanied by a decreased expression of age-related Wnt genes [6], a decrease in bone density and lean mass, a reduced mobility, an increased frequency of bone fractures, and increased risk of infection and diseases [3]. All these age-dependent temporal expressions of genes greatly affect human behavior. A young adult may think of death as an unlikely event and may engage in riskier activities. And with his vigor, he may be more productive than at any other age.

The frailty and limited mobility of the elderly greatly affect his behavior. The outcomes of genes' expressions vary from one individual to another and individuals of a population in the same environment do not all have the same skills and the same potential. Some individuals may fail in one area where others succeed, and may succeed in other areas where others fail. Along the life of an individual, different genes are expressed. The proteins synthesized from those genes carry on activities of varying degrees depending on the individuals in the population, and make them think and behave differently. But, the Nuffield Council on Bioethics [7] reported that the proteins that genes make and how they affect our bodies and brains are only part of an explanation of human behavior.

Despite the variation in thoughts and behavior, survival of humans and the search for a better quality of life require knowledge and an adaptation to the environment, a modification of some environmental parameters and the symbiotic aggregation of individuals in the form of communities. Living in communities forces individuals of that population to set limits to behavioral traits that are acceptable and beneficial to all members of the community and to develop a culture for that community. The acceptable behavior in a culture may be based on religious laws, moral laws, or laws voted by a democratically elected legislative body.

Deterrence measures are often attached to the laws to encourage or enforce abidance to the laws in that culture. From that perspective, the environment models the daily lives of the individuals in the population. Plomin [8] noted that behavior is dynamic, substantially influenced by epigenetic factors, and changes in response to the environment. From the early age, children already start to explore their environment by touching, tasting, smelling, and playing with objects around them. With the inherent survival instinct, they quickly identify who best protect them, usually their mother. Their pick up and record in memory all information they need to adapt and survive in their culture, as they grow. Parents, especially mothers, are the most important source of the information they record. Mothers have great influence on human behavior. In a very conservative environment, knowledge of the culture can be integrally passed to offspring with little foreign contamination, thereby persisting behavior over generations or regions. We conducted this investigation to explore the persistence of the traditional method of Attieke processing in two different communes. The population of one commune is made of great grand children of individuals who
migrated from the other.

II - SAMPLING DESIGN AND METHODOLOGY

Women of the Attié ethnic group from the communes of Adzopé, and Alépé, Ivory Coast, who make a living off the production and sales of Attiéké, were surveyed by means of a set of questionnaires administered by graduate students of the University of Abobo-Adjamé, Ivory Coast. Attiéké is a traditional staple commonly eaten in the Ivory Coast for breakfast, lunch, and diner by most of the Ivorian people. It is made from the tuberous roots of Cassava, *Manhiot esculenta,* that contain more than 90% of starch molecules with 83% of amylopectin and a small amount of amylose [9]. Attiéké meal quickly fills up for a longer period of the day and at very low cost, making it the most consumed meal in the Ivory Coast.

Questionnaires were developed on the basis of the information collected on the traditional Attiéké processing technology from residents of the oldest Attié town created over millennia ago, Assedji, Ivory Coast. The systematic choice of the communes of Adzopé and Alépé as strata was based on the fact that original residents of Adzopé had spread in search of agricultural land and created what is now the commune of Alépé. Within each stratum, we randomly selected eight Attié towns to include in the study.

In each town, eighty female residents among the women who produced Attiéké for a living were randomly chosen to participate. A week before the interviews, delegations from the University of Abobo Adjamé met with the villages' chiefs to explain and to ask for formal authorization to conduct the interviews and to encourage participation. Questions submitted to participants included the length of time from harvest of the *M. esculenta* roots to use in the processing of the Attiéké, the size of the pieces of tuber used, if the pieces were cut in smaller cubes, if the pieces or cubes of tuber were boiled before fermentation, the fermentation period, the size of the particles of starch after grinding, and the period of steam cooking to get the final edible product. As a token of appreciation, we gave two hundred CFA francs (about $0.40) to the participants when they completed the interview. The ethical committee of the University of Abobo Adjamé gave its approval of the procedure used in the study.

We used a very conservative data collection procedure. A single answer deviating from the established method of Attiéké processing resulted in a non-consistent or modified behavior. All answers must conform to the information obtained on the traditional Attiéké processing method to get a consistent behavior. A total of 640 participants were randomly sampled in each commune and served to build the 2x2 contingency table in table 1 with the two independent binomial random variables, X and Y; the variable X representing the number of women who used the traditional method of Attiéké processing with consistency in a total of m randomly sampled

women in the commune of Adzopé, with success probability p_1 ; and the variable Y representing the number of women who used the traditional Attiéké processing method with consistency in a
total of m randomly sampled women in the commune of Alépé, with success probability p_2.
Then $X \sim \text{Bin}(m, p_1)$ and $Y \sim \text{Bin}(m, p_2)$.

