Genetic parameters for growth and colour traits in Pacific blue shrimp *Litopenaeus stylirostris* in a mixed family design with SNP parentage assignment in New-Caledonia

F. Enez\(^1\), B. Lorgeoux\(^2\), H. Mahunon\(^1\), J. Bugeon\(^3\), M. Vandeputte\(^4\)\(^5\), P-A. Gagnaire\(^6\), N. Bierne\(^6\), P.-P. Blanc\(^2\) & P. Haffray\(^1\)

\(^1\) Syndicat des sélectionneurs avicoles et aquacoles français, Campus de Beaulieu, Rennes, France  
florian.enez@inra.fr (Corresponding Author)  
\(^2\) ADECAL Technopole, Centre tech. aquacole de Saint-Vincent, Boulouparis, New-Caledonia  
\(^3\) INRA, LPGP, Campus de Beaulieu, Rennes, France  
\(^4\) Ifremer, UMR 9190 MARBEC, chemin de Maguelone, Palavas-les-Flots, France  
\(^5\) INRA, GABI, Jouy-en-Josas, France  
\(^6\) Institut des Sciences de l'Evolution, UMR5554 University Montpellier-CNRS-IRD-EPHE, Place Eugène Bataillon, Montpellier, France

**Summary**

Pacific blue shrimp *Litopenaeus stylirostris* farming is the major aquaculture activity in New-Caledonia and represents a great socio-economic development opportunity for the region. Knowledge on genetic parameters is a prerequisite to initiate a selective breeding program, one of the main ways envisaged to improve the performance of the sector.

To estimate genetic parameters, three groups of blue shrimp families were created with a total of 37 sires and 31 dams in April 2016. They were reared in parallel in earthen ponds up to 6 months of age. In October 2016, N=1200 raw shrimp were individually measured for body weight, body length and photographed. After cooking, they were again photographed, peeled and weighed. Body colour was characterised using L*a*b* international reference system. A 171 SNP panel was used for parentage assignment, and gave 99.7% perfect assignment. Heritabilities and genetic correlations were estimated with an animal model.

Estimates of heritability were moderate for tail yield (h²=0.22) and high for weight (h²=0.52) and colour (h²=0.41–0.59) of raw and cooked shrimps. Length and weights for raw and cooked shrimps were shown to share the same genetic basis (r\(_g\)=1.00–0.97). Correlations between these traits and tail yield are lower but still positive (r\(_g\)=0.44–0.56). Correlations between blue colour measured on raw shrimps and growth-related traits did not differ from zero (r\(_g\)=–0.23–0.11). The blue colour on raw shrimps is was negatively correlated with red colour on cooked shrimps.

This first work to estimate genetic parameters on the Pacific blue shrimp demonstrates that selective breeding for growth and colour traits is possible on commercial lines of this species.

**Keywords:** Pacific blue shrimp, *Litopenaeus stylirostris*, genetic parameters, growth, colour, SNP

**Introduction**

Pacific blue shrimp *Litopenaeus stylirostris* is the major aquaculture species in New-Caledonia. With around 1200T produced each year, production stays limited but valuable, with recognized high quality and a blue colour added value for the export market. Thus, shrimp farming represents an important socio-economic activity for the island. Selective breeding is a way to develop the sector and increase the genetic potential of the stocks.

In aquaculture, 5% to 20% of genetic gain per generation is expected on growth traits (Gjedrem and Olesen, 2005). However, presently farmers are afraid to lose the blue colour
together with selection for increased growth. The aim of this study is to provide a first estimation of genetic parameters for growth and colour traits, in order to evaluate the opportunity to initiate a selective breeding program.

**Material and methods**

**Production of shrimps**

Broodstock were collected in nine New-Caledonian farms, and reared as one base population. In April 2016, artificial inseminations were carried out daily with spawning dams. Each dam was crossed with 2 sires. Three groups of families were produced with 18, 9 and 10 sires, and 13, 8 and 10 dams respectively. One pleopod of each parent was kept in ethanol for parentage assignment.