Table 1: *Theoretical frequencies of a 2x2 contingency table*.

Commune	**Behavior**		**Total**
	Consistent	Modified	
Adzope	x	m-x	m
Alepe	y	m-y	m
Total	x+y	t-(y+x)	t=2m

Our interest was to test if the consistent behavior in the commune of Adzopé persisted in the commune of Alépé, that is, a test of homogeneity. The appropriate null and alternative hypotheses were:

Ho: $p_1 = p_2$ versus Ha: $p_1 \neq p_2$

The null hypothesis translates into no significant difference in the proportions of women with consistent behavior in the two communities with respect to the traditional Attiéké processing method. In other words, the observed behavior in the commune of Adzopé was not different from the observed behavior in the commune of Alépé regarding the traditional Attiéké processing technology. Suissa and Shuster [10] proposed the pooled Z test to test such null hypothesis, based on the central limit theorem, where Z had the standard normal distribution under the null hypothesis:

$$Z_p(x, y) = \frac{\frac{x - y}{m}}{\sqrt{\frac{2\hat{p}(1-\hat{p})}{m}}} \sim \text{N}(0, 1) \ \textit{with} \ \hat{p} = \frac{x + y}{t} \qquad (1)$$

The *squared* $Z_p(x, y)$, $Z_p^2(x, y)$ is the Pearson Chi-square (score statistic) with 1 degree of freedom:

$$\chi^2_{(1)}(x, y) = \frac{(x - y)^2}{2\hat{p}(1-\hat{p})m} \qquad (2)$$

Another test statistic often used is the Likelihood Ratio Chi-square, G^2, derived from the principle of the likelihood ratio test:

$$G^2 = 2 * \sum_{i}^{r} \sum_{j}^{c} n_{ij} \log\left\{ \frac{n_{ij} * n_{++}}{n_{i+} * n_{+j}} \right\} \qquad (3)$$

Using ***Table 1***, $n_{11} = x, n_{12} = m - x, n_{21} = y,.\quad n_{22} = m - y, n_{1+} = n_{2+} = m,$ $n_{+1} = x + y,\quad n_{+2} = t - (x + y), n_{++} = t,$ $r =$ number of rows, and c = number of columns. It is worth mentioning that the χ^2 test and the G^2 test are asymptotically equivalent. One powerful method of analysis of such contingency table is the logistic regression where a logit transformation of behavioral event is modeled as a linear function of commune. Hosmer and Lemeshow [11] noted that the logit function is an extremely flexible and easily used function that lends itself to a biologically meaningful interpretation. The logistic regression is given by:

$$\theta(x) = \frac{e^{(\beta_0 + \beta_1 x)}}{1 + e^{(\beta_0 + \beta_1 x)}} \qquad (4)$$

The logit transformation yields:

$$\log it(\theta(x)) = \ln\left(\frac{\theta(x)}{1 - \theta(x)} \right) = \beta_0 + \beta_1 x \qquad (5)$$

Therefore the dependent variable is a logit. Without belaboring the statistical theory, the method
used to estimate the regression parameters is the maximum likelihood method. The responses, y_i , being independent, the likelihood function is given by the product:

$$L(\beta_0, \beta_1) = \prod_{i=1}^{n} \left[\theta(x_i)\right]^{w_i y_i} \left[1 - \theta(x_i)\right]^{w_i (1 - y_i)} \qquad (6)$$

By using the natural logarithm of the likelihood function, we get:

$$Ln(L(\beta_0, \beta_1)) = \sum_{i=1}^{n} \left[w_i y_i Ln(\theta(x_i)) + w_i (1 - y_i) Ln(1 - \theta(x_i)) \right] \qquad (7)$$

The estimates of $\beta_{0.}$ and $\beta_{1.}$ that maximize the likelihood function are determined through iterative methods. A test of the significance of β_1 illustrated by the null hypothesis:

Ho: $\beta_1 = 0$ versus Ha: $\beta_1 \neq 0$ is given by the Wald's test:

$$W^2 = \left(\frac{\hat{\beta}_1}{SE(\hat{\beta}_1)} \right)^2 \qquad (8)$$

where $SE(\hat{\beta}_1)$ is the estimate of the standard error of β_1. However, Hauck and Donner [12] found that the Wald test often resulted in a Type II error. Agresti [13] obtained a similar conclusion with small samples. Another statistic used to compare the model with and without the covariate is the likelihood ratio test:

$$G^2 = -2 * Ln\left\{ \frac{\text{likelihood with the intercept only}}{\text{Likelihood with covariates}} \right\}$$