After a nursing period in batches, each group was transferred at 40 days old in earthen pond at a density of 30 shrimps /m². Groups were reared separately along all growing until their final phenotyping.

**Measurement of growth-related and colour traits**

At 6 months old, 400 shrimps per group were sampled for phenotyping. They were euthanized in ice. One pleopod was collected for parentage assignment, then each individual was measured for body weight, body length and photographed. Moulting stage was also recorded. Then, shrimps were frozen at -18°C.

In a second time, the same individuals were cooked according to a commercial process, photographed once again, weighed and sexed. The tail was weighed after peeling. Tail yield is calculated as the ratio of tail weight on cooked shrimp weight.

Colour was evaluated *a posteriori* on pictures of raw and cooked shrimps using CIEL*a*b* color space. Dimension a* describes colours from green in negative values to red in positive values, dimension b* colours from blue to yellow and lightness is defined by dimension L*. Colour was measured in six manually selected spots per shrimp segment, after which the mean of all spots was calculated as the colour individual data point.

**Evaluation of genetic parameters**

A specific panel of 171 SNPs previously ascertained from RAD sequencing was used for the project. Parents of each phenotyped shrimp were identified using the SNP panel with the Accurassign software (Boichard *et al.*, 2014).

Group, sex and moult stage were tested as fixed effects by analysis of variance for each trait. These effects were introduced in the following animal mixed model as fixed effects if they were significant:

\[ Y = X\beta + Zu + \epsilon \]

where \( Y \) was the individual data for the studied traits, \( \beta \) the fixed effects associated with the studied trait (group, sex and moult stage if significant) and \( u \) the random animal genetic effect. All traits were scaled to zero mean and unity variance. Genetic analyses to estimate heritabilities and genetic correlations were performed with the VCE software.

**Results and discussion**

**Parentage assignment**

Only two shrimps from one group had unknown parents after parentage assignment. Although Caledonian shrimp populations have low genetic diversity (Goyard *et al.*, 2003), our
SNP ascertainment from 2582 SNPs obtained by RAD sequencing allowed us to design an efficient panel for parentage analysis.

**Heritabilities**

Table 1. Mean and heritability of traits.

<table>
<thead>
<tr>
<th>Trait</th>
<th>Raw shrimp</th>
<th>Cooked shrimp</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (Std)</td>
<td>Heritability (S.E.)</td>
</tr>
<tr>
<td>Weight (g)</td>
<td>14.5 (3.0)</td>
<td>0.52 (0.11)</td>
</tr>
<tr>
<td>Length (mm)</td>
<td>129.6 (7.9)</td>
<td>0.46 (0.10)</td>
</tr>
<tr>
<td>L*</td>
<td>48.1 (2.4)</td>
<td>0.41 (0.10)</td>
</tr>
<tr>
<td>a*</td>
<td>1.2 (0.8)</td>
<td>0.59 (0.11)</td>
</tr>
<tr>
<td>b*</td>
<td>6.4 (3.4)</td>
<td>0.51 (0.10)</td>
</tr>
<tr>
<td>Tail yield</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Heritability of weight for raw or cooked shrimps was similar, 0.52±0.11 (Table 1), despite 10% loss of weight after cooking. This result is similar to those estimated in mixed family design in Banana shrimp (Nguyen et al., 2014) and Pacific white shrimp Litopenaeus vanamei (Nolasco-Alzaga et al., 2018). Heritabilities estimated in separate families in Pacific white shrimp (Gitterle et al., 2005, Castillo-Juárez et al., 2007) or tiger prawn Penaeus monodon (Sun et al., 2015) are lower. The tail yield after cooking has moderate heritability (0.22±0.06) and twice as high as the estimate in separate families in Litopenaeus vanamei (Campos-Montes et al., 2017). This result confirms the interest of the mixed family design.