Under the null hypothesis, both G^2 and W^2 have a Chi square distribution with 1 degree of freedom. A proper measure of behavior persistence is given by the parameter

$$h = \frac{p_2}{p_1}, \quad 0 \leq p_2 \leq 1, \quad 0 < p_1 \leq 1 \qquad (10)$$

where p_2 is the success probability in the derived population of the commune of Alépé and p_1 is the success probability in the commune of Adzopé. The parameter, *h*, is also called risk ratio in the literature. All the analyses were performed with a hand-calculator, and with SAS/STAT and SAS/ IML, version 9.1.3 [14]. Some of the computing steps are included in this article.

III – RESULTS AND DISCUSSION

The Chi-square Tests

The probability distribution of the responses per commune is given in figure 1. About 89.1% of the women who make Attiéké for a living in the commune of Adzopé consistently used the traditional Attiéké processing method commonly used by the Attié ethnic group. That was a ratio

of 570 to the 640 women interviewed in the commune of Adzopé. In the commune of Alépé, the percentage was 85.8% corresponding to a ratio of 549 to 640. To test if each of the two percentages can be approximated to one half of the women interviewed against the one-tailed alternative of greater than one half, we used the Pearson's Chi-square test $\chi^2_{(1)} = \frac{(p_i - 0.5)^2}{(0.5 * 0.5)/n}$ with 1 degree of freedom. The Chi square values were 390.62 and 327.75 respectively for the communes of Adzopé and Alépé and p-values were <0.0001. A significantly larger number of women used the traditional Attiéké processing method in both communes. To test the null hypothesis of no significant difference in the proportions of consistent behavior between the communes, The Pearson's Chi-square from (2) was $\chi^2_{(1)} = 3.1332$. with a p-value = 0.0767, the likelihood ratio Chi square from (3) was $G^2_{(1)} = 3.1411$ with a p-value = 0.0763. Under both tests, we concluded the null hypothesis at the level of significance α = 0.05. Equal larger number
of women exhibited consistent behavior with respect to the traditional processing method of Attiéké in both communes. The remarkable persistence of the way of making Attiéké in the two communes over generations and environment may be seen as counter to the evolutionary changes that define humans. However, one accepts to change only when he finds or is exposed to new and convincingly better way of doing things. On the other hand, evolutionary change may come from creativity. But, under tight control of the delivery of knowledge from parents to progenies especially in conservative environment, creativity is not usually encouraged and may even be inhibited, and some behavioral traits are persisted with very high heritability. This is the case in many rural regions of the world where, under tight control of the delivery of knowledge, behavior is shaped by traditional or religious laws inherited from the medieval times. In the case of making Attiéké for sale, one force that may induce changes is the demand for that meal. But, if consumers continue to appreciate the Attiéké made the old-fashion way, the same knowledge will be passed to successive generations without alteration. This often happens when the producers and the consumers are indigenous to the same commune and know only that quality of Attieke from the young age. Without an intrusion of a foreign behavior to challenge the existing one, changes in behavior rarely occur.

The Logistic Regression Analysis

One powerful method of analysis of binary response data is the logistic regression method [11] that models the log of odds as a linear function of the independent variables. The logit transformation is given by equation (5). By equating the $\log it(\theta(x_i))$ to $f(x)$ we can rewrite the logit transformation in

the form $f(x) = \beta_0 + \beta_1 x_i$. . Hosmer and Lemeshow [11] produced table 2 corresponding to the probabilities of consistent behavior, when the independent variable, commune, is dichotomous: The odds of consistent behavior in the commune of Adzopé is given by $\phi_1 = \frac{\theta(1)}{1-\theta(1)} = e^{(\beta_0+\beta_1)}$, and the odds of consistent behavior in the commune of Alépé is $\phi_2 = \frac{\theta(0)}{1-\theta(0)} = e^{\beta_0}$ The maximum likelihood estimate [15] of the intercept is $\hat{\beta}_0 = \ln\phi_2 = \ln\left(\frac{549}{91}\right) = 1.7972.$

Table 2 : *Theoretical response probabilities under the full model*

Commune	**Behavior**	
	Consistent=1	Modified=0
Adzope=1	$\theta(1) = \frac{e^{(\beta_0+\beta_1)}}{1+e^{(\beta_0+\beta_1)}}$	$1-\theta(1) = \frac{1}{1+e^{(\beta_0+\beta_1)}}$
Alepe=0	$\theta(0) = \frac{e^{\beta_0}}{1+e^{\beta_0}}$	$1-\theta(0) = \frac{1}{1+e^{\beta_0}}$

The odds ratio of consistent behavior in the commune of Adzopé to consistent behavior in the commune of Alépé is $\psi = \frac{\phi_1}{\phi_2} = \frac{e^{\beta_0} * e^{\beta_1}}{e^{\beta_0}} = e^{\beta_1}$.

The maximum likelihood estimate of the regression coefficient β_1, is $\hat{\beta}_1 = \ln\phi_1 - \ln\phi_2$ or $\hat{\beta}_1 = 0.2999$. The estimated logit is therefore, $\hat{f}(x) = 1.7972 + 0.2999 * Commune.$ To determine if the variable, commune, significantly affected the distribution of the response probabilities compared to the restricted model without the covariate, we used the likelihood ratio test statistic in equation (9). Under the null hypothesis, G^2 is asymptotically equivalent to a Chi square test with one degree of freedom. The response probabilities when the variable, commune, is not included in the model are given in ***Table 3***.

Table 3: *Actual response probabilities under the reduced model.*

Behavior	
Consistent = 1	Modified = 0
0.8742	*0.1258*

The estimate of the likelihood with the intercept only in the model given by the equation (6) is $\hat{L}_1 = 0.8742^{1119} * 0.1258^{161} = 5.1413 * 10^{-211}$. And the logarithm of the likelihood in (7) gives $Ln(\hat{L}_1) = -484.208$ and $-2 * Ln(\hat{L}_1) = 968.416$. The response probabilities under the full model are given in ***Table 4***.

Table 4 : *Actual response probabilities under the full model.*

Commune	**Behavior**	
	Consistent = 1	Modified = 0
Adzopé=1	0.8904	0.1094
Alépé=0	0.8578	0.1422

The estimate of the likelihood when the variable, commune, is included in the model is given by $\hat{L}_2 = 0.8904^{570} * 0.1094^{70} * 0.8578^{549} * 0.1422^{91} = 2.4726 * 10^{-210}$. The logarithm of the likelihood is $Ln(\hat{L}_2) = -482.6375$ and $-2 * Ln(\hat{L}_2) = 965.275$. The likelihood ratio Chi square given by (9) is $G^2_{(1)} = -2 * \{Ln(\hat{L}_1) - Ln(\hat{L}_2)\} = 3.1411$ with p-value = 0.0763. The model including the variable, commune, does not significantly differ from the model with the intercept only.

The Wald's test is used to test whether the parameters of the model are significantly different from zero and is given by the equation (8). The denominator of equation (8) is the standard error and its computation requires the information matrix, I = (X'WVX) where $X = \begin{bmatrix} 1 & x_1 \\ 1 & x_2 \end{bmatrix}$, $W = \begin{bmatrix} w_1 & 0 \\ 0 & w_2 \end{bmatrix}$, and $V = \begin{bmatrix} \theta(x_1)(1-\theta(x_1)) & 0 \\ 0 & \theta(x_2)(1-\theta(x_2)) \end{bmatrix}$.

The covariance matrix of the parameters is the inverse of the information matrix, $\Sigma = I^{-1}$. And the square root of the diagonal elements of the covariance matrix gives the standard errors, $SE = [\Sigma]^{1/2}$:

$$\hat{I} = \begin{bmatrix} 140.40469 & 62.34375 \\ 62.34375 & 62.34375 \end{bmatrix}, \quad \hat{\Sigma} = \begin{bmatrix} 0.0128105 & -0.012811 \\ -0.012811 & 0.0288506 \end{bmatrix}, \quad \hat{SE} = \begin{bmatrix} 0.1131819 & 0 \\ 0 & 0.1698521 \end{bmatrix}$$

The Wald's test for the regression coefficient β_1, is $W^2_{(1)} = \left(\frac{\hat{\beta}_1}{\hat{SE}(\beta_1)} \right)^2 = \left(\frac{0.2999}{0.1699} \right)^2$ = 3.1173 with p-value = 0.0775. Using a level of significance α = 0.05 we concluded that the contribution of the variable, commune, to the response probabilities was not significant. The two communes offered the same response profile. The consistent behavior with respect to the traditional Attieke processing method in the commune of Adzope persisted over to the commune of Alepe. The persistence of a behavioral trait over environment and generation by a clan or an ethnic group is often called tradition of that clan, and is not very rare in rural regions of the world. Often, the same activities are repeated year after year, and the same beliefs are transmitted generation to generation. Any small deviation from the pattern of acceptable behavior in the clan is vigorously denounced and discouraged. In such environment, some behavioral traits are passed from parents to progenies and respectfully exhibited by the progenies without modification.