Blue color, described by negative values of dimension b*, is not well detected on pictures of raw shrimp. Raw shrimps appear mostly grey on the pictures. CIEL*a*b* color system may not be the most suitable to capture the blue in these pictures. However heritability of the b* trait is high, like that of the other color traits (0.41–0.59).

Genetic correlations between growth-related traits

Raw and cooked weight and length have close to unity genetic correlations (0.97–1.00; Table 2) and thus share the same genetic basis. Selection on length will be effective to improve both raw and cooked weight, without necessity to cook shrimps. Moreover, the genetic correlation between length and cooked tail yield is positive (0.56±0.15).

Table 2. Genetic correlations (Std) between growth-related traits.

<table>
<thead>
<tr>
<th>Trait</th>
<th>Raw shrimp weight</th>
<th>Cooked shrimp weight</th>
<th>Tail yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>0.98 (0.01)</td>
<td>0.97 (0.01)</td>
<td>0.56 (0.15)</td>
</tr>
<tr>
<td>Raw shrimp weight</td>
<td>-</td>
<td>1.00 (0.00)</td>
<td>0.44 (0.17)</td>
</tr>
<tr>
<td>Cooked shrimp weight</td>
<td>-</td>
<td>-</td>
<td>0.45 (0.16)</td>
</tr>
</tbody>
</table>

Genetic correlation for colour traits

Table 3 presents genetic correlations between growth-related traits and colour dimensions of raw and cooked shrimps. Colour trait b*, characterizing blue colour, is independent of growth-related traits ($r_g$=-0.23–0.11). Selection for growth will thus have no impact on this characteristic colour of Pacific blue shrimp. The heavier shrimp tend to be redder after cooking ($r_g$=0.37±0.16). Nguyen et al. (2014) suggests that darkest raw Banana shrimps are heaviest ones but with a lower yield. The way to measure colour seems to be determinant in results.

Genetic correlation between raw shrimp b* and cooked shrimp a* is 0.48±0.14. This moderate correlation highlights that the bluest shrimps tend to be the less red. This result contrasts to those of Wade et al. (2012) and Nguyen et al. (2014) for which the most colourful raw shrimps are the most colourful cooked shrimps. Additional analyses are needed to explain
discrepancy with these results.

Table 3. Genetic correlations (S.E.) between growth traits and colour traits.

<table>
<thead>
<tr>
<th></th>
<th>Raw shrimp weight</th>
<th>Cooked shrimp weight</th>
<th>Tail yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw shrimp L*</td>
<td>0.09 (0.18)</td>
<td>0.10 (0.19)</td>
<td>0.28 (0.20)</td>
</tr>
<tr>
<td>Raw shrimp a*</td>
<td>0.54 (0.13)</td>
<td>-0.58 (0.12)</td>
<td>-0.21 (0.19)</td>
</tr>
<tr>
<td>Raw shrimp b*</td>
<td>0.11 (0.18)</td>
<td>-0.15 (0.18)</td>
<td>-0.23 (0.19)</td>
</tr>
<tr>
<td>Cooked shrimp L*</td>
<td>0.30 (0.17)</td>
<td>0.31 (0.15)</td>
<td>0.40 (0.14)</td>
</tr>
<tr>
<td>Cooked shrimp a*</td>
<td>0.37 (0.16)</td>
<td>0.37 (0.16)</td>
<td>0.12 (0.17)</td>
</tr>
<tr>
<td>Cooked shrimp b*</td>
<td>0.43 (0.15)</td>
<td>0.44 (0.15)</td>
<td>0.17 (0.17)</td>
</tr>
</tbody>
</table>

This first estimation of genetic parameters in Pacific blue shrimp shows that selection for growth should be efficient in this species, with no impact on the raw blue color and a limited increase of the red cooked color. It also highlights the interest of mixed family design and SNP panel to design efficient breeding programs in aquaculture (Vandeputte et Haffray, 2014).

List of References