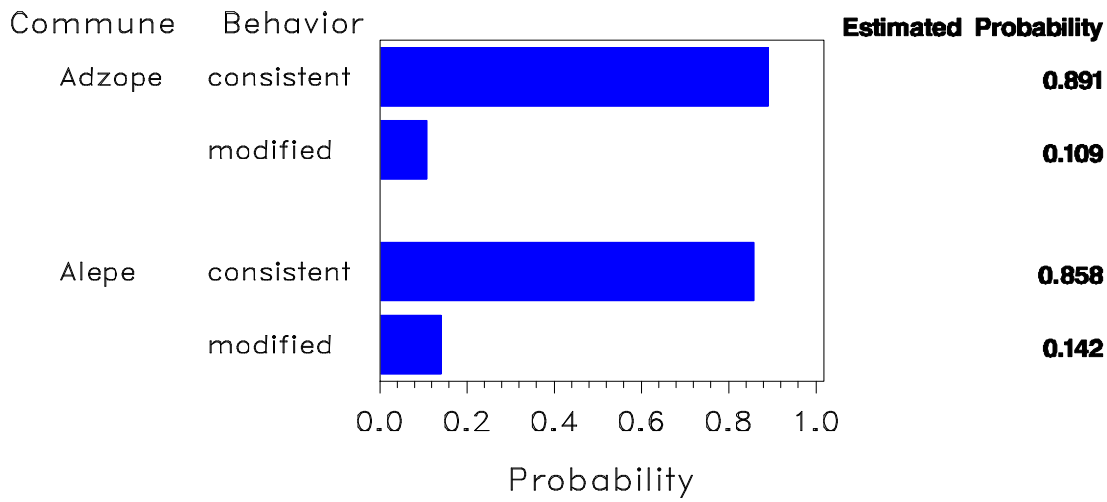

Figure 1: *Probability distribution of the behavioral events per commune.*

A Proper Measure of Behavior Persistence

A measure of behavior persistence is given by the parameter *h* given in (10). The range of *h* extends from zero to infinity. A value of *h* equal to zero indicates the behavior in the original population, did not evolve in the derived population. A value of *h* less than one means the behavior is present in the new population but to a lesser degree than in the original population.
A value of one means the degree of exhibition of the behavior is equal in the two populations.
And a value greater than one betokens the behavior is more developed in the new population compared to the original population. Katz et al. [16] developed a confidence interval for the parameter *h*, using a logarithmic transformation of the parameter formulated by Abramowitz and Stegun [17]. The 95% confidence interval for *h* is $e^{Ln(\hat{h})\pm 1.96*\hat{SE}(Ln(h))}$ where $\hat{SE}(Ln(h) = \left[\frac{1-\hat{p}_2}{n_{21}} + \frac{1-\hat{p}_1}{n_{11}}\right]^{1/2} = \left[\frac{0.142187}{549} + \frac{0.109375}{570}\right]^{1/2} = 0.02123$ and $Ln(\hat{h}) = Ln\left(\frac{\hat{p}_2}{\hat{p}_1}\right) = -0.037538$. Therefore, the measure of behavior persistence, *h*, with respect to the traditional method of Attiéké processing can take values between 0.9239 and 1.00409. An induction based on the confidence interval concludes that the behavioral trait equally developed and persisted in the two populations investigated. With the particular environmental settings of the communes of Adzopé and Alépé, and the given culture and tradition of the Attié ethnic group, the traditional method of processing Attiéké has not changed across communes or generations. Some of the fundamental reasons are the lack of exposure to other methods of making better quality Attiéké, the need to conform to tradition for acceptance in the society, and the pragmatic reason to satisfy the consumers of Attiéké in those two communes who are themselves not exposed to other Attiéké of better quality. All the reasons lie on the unconscious instinct to adapt, survive, persist oneself and all along pursue happiness.

IV - CONCLUSION

The traditional method of producing Attiéké was integrally reproduced in the commune of Alépé by the great grand children of individuals who migrated from the commune of Adzopé to create Alépé. With the absence of a foreign contamination that could convince the women of the Attié ethnic tribe of a better way of producing Attiéké, very little change occurred in the commune

of Alépé $(1-\hat{p}_2 = 0.1421)$ compared with the commune of Adzopé $(1-\hat{p}_1 = 0.1093)$. The reproduction of the same habits over environment and time impedes creativity and technological innovation and excludes any attempt to improve the methods of production. Generalizing with this observation, we may understand the lack of progress toward development in most African countries since their political independences.

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